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SELECTIONS FROM THE RECORDS OF THE BOMBAY GOVERNMENT.

No. I.—New Series.

ON THE SUPPLY OF WATER TO BOMBAY.

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THE present number of the Selections consists of various letters, reports, and minutes on the supply of water to the town of Bombay. The Government records abound with papers on this subject, but those only have been selected for publication which appeared to promise to be of some practical importance.

A report by Drs. Graham and Leith on the state of the tanks and wells in the hot season of 1845, although various minor improvements have since been effected, is yet a sufficiently correct description of what the water supply in Bombay would be after a deficient monsoon to possess a present practical interest ; while the remaining papers in the volume relate almost entirely to projects yet unrealized.

Of these the one which will probably be considered the most important is the plan for damming up a nullah at Vehar in Salsette, and creating an enormous artificial lake, to contain from a thousand to two thousand millions of gallons. The papers at pages 25, 29, 35, 38, 40, 47, 49, 53, 141, and 148 relate to this project ; while a very sufficient *summary* of all the information collected concerning it will be found in the minute of Government which concludes the volume.

The following on the subject of a water-rate is from a gentleman likely to be very well informed as to the disposition of the people :—

" The people generally, both the well-to-do and the poorer classes, are averse to a water-rate, and have an idea that if once assessed for this the rate will never be reduced or taken off. Large classes of the people do, nevertheless, actually pay for water, and pay for it very highly. Very few Mussulman females go out to the wells or tanks, owing to prejudices, and the distance they would have to go; while the abusive language, and the law of might which prevail at such places are sufficient to prevent any well-disposed female from going to them except under most urgent necessity. Therefore, although averse to a permanent water-rate, a large proportion of the people would willingly pay a sum down to have a supply of good water brought into the island, and delivered *in their own streets.* (Even Mussulman women would go out in the dusk of the evening for water if they had not to leave their own street for it.) I am informed that a very great many people pay for water annually a sum equal to six years of the assessment on their houses ; and many have signified their willingness to come forward at once with two years of this outlay, equal to twelve years of their house assessment, as a contribution towards the expense of bringing a supply in from Salsette. It has been suggested, that if it were thought desirable to defer to the wishes of those who would thus prefer to pay a sum at once, any water-rate imposed might be made redeemable at the option of the householder."

H. GREEN,

Compiler and Editor of the Selections from the Records.

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WATER SUPPLY FOR BOMBAY.

RESOLUTION.

As it has been brought to my notice that there is at present an alarming want of water in Bombay, I think it would be desirable to appoint a Committee to report on the subject.

Drs. Graham and Leith, who were on last year's Medical Committee of Inquiry being still in Bombay, I would propose to appoint them as a Committee, with directions to report, with the least possible delay, on the state of the wells, and the quality of the water, and the quantity of water remaining for consumption.

(Signed) G. Arthur.
Concurred in by L. R. Reid.

June 2nd, 1845.

REPORT OF THE COMMITTEE ORDERED BY THE HONORABLE THE GOVERNOR IN COUNCIL TO REPORT ON THE STATE OF THE WELLS AND TANKS IN THE ISLANDS OF BOMBAY AND COLABA.

The Committee have inquired into the state of the wells and tanks in the islands of Bombay and Colaba, and are able to report from personal observation on the supply of water in the island of Colaba, the Fort, Esplanade, and Native Town of Bombay, and as far northward as Parell, beyond which information has been obtained by the examination of persons employed in the Police.

The Committee are able to verify the report which has been made to Government as to the great want of water at present in Bombay, and they have to bring before His Honor the Governor in Council the great distress suffered by the people from this deficiency.

The inhabitants from the centre of the island and from the eastern part of the town have to go to great distances to beg for water from the owners of wells in gardens, or to obtain it with difficulty on the Esplanade. They are thus obliged to leave their occupations, by which they gain their livelihood, and are at the same time made liable to attacks of the cerebral fever now prevalent, from exposure to the sun in their wanderings during the day, or they are from exhaustion, or from using bad and brackish water, predisposed to attacks of the now epidemic cholera.

Deficiency of the Monsoon.

The supply of water to the Native Town and Colaba is every year found to be deficient, but this year the deficiency is greater, from the fall of rain during last monsoon having been less than the average.

Public Supply of Water in the Native Town.

In the Native Town there are but three places at which the public are supplied with water, viz. Baboola Tank, Musjid Bunder Reservoir, and Framjee Cowasjee's Wells in Duncan Road.

Baboola Tank.

Baboola Tank, the water of which is at all times foul and impure, as it must be while it continues to be supplied in the rains by the drainage from the filthy streets and lanes in the neighbourhood through the common sewer, is now in great part dry, and the fœtid sediment from its impure water is being removed from the bottom; but there are so few workmen employed in comparison to the quantity of filth to be cleared out, that there is little prospect of its being finished before the monsoon commences. The little impure water that remains in pools at the south-end of the tank will not, it is thought, last more than a few days.

Musjid Bunder Reservoir.

The supply at Musjid Bunder Reservoir is now very scanty. It is raised at the Esplanade by means of bullocks from three wells, one only of which is drawn each day. In one of these wells there are between 4 and 5 feet of water, and in each of the other two there is 1 or 1½ foot; and these latter afford a supply at the reservoir for about 2 or 2½ hours only in the day. The first mentioned of these wells would, it is thought, yield a daily flow of 5 or 6 hours' duration; but it is not drawn to this extent. For a few days past the dhobees have been allowed to draw water from it, but it appears very desirable that they should not be allowed to continue to do so.

Framjee Cowasjee's Wells in Duncan Road.

The wells built by Framjee Cowasjee in Duncan Road, which are fed through an underground conduit from three wells in Khutur Wadee, in Girgaum, afford a supply always inadequate to the demand in the hot season, and at present the water flows into them for only 2 or 3 hours in the morning, and for about the same time in the evening. From observation it is known that the wells continue to be drawn at each time until dry, but it is suspected that much of the water is diverted to the irrigation of the cocoanut grove in which they are. The attention of the Superintendent of Police has been directed to this by the Committee, and a guard is to be placed over the wells.

Wells in Mazagon.

In Mazagon all the public wells are dry, and the Nuwab's tank alone has water in it, but it is too brackish for man or beast to drink. There are a few private wells in gardens, from which the people get a little water in driblets, after they have been emptied by their owners in irrigating their grounds.

Quarry Holes and a Well at Wall Pakadee.

At Wall Pakadee there is no public well, and the private sources have failed, with the exception of a well of brackish water in the wood-yard, of which many of the people in their necessity are obliged to drink. There are two deep quarry holes now being excavated near this, belonging to Merwanjee, into which excellent water is beginning to spring, and the Committee, although it is a little apart from their present duty to allude to more than the present supply of water, beg to suggest that these be obtained by Government, and formed into wells for public use.

Byculla Tanks and Parell Wells.

Byculla Tank has only a pool of dirty water a few inches deep at one end; at other parts the mud is being removed from the bottom. The unbuilt tank adjoining to the principal one has still in it a few feet of water, which is fit only for cattle, and to it the inhabitants along the Parell Road bring their animals to water. Beyond Byculla, at Chinalpara, and as far as Parell, the want of water is severely felt; the people have to go great distances, and have difficulty in obtaining it from private wells, the owners of which generally allow but those living in their neighbourhood to draw from them. Those living in the neighbourhood of Parell get drinking water from the gardens about it.

Supply at Girgaum, Mahim, Naegaum, Matoonga, Sewree, and other places.

Girgaum and Mahim are well supplied with water at all times, but the villages along the east side of the island, such as Naegaum, Matoonga, Sewree, and others, suffer much from drought, and from some of them the cattle have to be taken to Mahim Woods to be watered.

Tanks which afford Water for Washing only.

Of the tanks which afford water for washing only, the Nagpada and Moombadavee Tanks have still a few feet of water left. The filthy Kara Tulao is empty, excepting the mud, and Cowasjee Patell's Tank has long been so.

The Washerman's Tank, near the Marine Battalion Lines, and at the commencement of the Native Town, has for some years been avoided by the inhabitants when water is abundant, but now they express a strong desire that it should be cleaned out, and that they may have a supply of what they own would be excellent water.

At present the deep mud at the bottom is partly uncovered, and the little water that remains at one end is too dirty for drinking, but it is being drawn by many for other uses.

The Committee wish to express strongly their opinion of the advantage that would result from employing the present opportunity that the low state of the water affords of cleaning out this tank.

It is for others to consider the propriety of employing convicts in cleaning out this and other tanks, when so many labourers are necessary, if workmen cannot be otherwise obtained.

Propriety of employing Convict Labour in cleaning the Tanks.

At present many of the wells on the Esplanade are completely dry, and the others have not more than a few inches of water in them. The people are crowding round them, and scrambling for the little water that slowly filters in through the rock at the bottom, and the Natives were seen at the bottom of some of the wells trying to get a few lotas full to carry away.

Scene at the Esplanade Wells.

With the exception of a few families who have wells in their compounds, yielding a very limited supply of water, the inhabitants of Colaba are wholly dependent on water drawn from the wells on the Esplanade, and they are in consequence suffering with others from the present scarcity.

Scarcity of Water at Colaba.

With the view of in some measure obviating the distress at present felt from want of water, the Committee beg to suggest that the use of private wells in Girgaum, where the supply never fails, and in Mazagon, be secured for the public, by affording compensation to the owners for the loss they would suffer by the discontinuance of their irrigation for a time. Also that those wells on the Esplanade at present used for watering cattle should be reserved for the use of man, while the cattle are allowed access, by an inclined plane or otherwise, to the water of the Fort ditch; and that some of the covered wells on the Esplanade be re-opened, or others deepened, or new ones made. The supply on the Esplanade being thus increased, the inhabitants of the Fort would be relieved from the want of water which many of them are at present enduring, through the failure of their wells.

Means of Relief proposed.

We have the honour to be, &c.

(Signed) A. GRAHAM,
Surgeon and President.

(Signed) A. H. LEITH,
Assistant Surgeon and Member.

June 3rd, 1845.

To W. ESCOMBE, Esq.,
Secretary to Government.

RESOLUTION CALLING UPON THE CHIEF ENGINEER TO FURNISH GOVERNMENT WITH A REPORT ON THE MEANS OF SECURING TO THE PRESIDENCY AT ALL SEASONS A PLENTIFUL SUPPLY OF WHOLESOME WATER.

The extreme distress which is now prevailing among the poorer inhabitants of Bombay in particular, and other classes in general, from the present great want of water, makes it of paramount importance that measures should be at once adopted for securing to the Presidency at all seasons a plentiful supply of wholesome water.

It should be left to the skill and ingenuity of the Chief Engineer to devise by what means this very desirable object can be best attained, and the Military Board should be requested to call upon Colonel Jervis to favour Government with a report on this very important subject, and should be informed that Government is most anxious to prevent a recurrence, even during one year, of such a calamity as is now felt.

Copy of our proceedings should be forwarded to the Honorable Court by the next Mail, with an expression of our sentiments, that after viewing the present distress, and which to a certain extent is of yearly occurrence, it would be a most serious responsibility on the part of Government not to use every effort to prevent its recurrence, and with an assurance that in the measures which may be resolved upon, the greatest economy will be exercised, and a hope, therefore, that our proceedings will meet with the approval of the Honorable Court.

(Signed) G. ARTHUR.

6th June 1845. „ L. R. REID.

MEMORANDUM BY L. C. C. RIVETT, Esq. ON THE PRACTICABILITY OF OBTAINING A SUPPLY OF GOOD WATER FOR THE NATIVE TOWN OF BOMBAY.

Effects in Bombay of a Dry Season, or an insufficient Monsoon.

1. The present supply of water to the Native Town of Bombay depends almost entirely on the rainy season; and, from want of a sufficient reservoir, the inhabitants are exposed to much inconvenience in case of either a protracted dry season, or an insufficient monsoon. This inconvenience is not limited to mere mechanical results; it extends throughout every phase of their social condition, and affects not only their comforts, but strikes deep into the very vitals of their existence. To a Native of India, of whatever caste, water is as essential as air; and no one in Bombay dreams of economizing one more than the other. With all classes water is associated with the most indispensable and every-day functions of their being: they never speak of any place or country without reference to the quality or quantity of its water; and, when sick, invariably talk of changing, not the air, as we do, but the water.

Apathy of the Natives.

With these habits, it is rather extraordinary that hitherto no efforts have been made by the leading Natives of Bombay to increase the supply and improve the quality of the water in this island; but the reason is obvious: Native apathy will do nothing till driven or excited by European energy, and European energy has hitherto had other fields on which to expend itself. But the increasing population of Bombay, now so forcibly and strikingly brought to our notice by the numerous Native buildings in progress almost all over the island, demands that the best energies of scientific civilization should be brought to the aid of the unenlightened Natives; and amongst the first requisites of a large and growing city may certainly be reckoned a plentiful supply of fresh and wholesome water. Within the last 3 years more attention has been paid by the Government to the cleansing and draining of the town than was afforded to those objects during the preceding half century; and this regard to some of the most urgent of our municipal wants gives fair promise that this, the most urgent of all, will also meet with the serious attention of Government.

Means of securing a plentiful Supply of Water.

2. The difficulty of procuring fresh water at any considerable depth below the surface precludes the hope of being able to supply the island by means of additional wells; while the nature of the rock, and the position of the strata throughout, afford small prospect of any advantageous results from sinking Artesian wells. There is no perennial stream in the vicinity of Bombay, which can be brought to the town by an aqueduct; and the only feasible means left appear to be the collection of a large body of water during the rains, of sufficient volume to keep the

present principal tanks at a certain level during the whole year. For this purpose the following are the principal desiderata :—

1*st.*—An elevated position for a reservoir.

2*nd.*—A large surface from which to fill this reservoir.

3*rd.*—A facility of conveying the water from this reservoir to the tanks in question.

Sites for Reservoirs.

3. The principal points which at first sight present themselves for such an object appear to be—

1*st.*—Nowrojee's Hill, at the back of the Jail.

2*nd.*—The hill above Mazagon.

3*rd.*—The Chinchpoogly Hills.

4*th.*—The hill above Parell.

5*th.*—Malabar Hill, adjacent to the Parsee cemetery.

6*th.*—The hill above Colonel Dunsterville's house.

These would at first sight appear tolerably well calculated for the proposed object; but to test their adaptability, we must first of all ascertain the extent of our wants, and, I think, from an examination of the following synopsis, that they will all turn out inadequate for the object.

List of the important Tanks in the Town, with the Superficies of each.

4. The most important tanks from which the Native Town is supplied are the following :—

1*st.*—The Byculla Tank.

2*nd.*—The Baboola Tank.

3*rd.*—The Mombadavee Tank.

4*th.*—A Tank No. 1, between the Bhendy Bazar and Duncan Roads.

5*th.*— Ditto No. 2, ditto ditto ditto.

6*th.*— Ditto No. 3, ditto ditto ditto.

7*th.*—Cowasjee Patell's Tank.

8*th.*—The Dhobees' Tank.

The following is an *approximative* view of the superficies of each of these tanks in square feet:—

The Byculla Tank.

Length............	600
Average breadth....	280
	168,000 square feet.

The Baboola Tank.

Length............	900
Average breadth....	260
	234,000 square feet.

Mombadavee Tank.

Length...........	350	
Breadth...........	220	
	77,000	square feet.

Tank No. 1, between Bhendy Bazar and Duncan Roads.

Length...........	300	
Breadth...........	220	
	66,000	square feet.

Tank No. 2, ditto ditto.

Length...........	200	
Breadth...........	140	
	28,000	square feet.

Tank No. 3, ditto ditto.

Length...........	300	
Breadth...........	120	
	36,000	square feet.

Cowasjee Patell's Tank.

Irregular shape, about 15,000 square feet.

Dhobees' Tank.

Length...........	300	
Average breadth....	160	
	48,000	square feet.

Recapitulation.

	Square Feet.
Byculla Tank........................	168,000
Baboola Tank	234,000
Mombadavee Tank..................	77,000
Tank No. 1	66,000
Do. No. 2	28,000
Do. No. 3	36,000
Cowasjee Patell's Tank.............	15,000
Dhobees' Tank.....................	48,000
Square feet......	672,000

There should not at any time be less than 16 feet of Water in the Tanks.

6. The water in all these tanks is nearly exhausted at the end of the dry season; and it is calculated, that to keep the water at a convenient level, and to preserve its purity from being polluted by the sediment at the bottom, it would be necessary that each tank should be supplied with 16 feet

perpendicular of water during the eight dry months of the year. We have therefore to supply a surface of 672,000 square feet, or a little more than 15 acres, with 16 feet depth of water, or, in other words, 10,752,000 cubic feet, or upwards of 67,200,000 gallons of water.

7. The average fall of rain at Bombay is about 78 inches, or 6 feet 6 inches* perpendicular height, or about 40 gallons and a half per square foot, or 1,742,400 gallons per acre. Were there, then, no loss by evaporation, absorption, wastage, or other causes, we should require a surface of about 40 acres to supply this quantity; but without entering very minutely into the subject, we may fairly assume that one-half the water that falls during the rains would in one way or other be lost, and we should thus require the drainage of 80 acres for the supply of 67,100,000 gallons. But as the reservoir should never be exhausted, and a much greater supply of water may eventually be required, we ought, I think, to calculate on a capacity of nearly three times 67,100,000 gallons, and make our reservoir hold 200,000,000 gallons. For this purpose, at the rate above specified, we should require the drainage of 240 acres.

200,000,000 Gallons required, or the Drainage of 240 Acres.

8. The reservoir should be situated at a considerable height above the level of not only the tanks and roads of Bombay, but also of that of the highest houses, in order that if eventually the scale of the plan of supply should be enlarged, there might be less difficulty in extending the size of the reservoir, so as to enable it to supply the loftiest houses with water. We have therefore these two great desiderata to look for in our choice of a locality for the reservoir:—

Choice of Site for Reservoir.

1*st.*—Sufficient height.
2*nd.*—Sufficient surface.

The highest point of Malabar Hill (itself the highest of all the island hills) is only 123 feet; and neither that hill, nor any of the others above enumerated, appear to me to possess any eligible point on which the rain of the 240 contiguous acres could be collected in a reservoir, the bottom of which should be sufficiently high to diffuse with facility the quantity of water above stated to the different tanks. It is true that reservoirs of minor dimensions might be constructed on all and each of these hills, but the great object, that of a large and inexhaustible supply, cannot, I think, be attained on any of them.

No Hill in the Island suitable.

9. There is, however, on the peninsula called the Neat's Tongue, a hill which offers all the requisite advantages, and where a reservoir sufficient to supply fifty times the amount above specified might be constructed. This hill is certainly 800 or 1,000 feet high; its sides are steep; and there are several spots on it in which

Proposed Reservoir on the Neat's Tongue.

* Other statements make the average slightly less.—Ed.

the ground, converging towards the nullahs, forms almost a natural crater, admirably adapted for a reservoir. There is here sufficient unemployed surface to collect water for a reservoir of almost boundless extent, and one, the bottom of which would be at least 300 feet above the level of the tanks it would have to supply. On this hill a point might be selected, distant from Sewree in a direct line 3 miles. The water from the reservoir might be conveyed from the hill by an aqueduct of iron pipes, supported on pillars of masonry, across the arm of the sea (dry at low water) which separates Sewree from the Neat's Tongue. From Sewree a similar aqueduct would lead the water to the Byculla Tank, in the first instance, and from thence it should be conveyed by underground pipes to the other tanks, or any other point in the Native Town, which in this manner might be as well supplied with water as London.

The new River Company supplies 70,000 houses in London with 114,000,000 hogsheads of water, being at the rate of 240 gallons per day for each house, throughout the whole twelve months.

In Bombay there may be about 18,000 houses, the inhabitants of which consume on an average 50 gallons per day per house, as I am informed by several respectable Natives of whom I have made inquiries as to their daily consumption of water. I do not mean to say that there are not more than 18,000 houses in Bombay, but I should think about that number, that consume on an average 50 gallons each of water per day. This implies a total consumption of 328,500,000 gallons per annum. It is only for three months at the utmost in the year that any inconvenience is felt from a scarcity of water in the Native Town, and the reservior I have proposed establishing would amply supply the deficiency existing during those three months. I would not, however, confine the use of the reservoir to those three months, but, by spreading it over eight months, and never allowing the tanks to sink below a fixed level, an uniform supply would be ensured, and no sudden deficiency ever allowed to originate.

Cost of such a Reservoir.

10. With regard to the cost of such an undertaking, I am disposed to rate it at somewhat less than seven lakhs of rupees, and the following are the data on which I have founded this somewhat rough calculation :—

Iron Pipes.

The distance from a hill above the village of Mahool, in the Neat's Tongue, to Sewree, is 3 miles ; from Sewree to the Baboola Tank 2½ miles : the reservoir would therefore require 5½ miles of iron piping. The pipes should be 12 inches in diameter, and half an inch in thickness, and such pipes weigh 61¼ lbs. per foot, consequently each mile of pipes would weigh 145 tons. To this must be added 15 tons for flanges at every 12 feet, making altogether 160 tons. This, I apprehend, might be procured from England, and laid down, all expenses included, for £10 per ton; cost per mile £1,600.

At every 12 feet there must be a pillar of masonry—the average height of each pillar, allowing for inequalities of ground, 28 feet, average diameter 3 feet 6 inches or 4 feet; probable cost of each pillar £7; 440 of these to each mile, cost per mile £3,080.

Masonry.

Two miles of iron piping would be required to distribute the water from tank to tank, cost £1,600 per mile.

Cost of Aqueduct.

5½ miles of pipe, at £1,600 per mile......	£8,800
2 ditto ditto ditto	3,200
5½ miles of masonry, at £3,080 per mile..	16,940
	£28,940

Or under three lakhs of rupees. Without a survey of the ground, it is impossible to even guess at the cost of a reservoir; but it must be very unfavourable indeed for such a purpose if it requires more than four lakhs. By laying the pipes on the ground, a saving in the masonry would be effected, but the pipes must then be much stronger, in order to resist the pressure arising from the inequalities of level, and would probably cost double the previous estimate, besides being less secure, and less within reach in case of leakage or fracture.

(Signed) L. C. C. Rivett.

14*th June* 1845.

ADDITIONAL MEMORANDUM ON THE COST OF THE RESERVOIR.

A capacity of 200,000,000 gallons being required, some idea may be formed of the expense of such a reservoir from the following data:—

A square of 1,300 feet by 20 feet deep gives a capacity of about 220,000,000 gallons. The superficial area of such a square would be about 38¾ acres.

A circle 1,350 feet in diameter and 20 feet deep gives a capacity of nearly 186,000,000 gallons, and a superficial area of about 32¾ acres. Supposing the walls of a reservoir 1,300 feet square to be 30 feet high, inclusive of foundation, and to have a medium thickness of 18 feet, such walls would require 2,808,000 cubic feet of masonry, which, at Rs. 14 per 100 cubic feet, would cost Rs. 3,93,120, or a little less than four lakhs.

But this is supposing the ground to possess no natural advantages; whereas we may fairly presume that at least two sides of the reservoir will be provided for by the natural walls of the hill itself. In such a case two lakhs would probably cover the expense of masonry, whilst a third lakh might be necessary for levelling, blasting, scarping, &c. &c.

(Signed) L. C. C. Rivett.

LETTER FROM THE CHIEF ENGINEER.

To the Secretary to the Military Board.

Sir,

Proposes three Reservoirs—near the Dhobees' Tank, in the Girgaum Oarts, and at Mahim.

I have the honour to acknowledge the receipt of your letter No. 2338, of 13th instant, with accompaniments, calling on me to devise means for securing to the Presidency at all seasons a plentiful supply of wholesome water; and in reply I beg to submit the following propositions for the consideration of the Military Board and Government.

2. To provide three reservoirs in the following situations, which afford sandstone strata, which are saturated with water throughout the year:—

1*st.*—The Dhobees' Tank, on the Esplanade.

2*nd.*—Some eligible spot to be purchased in the Girgaum Oarts.

3*rd.*—The Cocoanut Oarts at Mahim.

Districts which the three Reservoirs are intended to supply.

The first for the supply of the Fort; the second for the supply of the Native Town, from the verge of the Esplanade to a line running east and west from the Mombadavee Tank; the third for the supply of Parell, Byculla, Mazagon, and the Native Town north of the line abovementioned.

Water how to be obtained.

The supply of water in the reservoirs to be obtained by galleries, cut as far as possible in the sandstone stratum.

4. The water to be pumped from the reservoirs by steam-engines, and conveyed through iron pipes to the different quarters.

The Reservoirs to be covered.

5. The reservoirs to be covered over by the engine-rooms, and other buildings, to prevent evaporation, and to preserve the water pure.

Recommends that Captain Goodfellow be employed to prepare Levels, Survey, and Estimate of Works at Vehar, suggested by Captain Crawford.

6. With reference to Captain Crawford's suggestion of an abundant supply of water being obtainable from Sankey in Salsette, I have the honour to recommend that the preparation of the necessary levels, survey, and estimate, should be entrusted to Captain Goodfellow, of the Engineers, lately returned from England, and that he also be entrusted with the duty of preparing the plans and estimates for the works suggested in the foregoing part of my letter.

7. I have had the honour to recommend to Government in the Military Department, that that officer should be appointed Executive Engineer at Ahmednuggur, but I would beg to suggest that that officer should be detached temporarily for the special duty of making the necessary investigations, and carrying out the plans for the supply of water in question.

I have the honour to be, &c.

(Signed) Geo. Jervis, Lieut. Col. Commandant,
Chief Engineer.

Bombay, Chief Engineer's Office, 16*th June* 1845.

RESOLUTION THAT THE ATTENTION OF THE COURT OF PETTY SESSIONS BE CALLED TO THE SUBJECT.

As it is probable, owing to the lightness of the monsoon, that the scarcity of water will next year be even greater than that which in May and June last occasioned such general and painful distress, I would beg to propose that the attention of the *Court of Petty Sessions* be at once called to the subject, with a request that they will consider what measures can be taken for husbanding the supply of water, and for keeping it pure and wholesome.

(Signed) G. ARTHUR.
Concurred in by J. H. CRAWFORD.
" " L. R. REID.

24th September 1845.

LETTER FROM THE CLERK TO THE PETTY SESSIONS, PROPOSING MEASURES FOR HUSBANDING THE SUPPLY OF WATER, AND FOR KEEPING IT PURE AND WHOLESOME.

No. 253 OF 1845.

GENERAL DEPARTMENT.

To WILLIAM ESCOMBE, Esq.,
Secretary to Government.

SIR,

I have the honour, under instructions from the Court of Petty Sessions, to acknowledge the receipt of your letter No. 2996, dated the 25th of last month, calling the attention of the Court to the probability, owing to the lightness of the present monsoon, of the scarcity of water being even greater in the next hot season than that which in May and June last occasioned such general and painful distress, and requesting that the Court will consider and report what measures can be taken for husbanding the supply of water, and for keeping it pure and wholesome.

Additional Establishment of Tank Peons.

2. In reply, I am desired to state, for the information of the Honorable the Governor in Council, that the Court, having taken the subject into mature consideration, would beg leave to suggest that Captain Cruickshank should be authorised to entertain such additional establishment of Tank Peons as would effectually prevent the waste of water at the several tanks and wells throughout the island, and the attention of that officer should be especially directed to this subject.

3. The Court understands that there is a spring of fresh and pure water on the land near the Cooperage, from which, in a season of scarcity, a considerable supply might be obtained between the time of half ebb-tide and the half flood of the next tide; and Captain Cruickshank should be called on to report what quantity could be obtained from that source fit for public use.

Spring of Water near the Cooperage.

4. A large quantity of water is consumed by the shipping in the port, and the Court suggest, that in the event of scarcity, ships be required to get their water from Elephanta or Salsette, whence, it is believed, they have occasionally procured their supplies ; and, as the Court is informed that a large ship with a crew of 100 men can be watered for a four months' voyage in one day, they are of opinion that a considerable supply might, in a season of scarcity, be obtained from Salsette, Caranjah, and neighbouring places.

Water for Ships in the Port.

5. On the last occasion of an anticipated scarcity of water in the season of 1838-39, the Court observe, that on the 20th of November 1838 a proclamation was promulgated by Government, prohibiting the use of private wheels, and the use of water from the public wells for irrigation and washing, and enjoining every private individual to be particularly careful in his own family to limit the use of water fit for domestic purposes, so that none might be unnecessarily or wantonly thrown away.

A Proclamation to be issued by Government.

6. The Court, I am desired to state, is of opinion, that the accompanying draft of a proclamation, which is similar to that formerly issued, would answer the object in view, and that by placing the control of all the public tanks and wells under the Superintendent of Repairs, that officer will be able to prevent any unnecessary waste of water. At present a portion of the tanks is under the Collector of Land Revenue.

I have the honour to be, &c.
(Signed) L. C. C. Rivett,
Clerk.

Bombay, Petty Sessions' Office, 14*th October* 1845.

PROCLAMATION.

The Honorable the Governor in Council, taking into consideration the small supply of water at present in the wells, tanks, and public reservoirs, and the necessity of preventing its lavish expenditure in the present season, that the water may be secured in sufficient quantities, for good and necessary uses, is pleased to order as follows :—

No private wheels shall be allowed, until after the rains of next year, on the public tanks where the water is wholesome, and which are so situated as to be available to the Native population.

The water shall not be taken from such tanks, or from public wells, in great quantities, by any other means for the purpose of cultivation, nor is any to be expended upon the public roads; it may, however, be used for the construction of buildings.

The Natives and others will not be allowed to wash themselves, or their clothes, at such tanks or wells, or in the immediate neighbourhood of them, except the Dhobees' Tank, but they will not be restricted in drawing water freely, and carrying it to their houses, for all domestic purposes.

In order to carry these measures into effect, the Governor in Council is pleased to place the public tanks and wells under the charge of the Superintendent of Repairs, who will station Peons at them, with strict orders to have these directions observed.

In thus controlling the public reservoirs of wholesome water, the Governor in Council trusts, that during the present season of drought, every private individual, European and Native, will be particularly careful in his own family, to limit the use of water fit for domestic purposes, so that none be unnecessarily or wantonly thrown away.

CAPTAIN TURNER'S LETTER, FORWARDING PLAN AND ESTIMATE FOR A RESERVOIR ON MALABAR HILL.

No. 100 of 1846.

General Department.

To the Secretary to the Military Board,
Bombay.

Civil Architect's Office, Bombay, 21*st March* 1846.

Sir,

With reference to your letter No. 790, of 21st ultimo, I have the honour herewith to forward a plan and estimate, amounting to Rs. 3,00,040, (three lakhs and forty,) of the probable expense, exclusive of 1,006 pieces of iron pipe, of making a large reservoir for rain water, prepared at the request and agreeably to the instructions of the Chief Engineer.

2. The plan shows a part of Malabar Hill, the extent of surface to be drained, the site of the proposed reservoir, and plan and section of the reservoir and feeding tanks, &c.

Quantity of Water to be supplied to the Reservoir.

3. It is proposed to have one feeder on the side of the road leading to Malabar Hill, and another on the side of the road leading up to the Shrubbery. The former will drain 728,225 square feet of surface, the latter 1,632,600 square feet; and, allowing that 24 inches are secured to supply the reservoir, this surface will yield in round numbers 29,000,000 gallons, sufficient to fill the reservoir within a small fraction, which will be more than made up by quantity secured from the roof of the reservoir itself. Allowing 1,000,000 gallons to be lost by evaporation, and allowing 5 gallons a day as the consumption of one person, it is calculated that this reservoir will supply 93,333 persons for 60 days, or 62,222 for 90 days.

4. The bottom of the reservoir is in the plan only sunk to the depth of 12 feet, as in making an experiment (in the vicinity of the site) to ascertain the supply of water for a Government distillery, strong salt-water springs were found at that depth.

Feeding Tanks.

5. To supply the feeding tank on the Malabar Point road, it is proposed to make a covered drain from the top of the hill to the feeding tank, with perforated stones at regular intervals. This drain will run partly under the road, and partly under the side gutter, and will have a sluice in it close to the feeding tank, and a branch going under the head, by which the impure water brought down by the first fall of rain will be carried

into the sea, and not allowed to enter the feeding tank. As soon as the water runs clear, the sluice will be taken from the entrance of the feeding tank, and placed across the mouth of the branch gutter.

6. The water from this feeding tank, which will have a height of 40 feet, will be carried by a 14-inch iron pipe to the reservoir.

7. The drains for conveying the water to the other feeding tank will be partly open and partly covered, those portions only being closed which pass under the road or through much frequented enclosures. This feeding tank will be connected with the reservoir by a double line of 14-inch iron pipe.

Huts near the Line of Drains should be removed.

8. The concurrence of the different holders of the land proposed to be drained will be required, and it is very desirable that the huts that exist in the vicinity of the line of drains should be removed, or otherwise some establishment will be required to prevent the inhabitants of these huts from making the drains a place of deposit for filth, and otherwise rendering the supply of water impure: this remark more particularly refers to the huts in the vicinity of the drain supplying the feeding tank on the Shrubbery road.

Cost of Pumping Engine and Pipe.

9. In the estimate I have charged Rs. 8,000 for a 12-horse pumping engine, with pumps to raise water 18 feet, including freight, Rs. 1,500 for landing and erecting the same, and Rs. 1,200 for coals and establishment for working the same for six months.

10. The cost of the pipe I have not included, as I do not know what the price may be at present in England, from whence both the pipe and the engine must be supplied.

I have, &c.

(Signed) T. M. B. TURNER, Captain,
Civil Architect at the Presidency.

(True copy)
(Signed) C. D. MYLNE, Captain,
Acting Secretary Military Board.

Estimate framed by Captain T. M. B. Turner, *Civil Architect at the Presidency, of the probable Expense of making a Reservoir, with Feeding Tanks, &c. complete, for securing a supply of Water from Malabar Hill. Prepared agreeably to the suggestions of the Chief Engineer.*

CONSTRUCTIONS.

Reservoir of Stone and Choonam, and Brick and Choonam Masonry, covered with Teak-trussed single-tiled Roof, with dammered Plank Gutters, Tank of Stone and Choonam Masonry, half covered with Teak Plank, with Drains partly open, and partly constructed of Choonam Masonry, and covered with Stones.

Bombay, 21st March 1846.

Dimensions.			Names of Items.		Rate.	Per	Amount.	Total.	Grand Total.
Length.	Breadth.	Depth or Height.		*Constructing a Reservoir.*	*Rs. a. p.*		*Rs. a. p.*	*Rs. a. p.*	*Rs. a. p.*
414	414	14	2,399,544	cubic feet. Digging a reservoir with foundation.	1 0 0	100 cubic feet ..	23,995 7 0		
1628	4¼	32	221,408	ditto. Building wall on four sides with stone and lime.					
400½	400½	1¼	200,500	ditto. Ditto foundation for bottom, with ditto.					
2¼	2¼	24¾	18,043	ditto. Ditto 144 choonam posts, support for the roof.					
			439,951	total cubic feet stone and choonam masonry.....	15 0 0	Ditto. ..	65,992 10 4		
1604	1	31	49,724	cubic feet. Building brick and choonam wall inside all round.					
398½	398½	½	79,401	ditto. Ditto for bottom.					
			129,125	cubic feet.					
2½	2½	½	449	ditto. Deduct for 144 choonam posts.					

					Rate		Amount
			128,676	cubic feet brick and choonam masonry....	25 0 0	Ditto. ..	32,169 0 0
$398\frac{1}{2}$	$398\frac{1}{2}$	$\frac{1}{4}$	158,802	square feet. A thick plaster for bottom, with gravel............	20 0 0	Ditto. ..	31,760 0 0
1600	$\frac{7}{12}$	30	48,000	ditto. Ditto ditto for inside, on the wall all round............	15 0 0	Ditto. ..	7,200 0 0
	Each						
9	..	24	31,104	ditto. Common plaster for 144 choonam posts	6 0 0	Ditto. ..	1,866 3 10
$\frac{8}{12}$	$\frac{8}{12}$	8	144	teak-wood posts on the top of choonam posts, complete	8 12 0	Ditto. ..	1,260 0 0
404	404	..	163,216	square feet. Roof, teak-wood trussed, and single tiled, complete........	46 0 0	Ditto. ..	75,079 5 9
404 × 4 × 12 404 × $2\frac{1}{2}$ × 4			23,432	ditto. Gutter on the roof, ditto.	37 8 0	Ditto. ..	8,787 0 0
				Truss.			
31	$\frac{4\frac{1}{2}}{12}$	$\frac{5\frac{1}{2}}{12}$	9,207	cubic inches. Beams.			
$16\frac{1}{2}$	$\frac{4}{12}$	$\frac{5}{12}$	7,920	ditto. 2 Principals.			
15	$\frac{4}{12}$	$\frac{5\frac{1}{2}}{12}$	3,960	ditto. Colour beam.			
			21,087	cubic inches.			
			9,278	ditto. Add wastage 44 per cent.			
			30,365 ÷ 1·728 = $17\frac{1}{2}$	cubic feet teak-wood, at Rs. 1-8-0 per cubic foot .... Rs.	26 4 0		
				Carpenters and Sawyers, &c.	5 2 0		
					31 6 0		
				Carried forward		Rs.	248109 10 11

Dimensions.			Names of Items.	Rate.	Per	Amount.	Total.	Grand Total.
Length.	Breadth.	Depth or Height.		Rs. a. p.		Rs. a. p.	Rs. a. p.	Rs. a. p.
			Brought forward..	....	....	248109 10 11		
Measuration of triangle.			156 trusses for the support of the roof....	31 6 0	Each..........	4,894 8 0		
1704	175	...	298,200 cubic feet. Properly sloping and beating down the earth slope all round the reservoir	0 8 0	100 cubic feet ..	1,491 0 0	254495 2 11	
12	12	10	*Tank No. 1.*					
16	16	10	2,560 cubic feet. Digging tank with foundation	2 0 0	Ditto. ..	51 3 2		
56	2½	10	1,400 ditto. Building stone and choonam wall all round.					
11	2	10	220 ditto. Ditto cross wall.					
			1,620 cubic feet.					
			20 ditto. Deduct for drain.					
			1,600 cubic feet. Building stone and choonam wall........................	15 0 0	Ditto. ..	240 0 0		
44	..	12	528 square feet. Plaster inside the tank.					
22	..	11	242 ditto. Ditto cross wall.					
			770 square feet.					
			40 ditto. Deduct for cross wall.					
	ins.		730 total square feet choonam plaster ..	6 0 0	100 square feet. .	43 12 9		
300	$\frac{8}{12}$	..	1,600 cubic inches. 16 maunds round iron bar for grating.	2 0 0	Maund........	32 0 0		

16	10	..	160	square feet. Plank cover over tank, with a trap door, joists 6×3 inches, plank 1½ inch thick, hook hinges complete.	0 12 0	Square foot......	120 0 0	486 15 11
20	20	6		*Tank No. 2.*				
24	24	7½	4,320	cubic feet. Digging Tank with foundation	2 0 0	100 cubic feet...	86 6 4	
24	24	1½	864	ditto. Building foundation for bottom.				
88	2½	6	1320	ditto. Ditto wall on four sides.				
19	2	6	228	ditto. Ditto cross wall.				
			2,412					
			24	ditto. Deduct for 2 drains.				
			2,388	total cubic feet. Building with stone and choonam......................	15 0 0	Ditto. ..	358 3 2	
18	18	..	324	square feet. Plaster for bottom.				
76	8	..	608	ditto. Ditto inside all round.				
38	7	...	266	ditto. Ditto for cross wall.				
			1,198	square feet.				
			60	ditto. Deduct for cross wall.				
	ins.		1,138	ditto. Plaster with choonam. ...	6 0 0	100 square feet..	68 4 5	
360	4/12	..	1,908	cubic inches. 19 maunds round iron bar for grating..................	2 0 0	Maund........	38 0 0	
24	13	..	312	square feet. Plank cover over tank, with a trap door, joists 6 × 3 inches, planks 1½ inch thick, hook hinges complete........................	0 12 0	Square foot.. ...	234 0 0	784 13 11
				Carried forward..........................Rs.			......	255767 0 9

Dimensions. Length.	Breadth.	Depth or Height.	Names of Items.	Rate.	Per	Amount.	Total.	Grand Total.
				Rs. a. p.		*Rs. a. p.*	*Rs. a. p.*	*Rs. a. p.*
			Brought forward ..	......	....	....	255767 0 9	
3100	2½	3	*One Drain covered with Stone, from the Top of Malabar Hill to Tank No. 1.*					
3100	4½	4½	62,775 Cubic feet. Digging drain	4 0 0	100 cubic feet ..	2,511 0 0		
6200	1	3	18,600 ditto. Building wall on both sides of drain..................	12 8 0	Ditto. ..	2,325 0 0		
3½	1	..	2,790 Covering stones complete...........	0 12 0	Each...........	2,092 8 0		
			310 Stone grating ditto	2 4 0	Ditto	697 8 0		
100	2½	3	*Cross Drain for letting off the first fall of Rain.*					
100	4½	4½	2,025 cubic feet. Digging for ditto..	2 0 0	100 cubic feet...	40 8 0		
200	1	3	600 ditto. Stone wall on both sides of drain..............................	12 8 0	Ditto. ..	75 0 0		
3½	1	..	100 Covering stones for ditto	0 12 0	Each..........	75 0 0		
	2½	3	15 square feet. 2 square gates complete.	2 0 0	Foot	30 0 0	7846 8 0	
5550	2	2	22,200 cubic feet. Digging earth for iron pipes from Tank No. 1 to the reservoir..........	2 0 0	100 cubic feet ...	444 0 0		
5550	2	2	5,550 Running feet. Covering with earth..	1 0 0	100 running feet.	55 8 0		
			653 pieces. Laying and joining iron pipes in joints, each piece 9 feet in length and 14 inches in diameter.	6 0 0	Piece...........	3,918 0 0		
			653 carts. Hire for conveying 653 iron pipes from Arsenal to Malabar Hill.	1 0 0	Ditto...	653 0 0	5070 8 0	

3450	3	3½	*One Drain, partly open and partly covered, from the Hill called Ryghur to Tank No. 2.*											
2350	3	3½	24,675 cubic feet. Digging part of open drain.											
1100	5	5	27,500 ditto. Ditto for covered do. from C to D.											
			52,175 cubic feet digging..................	1	8	0	100 cubic feet..	782	10	0				
2200	1	3½	7,700 cubic feet. Stone and choonam wall on both sides of covered drain......	12	8	0	Ditto. ..	962	8	0				
4	1	..	990 covering stones	0	12	0	Each..........	742	8	0				
4	1	..	110 stone grating.........................	2	4	0	Ditto...........	247	8	0				
400	3	3½	*Cross Drain for letting off the first fall of Rain.*											
400	5	5	10,000 cubic feet. Digging drain.	2	0	0	100 cubic feet..	200	0	0				
800	1	3½	200 ditto. Wall on both sides of drain.	12	8	0	Ditto. ..	350	0	0				
4	1	..	400 covering stones.	0	12	0	Ditto. ..	300	0	0				
...	3	3½	21 square feet. 2 sluice-gates complete...	2	0	0	Foot..	42	0	0				
												3627	0	0
3000	2	2	12,000 cubic feet. Digging earth for double drain of iron pipes from Tank No. 2 to the reservoir..............	2	0	0	100 cubic feet..	240	0	0				
3000	..	..	3,000 running feet. Ditto covering with earth.	1	0	0	100 running feet.	30	0	0				
			353 pieces. Laying and joining iron pipes in joints, each piece 9 feet long and 14 inches diameter..............	6	0	0	Piece	2,118	0	0				
			353 carts. Hire for conveying 353 iron pipes from Arsenal to the Tank No. 2..............................	1	0	0	Each.............	353	0	0				
												2741	0	0
			1,006 pieces of iron pipes, each 9 feet long and 14 inches diameter. For a 12-horse pumping engine complete	....			......	8,000	0	0				
			Carried forward........................Rs.					8,000	0	0		275052	0	9

Dimensions. Length.	Breadth.	Depth or Height.	Names of Items.	Rate.	Per	Amount.	Total.	Grand Total.
				Rs. a. p.		*Rs. a. p.*	*Rs. a. p.*	*Rs. a. p.*
			Brought forward.....	....	....	8,000 0 0	275052 0 9	
			Levelling and erecting..	....	....	1,500 0 0		
			Coals, and establishment for working the same for 6 months	.....	....	1,200 0 0		
							10700 0 0	
							285752 0 9	
			Contingencies at 5 per cent....				14287 10 0	
								3,00,039 10 9
			Exclusive of iron pipes, Total Rupees Three Lakhs and Forty....					3,00,040 0 0

(Signed) T. M. B. Turner, Captain,

Civil Architect at the Presidency.

LETTER FROM CAPTAIN CRAWFORD TO THE BOARD OF CONSERVANCY, PROPOSING TO BRING WATER FROM SALSETTE.

No. 108 of 1846.

To George Hancock, Esq.,
Clerk to the Board of Conservancy.

Sir,

In consequence of the scarcity of water in the island of Bombay during the present season, I have been induced to turn my attention to the question of the practicability of increasing the annual supply, and hope I may be excused in troubling the Board on a subject upon which my opinion has not been required.

2. In former years, whilst employed in the Tanna districts, it had often struck me, on hearing complaints of a scarcity of water in Bombay, that the range of hills in the neighbourhood of Vehar, and the nullah that takes its rise in it, afforded the means of supplying pure water to the island to a considerable extent; and with this in view I have lately paid a short visit to the village of Koorla and its neighbourhood, for the purpose of refreshing my memory with regard to the different localities, and to consider what would be the most feasible scheme of procuring such supply.

3. I am of course unable to furnish any detailed plan on such a flying visit, having taken no instruments with me, and having no time to use them if I had. I was occupied merely in riding and walking in various directions over the country, gathering what information I could by the eye, and the reports of the inhabitants; and the result is, that although I am not prepared to promise that a constant supply of water throughout the year could be obtained, (but even on this point I am sanguine, although future experiment alone can decide it,) still there is no doubt that a very large supply of pure water may be thrown into Bombay, to an extent that would ensure all the tanks and reservoirs being filled with pure water up to the end of December, which at any rate would remove all chance of scarcity throughout the ensuing hot season.

4. This might be ensured, I think, by carrying out the first portion of my project; and, by future extension of the plan, (which it admits of to almost any extent,) the desideratum of a *constant* supply to public fountains throughout the town for drinking and cooking purposes I have great hopes might be obtained.

5. It is hardly necessary to allude to the present supply of water in Bombay: with the exception of wells, most of which are private property, the inhabitants are dependent upon the tanks, which are generally filled by the foul surface drainage of a populous town. The monsoon may generally be considered as closed by the beginning of October, and

If the present Tanks in Bombay could be filled in December, there would never be any scarcity.

from the date of the rain ceasing to fall it may, I think, be assumed, that the water in the tanks begins to decrease by evaporation, and that drawn for use. A few have springs in them, but not, I imagine, of any great strength, and by no means equal to the draught upon them; it may, therefore, as I said before, be safely assumed, that the commencement of October sees the tanks and reservoirs at their highest. Now if by any means the period of full tanks could be deferred to the end of December, even this alone would be a great benefit—it would be a clear gain of upwards of a two months' supply; and we should start at the commencement of the new year with full tanks, and little fear of scarcity before the next rainy season.

6. There are two questions on this point—1*st*, as to the feasibility of the plan; 2*nd*, as to its value, or, rather, as to whether the supply above calculated upon would be worth the expense of procuring it.

7. The first question admits of easy reply: we have the supply of water at a certain point, and there is no doubt that with the aid of pipes and machinery we can bring it to any other point we wish. The second requires accurate surveys and plans, and many inquiries to be made, before it can be answered as satisfactorily.

8. I shall now proceed to show how the first mentioned supply of water may be obtained, and then the plan upon which the system may be extended by degrees in after years, until I have but little doubt that the supply will fully answer the demand of the inhabitants of Bombay.

Proposal to dam up the Nullah which flows from the Vehar Hills to Mahim Creek.

9. The watercourses descending from the southern face of the lofty range of hills in the vicinity of the village of Vehar, on the road to Tanna, and about 5 miles from the last named place, unite at the foot of the range, and form a pretty large nullah, which proceeds in a nearly southerly course for six or seven miles, and falls into the head of the Mahim Kharree close to the village of Koorla, about 13 miles from Bombay. By my own recollection I was aware that this nullah continued to flow for some time after the cessation of the monsoon, but, having made no memorandum on the point, I could not hazard an assertion as to the period up to which it continued to do so (which of course in a mountain torrent is dependent upon the continuance of the monsoon itself). By questioning the inhabitants and Patels of villages, and comparing their evidence, I think it may be assumed that it does run with a pretty considerable stream up to the end of December, that it rapidly diminishes in January, and about the middle of that month ceases to flow altogether, the water then standing in pools in various parts, many of which remain even up to the present date.

10. A small bund should be thrown across the nullah near its termination at the village of Koorla, and where there are many facilities for the construction of one. This bund would not be built with a view of retaining any large body of water, but merely to give a sufficient depth, and form a reservoir

to pump from. A line of main pipes would be laid down from Bombay to this point, giving it a sufficient head to overcome any intermediate rise in the ground; and with pumping engines, worked either by steam or animal power, as found most economical, there is no doubt, that with pipes of large bore, and sufficient pumping power, a great portion of the very large quantity of pure water annually poured into the sea at Koorla might be brought into Bombay, for the benefit of its inhabitants. Of course this supply would only last as long as the water in the nullah continued to flow. This is the first part of my plan for keeping the tanks full up to the end of December.

11. It may here be observed, that whilst the flow of water in the nullah is much in excess, during the continuance of the monsoon, that it is possible to bring the supply of water into the island without the expense of pumping. Supposing the head of water required at Koorla to be 30 feet, it is obvious, that by proceeding up the nullah until we arrive at that elevation, a line of pipe being laid down from this point to Koorla would effect a constant flow without further mechanical aid. It would only be a question of difference of expense between laying down such extra line of pipe and the cost of working the engine for about three months of the monsoon.

Extension of the Plan.

12. As to the extension of the plan for procuring a further supply than the above provides for:—In looking at the nullah throughout its length, it will be found, I think, on accurate survey, to be well adapted to the formation of reservoirs, by having bunds thrown across at various points, which, on the water ceasing to flow in the nullah, might be opened as occasion required, their contents led down to the lowest reservoir, and thence pumped up. It fact, the nullah might be transformed into a chain of tanks, and good pure water preserved in the open country, instead of within the limits of the town, exposed to all the pollutions of such a vicinity. Expensive, no doubt, as such a plan would be by the time the whole of these works were completed, it is to be remembered that it would be extended over a series of years, as the whole system of tanks would not have to be formed at once, but only as an increased supply of water was called for.

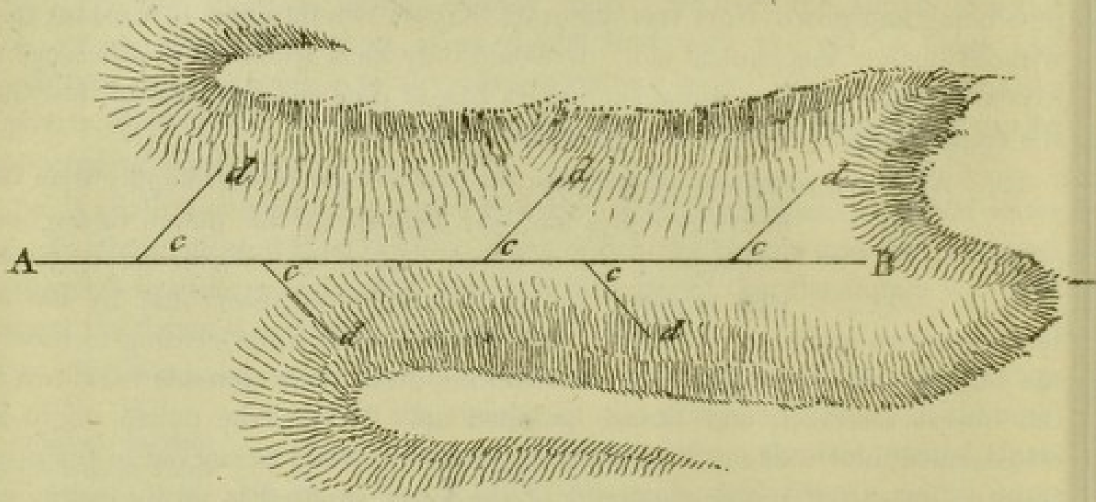
Alternative Plan for obtaining Water near Koorla.

13. There is, however, a locality in the neighbourhood of Koorla deserving of the closest investigation, and should my ideas with regard to it prove well founded, there is, I think, every prospect of obtaining a fine and continued supply of drinking water, after that in the nullah has ceased to flow, and probably at much less cost than the construction of bunds in the bed of the nullah.

14. In proceeding along the road from Koorla, and about 2 miles from that village in the direction of Tanna, there is a range of hills on the right, which terminates in some curious spurs and knolls. These spurs include some valleys, which, from a hurried inspection, I believe to be large natural reservoirs of water. In many parts the herbage is yet green and fresh on the surface. One or two old wells have 12 or 15 feet of beautiful cold spring-water in them.

In one place I saw a hollow, merely scraped in the surface, for watering cattle at, and full of water. In another spot, even in this dry season, water was still trickling on the surface, to say nothing of local reports, which, although often exaggerated, have generally some foundation in truth, and which reports state the water to be very close to the surface. In fact, I look upon this place as something of the same character of ground as that around Ahmednuggur, and in which are constructed the well-known aqueducts of that town. Should the ground prove to be what I imagine it, but which can only be ascertained by trials with the boring rod in various parts, the plan to be adopted would be much the same as that of the Ahmednuggur aqueducts.

15. Suppose a valley, as in the accompanying rough sketch, the nature of the soil being what I imagine it :—



I should sink a shaft (A) at the lowest point whence I wish to draw my water —in the present instance it would probably be 15 or 20 feet deep; I should then run an open drain (A B) $2\frac{1}{2}$ feet wide, and as deep as circumstances would admit of, with a slight slope downwards towards A, building up the sides if necessary, and covering the surface with flag-stones and earth; and at certain distances I would in like manner open the shorter cross-drain (*c d*). In this way, looking at the bed of the valley as a vast sponge, the whole would be thoroughly drained without any loss from evaporation.

16. In conclusion, I must apologise for troubling the Board with a report, which, wanting plans and estimates, can be of such little practical utility. I forward it, however, because, although there may be no immediate prospect of such a project being carried out, I think that before many years are over

The Land at these places should not be alienated.

something must be done with regard to supplying Bombay with water; and though my present plans and ideas may be very crude, I still think, that when any project is undertaken, the locality I have pointed out is that from whence the supply of water will have to be drawn. It would be as well if an accurate survey of the nullah was made, both as regards mapping and levelling, and the same more especially with respect to the ground included in the spurs of the hills in the vicinity of Koorla, alluded to in the latter part of this report; and should the said ground be found to correspond with the ideas I have formed regarding it, although no further project were entertained for the present, it would have the effect of preventing the land being granted to any parties on terms which might render it difficult of resumption hereafter if it is not already in that predicament.

I have the honour to be, &c.

(Signed) J. H. G. Crawford, Captain,
Acting Superintendent of Repairs.

Bombay, Superintendent of Repairs' Office, 16th May 1846.

SECOND LETTER FROM CAPTAIN CRAWFORD, ON THE SAME SUBJECT.

No 179 of 1846.

To George Hancock, Esq.,
Clerk to the Board of Conservancy.

Sir,

With reference to the extract from the proceedings of the Board of Conservancy dated 26th May, I have the honour to forward the accompanying sketch of ground, and following report on the subject of procuring a supply of water from the island of Salsette.

2. I am exceedingly loath to forward these papers in such a very incomplete state; but the very few days in the month of June during which the weather admitted of any out-of-door work, viz. from 3rd to 10th, and that short period frequently interrupted by rain, will, I hope, prove a sufficient excuse.

3. To furnish detailed and accurate estimates would require a complete survey of the ground within the compass of the accompanying sheet, together with a large series of levels through it, and a correct line of levels from the point A to the town of Bombay. This, in the short opportunity that was allowed me, was not to be accomplished. Seeing, from the threatening appearance of the weather, that it was useless to commence upon a systematic survey, my object was to ascertain at once such principal points as would enable me to give some report on the matter, leaving smaller details to be arrived at hereafter, should it ever be deemed necessary.

4. Insufficient, therefore, as the survey is, to enable me to furnish detailed estimates of the cost of the work, it will still allow of my reporting on the feasibility of the scheme, and offering some idea of what might be the probable cost of carrying it into execution; and this latter, taking it at the lowest, is, I regret to say, so large in amount, both as regards first cost and annual expenses, that I fear it will be considered greater than the benefit to be derived from the plan would warrant.

Cost, and Annual Expenses, compared with the Results.

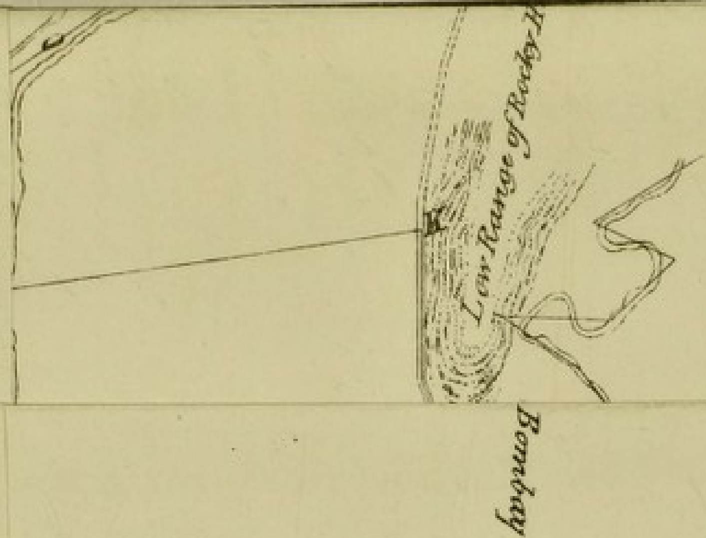
5. I was able to get a survey by compass of the nullah up to the Sankey bridge. Accurate levels throughout its length, which I extended into the country to the well M, at the village of Chandoolee, cross-sections and levels on the lines F, G, H, I, K, to enable me to determine to what height a bund might be constructed at B C, and to form some idea as to what quantity of ground it would lay under water; and also levels to the top of the hill at D, to determine what head of water could be procured. At this point further proceedings were stopped by the weather, but the levels, as far as they have proceeded, will, I think, be found correct, as they were taken with a good instrument, and entirely by my own hands.

Survey of the Nullah up to the Sankey Bridge.

6. The sketch exhibits the mouth, and a small portion of the course of the nullah, which takes its rise in the range of hills near the village of Vehar, in Salsette, and empties itself into the sea at the village of Koorla. The portion here represented flows through a nearly level country, partly waste ground, covered with trees and low jungle, and partly of rice cultivation. The bed of the nullah consists of rock and shingle, whilst the banks, which are 8, 10, and 12 feet high, are in places nearly perpendicular, and consist principally of earth. Across the mouth of the nullah, and just above high-water mark at B C, there is a natural bund of rock, which extends into the country on both sides of the nullah, and a little higher up there is another of the same description. The hill D is 70 feet above high-water mark; it is almost a solid rock, and conveniently situated for any works requisite for establishing a head of water.

Description of the Nullah.

7. The well M is at the village of Chandoolee: its position is laid down by survey; the ground to the southward of it, bounded on the east by the range of hills, and on the west by the high road to Tanna, is that particularly alluded to in my letter of 16th May, but I was prevented from examining it further both by the weather and the impossibility of collecting a sufficient body of labourers at that season, without sufficient notice having been given. The range of hills on the east of this ground is lofty; they are merely laid down by guess. Along the foot of the range are many springs and pools of water, and of the whole of this ground I still retain the favourable opinion I formerly had regarding it. But a searching examination by boring would be required before its capabilities could be sufficiently ascertained. The position of the two knolls



"True Copy"

(Sig$^{d.}$) H. Conybeare,

Superintendent of Repairs

terminating the range of hills, is correctly laid down by intersection during the survey of the nullah. The point A, at the bottom of the nullah, and just within the natural bund before alluded to, I assume as about on a level with the high-water mark, and all the levels I reduce to this point. On the plan the figures (1, 2, 3, &c.) show the height of that particular spot above A in feet and tenths.

8. Of the feasibility of bringing into Bombay a large portion of the supply of water annually brought down by this nullah, there can be no doubt—it is only a question of expense; and as this would undoubtedly be great, it is to be considered whether an equal sum might not be laid out to greater advantage on tanks and works connected with the supply of water within the island of Bombay itself. As already stated, I have not sufficient data upon which to ground accurate plans and estimates; but if I am able to give an approximation to the outlay, it will admit of a judgment being formed as to the use of proceeding further with any survey.

9. The nullah continues to flow until the end of December. By erecting an engine at a favourable point for pumping, and laying a main of pipes to Bombay, there is no doubt that a considerable body of fresh water might be led into the town; and taking advantage of the favourable natural formation at the mouth of the nullah, and throwing a bund across at that point, the top of which might be at least 20 feet above the point A, the supply of water would be much increased, at a comparatively small cost. As near as I can judge, such a bund would inundate the ground within the light blue line on the plan, forming a very considerable tank, capable of great improvement hereafter by excavation. The road at H would require to be raised 5 or 6 feet for a short distance, and the Sankey bridge the same. As future increase of population would call for increased supplies, the nullah throughout its whole length might be converted into a chain of tanks, and the water let down from the upper ones to the lower, and pumped in as required.

Cost of erecting Bund, Engine, &c.

10. I shall, however, omit any calculation on this point, as at any rate it would only be a question of future improvement and extension, and proceed to show what would be (as near as I can at present ascertain) the first cost of the necessary works. These would consist of the erection of a bund at B C; providing a suitable engine and engine-house; building reservoir on the top of D, for procuring a head of water; and laying down a main of pipes from Koorla to Bombay.

11. The hill D is 70 to 86 feet above the point A, or high-water mark; on the top of this hill an extra 10 feet might easily be obtained in building a reservoir without any very heavy extra cost, thus giving a total of 80 feet. I suppose, on the average, that the water is to be delivered at a height of 20 feet above high-water mark in Bombay, which would, I think, be more than sufficient to reach all the public tanks. This will leave a height of 60 feet for

a head of water upon which to calculate the discharge. I assume the length of pipe to be laid down at about 10 miles, its diameter 14 inches. These conditions, with a head of water of 60 feet, would give a discharge of 6,992,542 cubic feet, or 43,575 gallons per hour, without making deductions for angles in laying down the pipe, which need be neither great nor sudden.

12. For raising this body of water to a height of 80 feet, an engine of 176 horse-power would be required, costing, with pumps, gear, &c £12,000

Engine and boiler-house, with residence for Engineer	1,500
Fixing engine and gear..................................	400
	£13,900

For this estimate of the necessary engines, and their cost, I am indebted to Captain H. Turner :—

Estimate of one Mile of Pipe.

14-inch pipe, ¾ inch thick, weighs 108·2 per lbs. lineal foot; it is in length of 9 feet, exclusive of joints, for which the weight of one foot is to be allowed extra to each length; therefore each length will weigh 108·2 lbs. × 10= 1,082 lbs. There will be 587 such lengths required per mile, weighing about 284 tons, which, shipped at Glasgow at £7 15*s*. per ton, will cost per mile £2,201

Additional Charges.

Freight, £1 per ton	284
Insurance 2 per cent.....................................	45
Landing charges, 4*s*. per ton	57
Carriage in Bombay, 4*s*. per ton	57
Extra per mile for valves, cocks, angle-pieces, &c.	50
	£2,694

[For particulars regarding cast-iron pipe I am indebted to Dr. Buist, who kindly made the necessary inquiries for me.]

Excavating a trench, average 2 feet broad, 3 feet deep, and 1 mile long, at Rs. 1 per 100 cubic feet..................................Rs.	316	12	10	
Refilling ditto, at 8 as. per ditto	158	6	5	
Laying and fixing each length, at 8 as. per length (no lead or caulking being required) for 587 lengths	293	8	0	
Rs.	768	11	3,	or £77
Total cost per mile				£2,771

Probable cost of a bund at B C..........Rs.	17,000	0	0
Reservoir at D	4,400	0	0
Rs.	21,400	0	0, or £2,140

13. Without detailed plans, the expense of small branches of pipe and reservoirs within the town of Bombay itself cannot be ascertained with any accuracy. I have added the cost of 3 miles extra of main pipe to cover this item.

Abstract of Estimate.

Cost of 13 miles of main pipe, including prime cost, shipping charges, laying down, &c. &c. at £2,771 per mile..........	£36,023
Engine of 176 horse-power, with pumps and gear complete....	12,000
Engine and boiler-house, with residence for Engineer..........	1,500
Fixing engine and gear....................................	400
Bund at B C..	1,700
Reservoir at D..	440
	£52,063

In addition to this, Captain Turner informs me that the monthly charge for fuel for such an engine, working 8 hours per diem, would be about Rs. 3,500.

Establishment, including one European, about Rs. 372, making a monthly charge of Rs. 3,872, exclusive of repairs.

Total probable Cost.

14. From this, it will be seen that a sum of upwards of five lakhs of rupees would be required as a first outlay for such a scheme; much larger, indeed, than I imagined when I first proposed the plan in May last; and as the plans and estimates are so crude, it is very possible that the present amount is underrated. As I have before mentioned, I am exceedingly loath to send these papers in at all in this state, and have delayed doing so with some idea of again taking up the matter after the monsoon; but as I understand that any information I may have on the subject is required at once, I therefore forward them as they are, as at any rate the very rough estimate I have here made will allow of its being determined whether it is of any use carrying the inquiry further.

I have the honour to be, &c.

(Signed) J. H. G. Crawford, Captain,
Acting Superintendent of Repairs.

Bombay, Superintendent of Repairs' Office, 20*th August* 1846.

(True copy)
(Signed) G. Hancock,
Clerk to the Board of Conservancy.

Bombay, Town Hall, 27*th August* 1846.

EXTRACT FROM A MINUTE BY THE LATE CHIEF ENGINEER, COLONEL JERVIS, DATED 25TH MAY 1848, PROPOSING THE CONSTRUCTION OF A RESERVOIR AND TUNNELS ON THE ESPLANADE.

I pass over, therefore, at once to the proposals which I had the honour to lay before the Board, in my letter to the Secretary, dated the 16th June 1845, to which reference is made in the conclusion of the 10th paragraph of the Court's Despatch No. 1 of 1848, dated the 12th of January. In order, therefore, with reference to the 5th paragraph of the Court's Despatch, to test the efficacy and the expense of this plan on a limited and economical scale, I would propose that Government be solicited to sanction the construction, in some convenient site on the northern boundary of the Esplanade, of a circular cut-stone well or reservoir, with one or two tunnels cut into the sandstone formation of the Esplanade as feeders to the reservoir, 100 yards in length, 6 feet broad, and 15 feet deep, or more if practicable; the tunnels to be filled to within 6 feet of the surface with loose rubble stone, with a covering of rough stone slabs levelled to the surface, with the soil excavated. It is by such a plan that Liverpool is partly, but largely furnished with water.

The Liverpool and Harrington Water Companies.

" The Liverpool and Harrington Company supply water collected from springs in the basin of the earth, by means of several very extensive tunnels formed in a natural rock of red sandstone, and having, through their whole length, a gentle descent towards large wells, from which the water is pumped by steam-engines."—*Mathews' Hydraulics*, p. 134.

If this plan succeeds, the tunnels may be lengthened and multiplied *ad libitum*, and other reservoirs and tunnels may be constructed in other sites; if it fail, the reservoir remains as a valuable well, and the trifling cost of the tunnels will be the only money lost.

It would be premature to suggest any other measure until the one here recommended has had a fair trial, in order to ascertain by what means a head or reservoir of water can best be obtained, and, if obtained, to decide on the best means of its distribution.

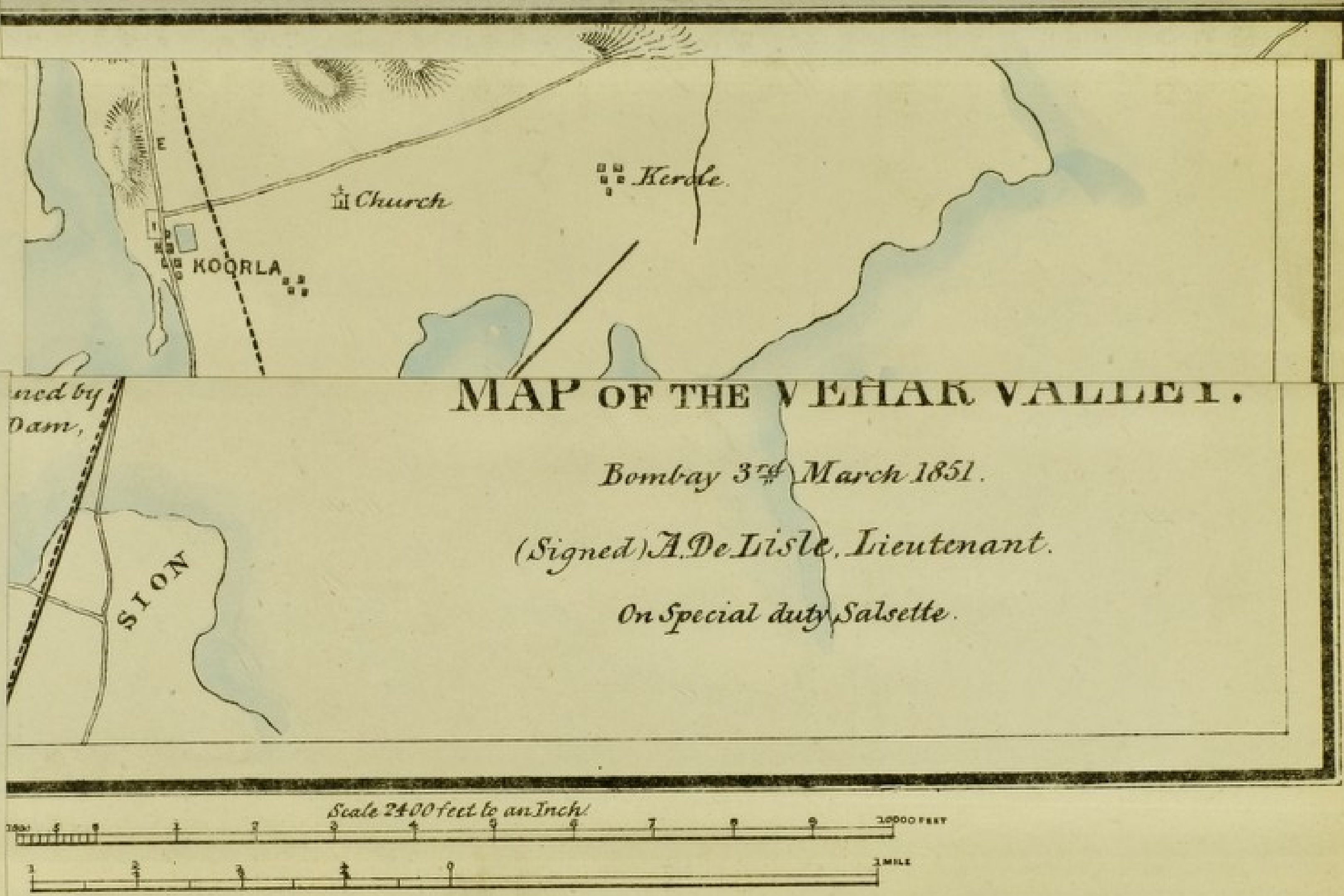
It must not, however, be concealed, that in order to supply the increasing demand for water to the whole of the inhabitants of the island of Bombay, a very large outlay of money will be indispensable here as in all other countries, and the question to be decided is, which of the two is of paramount importance, the preservation of the lives and health of the inhabitants, or the pecuniary sacrifice?

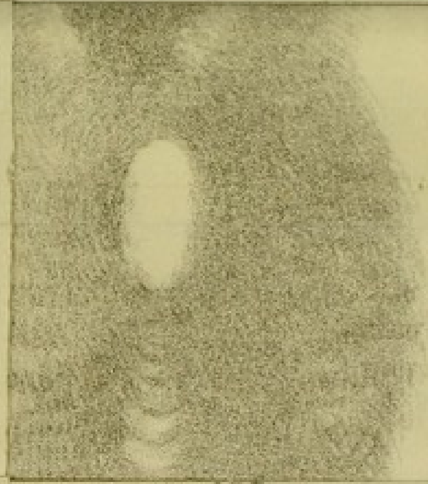
The duty of carrying out the experiment proposed should be confided to the Garrison Engineer, who should place himself in communication on the subject with the Chief Engineer.

In the present state of the public finances, the foregoing scheme is the most economical that can be devised.

(Signed) GEO. JERVIS, Lieut. Col. Commandant,
Chief Engineer.

Bombay, 25*th May* 1848.


MAP OF THE VEHAR VALLEY.
Bombay 3rd March 1851.
(Signed) A. De Lisle, Lieutenant.
On Special duty Salsette.
Kerole.
Church
KOORLA
SION
ned by
Dam,
Scale 2400 feet to an Inch
10,000 FEET
1 MILE



HE PROPOSED

E AT VEHAR

Bombay 3d. March 1851.

(Sigd.) A. de Lisle, Lieutenant.

On special duty Salsette.

FROM CAPTAIN CRAWFORD, DATED 27TH AUGUST 1850, REPORTING THE PROPOSAL TO OBTAIN WATER FROM VEHAR.

To ARTHUR MALET, Esq.,

Chief Secretary to Government, Bombay.

SIR,

The very unpromising appearance of the present monsoon, and consequent apprehensions that an extreme scarcity of water will be experienced during the months of April and May in the ensuing year, has induced me again to consider the matter of the supply of the island of Bombay, and I therefore do myself the honour to lay before you the following notes on the subject.

2. For many years past, the scantiness of the supply of water during the hot months immediately preceding the monsoon has been the subject of serious complaint, even although the previous rainy season may have afforded the average quantity. The prospect, therefore, for the hot season of 1851 (the present monsoon, which may now be considered as closed, exhibiting a fall of barely 40 inches up to this date,) is one calculated to give rise to much apprehension: as yet not a single public tank, with the exception of that at Byculla, is full.

Salsette is the nearest place from which an adequate Supply is obtainable.

3. In the year 1846 I addressed two letters (No. 108 of 1846, dated 16th May, and No. 179 of 1846, dated 27th August,) on this subject to the Board of Conservancy, under whom I was then employed, which letters were at the time submitted to Government. I have re-perused these letters, and can see nothing in the general project therein set forth, that, on a further consideration, I would desire to alter, and still remain of my former opinion that an adequate supply of water for Bombay is not to be found at a nearer point than the island of Salsette.

* * * * * *

Water obtainable from the Nullah, but which now flows into the Sea.

6. If, therefore, it is desired to adopt means for increasing to any great extent the supply of water to Bombay, resort, I feel confident, must be had to the island of Salsette. I beg to forward with this a sketch of the nullah, which, having its source in the hills near the village of Vehar, and flowing through the valley past the village of Sankey, discharges itself into the Mahim Kharree near Koorla. This nullah drains an extent of country of upwards of 13 square miles; and taking the average fall of rain throughout it at only that of Bombay, (although from the vicinity and height of the hills this might probably be doubled,) we shall see that it affords a quantity from which it is reasonable to hope that a sufficiency might be diverted for the supply of this island. The falls of rain on Bombay for the last 33 years

exhibit an average of 76.82 inches, and this gives on the 13 square miles a quantity of 14,459,019,546 gallons, or, supposing the population of Bombay to be (but this is probably overrated) 600,000 souls, it would give a daily supply throughout the year of 66 gallons for every inhabitant. Now this calculation is merely to allow of some idea being formed of the quantity of water annually wasted in the sea, within so short a distance of the town. It is not, of course, contended that anything like the above quantity could be brought into the island. The country itself must absorb much; much, also, even with the largest extent of works, would still find its way to the sea; but can it for a moment be doubted, that of this large quantity a very considerable portion might be diverted, by simple means, for the use of this city.

Modification of Original Plan.

7. Without going too much into detail at present, I shall proceed to give a general idea of what I would propose. In my former letters to the Board of Conservancy, I suggested the damming up of the mouth of the nullah at A, establishing a reservoir on the hill marked B in accompanying sketch, 80 feet above high-water mark, pumping up the water into this reservoir, and thence, with that head, distributing it throughout the island. I also suggested that the line of pipe might hereafter be extended until it reached a point of the nullah 80 feet above high water, and by this means a stream of water might be conveyed to the island, as long as the nullah continued to flow, without the intervention of any machinery. As I have already said, I see no reason to alter the plan thus originally proposed in *any essential particular*. On a further consideration of the matter, however, I would reverse the order formerly laid down. I would commence by proceeding up the nullah until I had obtained a height above the sea of about 80 feet. Supposing this might be at the point C, near the Puspolee bridge, I would there establish the first bund, and from it lay a main of the largest description which is used, as this in the end would be much cheaper than laying down several mains of a smaller diameter. In my project of 1846 I mentioned pipes of 14 inches, but those of 24 or even 30 inches would be far preferable. I would, however, have the reservoir constructed on the hill at B, as first proposed, keeping in view its use in any further extension of the plan in which it might be required to raise mechanically the water that might be preserved in tanks between the points C and A; and into this reservoir at B I would lead the main from C, thence carrying it forward to another reservoir on Nowrojee Hill. The object gained in thus bringing the water to the level of its original head, at points between its source and that at which it is to be delivered, is, first, that it affords opportunity for the discharge of air, which at all times is conveyed into the pipes by the water; and if no vent is allowed, it accumulates at certain points, and much impedes the flow. Secondly, it gives a rest to the water, which has thus an opportunity to deposit any earthy particles it may have brought with it, and the water is consequently delivered in a purer state. These reservoirs, being open to the air, admit of being cleaned periodically.

8. This simple line of pipe and bund would thus, as long as the nullah continued to flow, that is until about the end of December, pour into Bombay a constant stream of water, which might be distributed to the various public tanks, and at least ensure their being filled up to the latest possible period. The expense of this great gain would therefore be the cost of building the bund at C, the construction of the reservoir on the hill B, and one on Nowrojee Hill, and the laying of a main pipe, of such dimensions as might be determined upon, from the point C to Nowrojee Hill, and smaller branches to the tanks. During future seasons, as occasion demanded, the whole of the upper part of the nullah above C might be bunded across in various directions, for which it offers excellent opportunities, until this part of the valley had become almost a continued lake; and then water might be distributed to private individuals and establishments in Bombay, to an extent which, it is to be hoped, would yield an adequate return for the original outlay. If, after the upper part of the valley had been appropriated, a still further supply was called for, the whole of the lower portion might in like manner be made available; only in this case, the water so obtained would have to be raised by steam power to the reservoir B. This, however, is a matter that might be left to future consideration. The first part of the project would ensure the island against scarcity of water, and if, when the bunds had been carried to such an extent as to admit of private supply, it was found that such system of supply was gaining ground in the favour of the Native gentry, and that they were willing to avail themselves of it, the carrying out of the second part of the project, and the application of steam power to such increased supply, would be a mere case for calculation as to the profits to be derived from it.

Cost of the Line of Pipe, and Bund.

9. I would beg, also, to point out that the construction of these bunds would offer excellent opportunities for the employment of convict labour. I have always been of opinion that such labour was profitable where it could be employed on works of a large but simple description, and which require for their execution large bodies of men for a considerable time upon one spot. These bunds would be works answering these conditions, and they would be situated within 7 or 8 miles of the criminal jail at Tanna, so that a subsidiary jail of able-bodied men might be formed with the greatest facility. Supposing that two or three bunds were constructed every season, how very soon the town of Bombay might be placed in an enviable situation as regards its supply of water; whereas at present there is, perhaps, no town in the world, of similar extent, in which so much suffering is experienced for a portion of each season by the lower orders, consequent on the very defficient supply of this necessary element.

Convicts should be employed in the construction of the Bunds.

I have the honour to be, &c.

(Signed) J. H. G. Crawford, Captain,

Bombay, 27th August 1850. Engineers.

CAPTAIN CRAWFORD'S GENERAL SKETCH OF THE PROPOSED PLAN FOR BRINGING WATER FROM THE VICINITY OF KOORLA FOR THE SUPPLY OF BOMBAY.

Principal feature of the Project.

1. To select a convenient site in the valley, at an elevation above the sea sufficient for the requisite head of water, and then to build in the first instance a small bund, merely to serve as the fountain head. From thence to lay a line of main pipes to some convenient site for a reservoir in Bombay (say Nowrojee Hill), from which smaller pipes to be laid on to the principal tanks and reservoirs of the island.

This is the principal feature of the project. The main pipes being laid, the plan is capable of future development to almost any extent to which the wants of the inhabitants may sanction its being carried. In this its simplest form, however, it would at least ensure, even in scanty monsoons, the principal tanks of the island being filled with pure water, and that up to a much later date than they now are with the foul drainage of the town.

Expenses to be incurred.

The expenses to be incurred will consist in the purchase and laying down of 15 or 16 miles of pipe of a large size, possibly some compensation for property, and the building of two or three small reservoirs.

There would be no charges for machinery or establishment, further than for a maistry, and two or three lascars, to look to the valves, and manage the discharge of the distributing pipes during the monsoon.

Extension of Plan.

Supply susceptible of considerable increase.

2. The main pipes being laid down as above, the supply of water (heretofore supposed to be derived from the nullah only whilst it continues running) might be increased to a very considerable extent, by the gradual construction of bunds at convenient sites in the nullah, above the fountain head.

This, in a few seasons, might be made considerably to exceed all the present tank accommodation of Bombay. The bunds would be constructed with simple sluice-gates to each, allowing of the water retained by them being let down when required to the fountain head, and thence conducted by the main pipes to the town. The benefits derivable from the plan would now be much increased. As soon as the tanks were full, which in their situation would probably happen with the first two or three days' fall of rain, their surplus water, overflowing, would, on reaching the fountain head, be conducted by the pipes to the tanks in Bombay, and would so continue during the monsoon. On the nullah ceasing to flow, however, the upper tanks should be retained in their full state by keeping the sluices closed, as it would be most advisable to keep the water stored for use (until wanted) in the open country. About the beginning of March, when the water in the Bombay tanks is rapidly diminishing, the sluices of those in Salsette might be at once opened, and the tanks in the town placed in as good a position at that late date as regards supply as they now are at the close of the monsoon.

Expenses to be incurred.

The expense of this part of the plan would, in comparison with the first and most essential portion, be trifling, and would be extended, probably, over a series of years. It would consist principally in the building of substantial masonry bunds. The materials are in abundance close at hand, and the ordinary portions of the work might be executed economically by convict labour from Tanna.

There would be no charge for machinery or establishment, further than it might possibly be necessary to have a few policemen to protect the extensive works from damage.

FURTHER EXTENSION OF PLAN.

3. Should the wants of the inhabitants call for a still further increase of the supply, or should it be found, during the working of the extended project, as laid down in the 2nd paragraph, that individuals and establishments were desirous of having water laid on to their own premises, paying a rate for the same, recourse would then, perhaps, have to be had to the lower portion of the nullah. There extensive dams might be constructed, and the valleys in the neighbourhood are, (even during the hottest seasons of the year,) I have reason to believe, full of water, and that close to the surface. To avail ourselves of this supply, it would be necessary to have recourse to extensive steam machinery for pumping. There is no need, however, to enter into detail on this subject at present—it will be a matter for future calculation as to the money profits derivable from it; all that we need concern ourselves about now is to keep this latter object so far in view as, in the execution of the first portion of the project, to lay down the main line of pipes in such manner that they may be available for this ultimate extension of the plan.

(Signed) J. H. G. CRAWFORD, Captain,
Engineers.

September 19*th*, 1850.

MEMO.—The cost of 24-inch pipe at home, *including laying*, is about £3 10*s*. per lineal yard. Supposing the cost of laying down at home to equal the shipping charges to this country, the cost per mile of such pipe at Bombay, NOT including the cost of laying, would amount to £6,160.

(Signed) J. H. G. C.

LETTER FROM CAPTAIN J. H. G. CRAWFORD, FORWARDING A REPORT FROM LIEUT. DeLISLE.

To the Secretary to the Military Board,
Bombay.

Sir,

The services of Lieutenant DeLisle having been placed at my disposal for the purpose of framing preliminary surveys and estimates of the cost of carrying out a plan for supplying water to Bombay, which I submitted for consideration through the Board of Conservancy in the year 1846, and again in a somewhat amended form in a letter to Government on the 27th of August last, I have the honour, in handing on his plans and report, to state that they have been drawn up, I consider, in a most satisfactory manner, and in full conformity with my design.

The site now selected for the bund, after careful levelling, is near to where, in the 7th paragraph of my report of August 1850, I imagined that a sufficient head would be obtained; but Lieutenant DeLisle's levels and measurements show the place to possess so much greater advantages for the formation of a lake, than a simple inspection of the ground had given me reason to expect, that all the propositions regarding future extension of plan, contained in the concluding portion of the 7th and most of the 8th paragraph of my last report, may be placed on one side as not requiring consideration.

The design of the present investigation is to show that an ample supply of water can be obtained within a moderate distance of this island, and that the source of the supply is so situated as to allow of the water being transmitted without any great engineering difficulty. The documents now forwarded I think fully establish these points. About 16 miles distant from the Fort Gate there is a situation amongst the hills where the construction of a really insignificant bund will convert a large portion of country into a lake. The bottom of the bund would be 70 feet above the plinth of the Church Gate, affording a most ample head of water, allowing it to be delivered 20 feet above that point. The supply would be unintermitting at the rate of 100,000 gallons per hour, night and day, throughout the year, and this without the intervention of any mechanical aid, as of pumping. It would but complicate the subject to attempt to discuss, at this moment, particular questions of future local distribution: the height of the point of delivery is quite sufficient to command the principal portions of the Native Town, the Fort, and Colaba. The first object of general distribution would be to direct the mains during the monsoon to the principal tanks on the island, thereby insuring their being filled with pure, instead of the present foul and unwholesome drainage water, and on the conclusion of the rains the mains should be turned on to public fountains, on those parts of the island most in want of water.

The estimated cost of this public portion of the scheme would amount to probably about £120,000, the expenditure of which sum, however, would, I feel confident, insure the island from all chance of future suffering, and place it, as regards water supply, in a better position than most places of the same importance.

I have the honour to be, &c.

(Signed) J. H. G. Crawford, Captain, Engineers.

Bombay, 4th March 1851.

Note.—The Croton Aqueduct, which supplies the city of New York with water, was constructed entirely at the expense of the municipality of that city, at a cost of £1,800,000 sterling, without including the cost of pipes for distribution within the town.

(Signed) J. H. G. Crawford, Captain, Engineers.

LIEUTENANT DeLISLE'S REPORT ON CAPTAIN CRAWFORD'S PROJECT.

No. 3 of 1851.

To the Secretary to the Military Board,
Bombay.

Sir,

Reference to the Orders under which the Report is drawn up.

1. With reference to Mr. Secretary Lumsden's letter No. 4117, dated 18th October 1850, paras. 1 and 2, of which copy is annexed, I have now the honour to submit the following report on the practicability of obtaining a supply of water for Bombay from the island of Salsette.

The Nullah and its Feeders.

2. A glance at the map of the Vehar valley (herewith forwarded) will show that the nullah, which empties itself into an arm of the sea near Koorla, is formed by a number of torrents from the high range of hills in the island of Salsette. The principal point of junction of these feeders is near Vehar. It also receives the contributions of several nullahs, more particularly of that which passes under a wooden bridge close to the 17th milestone from Bombay, of another which runs under two wooden bridges, south of Puspolee, and again of a third north of the village of Koorla.

Description of the Valley.

3. The upper part of the valley presents, on the map, a nearly square form, being enclosed to the westward by the high range of hills, and towards the north and eastward by an outlaying branch, the spurs of which come down to the village of Vehar, and along the Tanna road as far as the small Ghaut. At Vehar, the

valley widens out considerably, but is again narrowed near the bridge by a spur from the hill to the south-east. South of Syee it is contracted by a chain of hills of no great elevation into a narrow gorge, which continues as far as the great bend of the nullah after passing the Puspolee bridges. From this point it gradually widens out into a broad flat valley, chiefly laid out in rice-fields, interspersed with grass-land. Generally speaking, the hills rise abruptly from the bottom of the valley, the high range especially being very steep and precipitous. The bottom is very flat in cross section, and, wherever the soil is favourable, has been laid out in rice-fields; the remainder, as well as the slopes of the hills, being grass-land. Rock is almost everywhere found at the depth of a few feet, and in many places crops out above the surface.

Levelling operation.

4. In commencing my lines of levels, I was indebted to the kindness of the Railway Engineers for a section of their line from Bombay to the cutting near Koorla, and for the particulars of a bench-mark at the same place. These levels I continued to Koorla, along the road, and from thence carried a double line as far as the bridge near Vehar, the single road line being continued beyond the village itself.

Sites of Dam and Waste-Weir.

5. It soon became evident that the most favourable site for a dam was at bench-mark 130, (see enlarged plan,) the bed of the nullah being there sufficiently elevated above Bombay to give the required pressure to force the water through the pipe with adequate velocity, and the cross section of the valley being exceedingly favourable. As a dam of considerable height is requisite to pond up a sufficient body of water, it became important to find some point for establishing a waste-weir, for the escape of the surplus drainage, without permitting it to flow over the dam, and thereby endanger its permanency. A most favourable situation was fortunately found over a low ridge, connecting the two hills to the eastward of the road, where it descends into the Vehar valley. The flood waters will thence find their way back to their original channel by the nalluh, which passes under the two bridges south of the Puspolee village.

The particulars of the Lake.

6. The datum line to which all the levels have been referred is supposed to be 100 feet below the top of the plinth of the Church Gate of the Fort of Bombay. It will be seen by the sections that the base of the dam will be 6,953 feet above the level of the plinth, and the dam is 5,047 feet in height up to the water line, so that the total head of water when the lake is full will be 100 feet, the delivery taking place 20 feet above the level of the plinth. The dam should be carried 3 or 4 feet higher, to prevent water running over during floods. The length of the dam at top, including 5 feet at each end for the foundations, will be about 450 feet, which is, when the height of the dam is considered, a singularly moderate dimension.

The top of the waste-weir is to be at the same level as the surface of the lake, viz. 120 feet above the level of the plinth. The length is taken at 200 feet, about five times the width of the nullah at the dam, so that the depth of water running over it will most probably seldom exceed 1½ foot. This length involves a trifling extent of cutting, as shown in the section.

Extent of the Lake.

7. The large plan of the lake shows approximately the extent to which the waters would be dammed up, and a cursory examination of the Roman numerals (I, II, &c.) will serve to give a general idea of the depth of the lake. Even at either side of the Vehar bridge, more than a mile from the dam, there will be about 13 feet of water. The comparative size of the Baboola Tank, the largest in the Native Town, and of which the average depth may be taken at 16 feet, will enable one to form an idea of the large quantity of water which would become available.

Quantity of Water ponded up.

8. A moderate calculation of the contents of the lake gives about 157,100,000 cubic feet, or 981,875,000 gallons, in round numbers one thousand million gallons. Should the above quantity at any future time be found insufficient for the wants of the inhabitants of Bombay, it would be nearly doubled by raising the dam and waste-weir 10 feet in additional height. It might, therefore, be as well to bear this contingency in mind, when calculating the thickness for the dam.

Village and Road submerged.

9. One village, that of Syee, and the road from station 68 to Vehar, will be submerged. The former contains only one permanent building in a dilapidated condition, the other huts being constructed of poles and palm leaves. The road may be diverted by bridging across at the waste-weir, and then skirting the borders of the lake, keeping, however, at a tolerable height above it, on account of the possible necessity of raising the surface level of the lake, which would at the same time place Vehar in the same predicament as Syee. Perhaps the best way would be to let the necessary communication be kept up *viâ* the new road along the coast line, or by ferry from Vehar to the dry portion of the old road.

Iron Pipe.

10. The diameter fixed upon for the iron pipe is 2 feet, for although it may deliver more water at first than would be required for the present number of inhabitants in Bombay, yet, as the population increases, provision should be made for their requirements, and the probable establishment of high service in the island. It is better, therefore, to lay down a pipe of sufficient diameter at once, than to have to incur the expense of putting down a supplementary one afterwards. The course of the pipe has been approximately traced on the map of the Vehar valley to Sion, whence, as shown on the general map, it follows the railway line to near Nowrojee Hill, where it again diverges, and finally delivers the water at a level 20 feet above that of the plinth of the Church Gate.

Discharge of the Pipe.

11. In calculating the discharge of the pipe, the formula of Mr. Hawksley, Engineer to the Nottingham Water

Works, has been used, on account of it being the result of experience with pipes of large diameter and great length. It is as under :—

$$d = \frac{1}{15} \sqrt[5]{\frac{q^2 \, l}{h}}$$

Or by transposition—

$$q = \sqrt{\frac{h}{l} \, (15 \, d)^5}$$

Where q is the quantity of gallons per hour, l the length of pipe in yards, h the head of water in feet, and d the diameter of the pipe in inches.

In the present case $l = 25{,}520$, $h = 100$, $d = 24$, the pipe being estimated at 14½ miles of length, to allow for curves of larger sweep than those shown on the map. By substituting these numerical values in the second equation, we shall find the quantity q to be equal to 153,974 gallons. Hydraulic formulæ, in the present state of the science, are not yet to be relied on with implicit confidence; it will therefore be prudent to assume two-thirds of the above, or in round numbers 100,000 gallons, as the discharge per hour, whilst the lake continues full.

Results attainable.

12. The Baboola Tank may be estimated to contain about 4,500,000 cubic feet, and would, at the assumed rate of discharge, be filled in a fortnight. The contents of the lake have in a previous paragraph (No. 8) been calculated at 1,000,000,000 gallons, a quantity which would keep the pipe flowing at the above rate for 13 months. But as the discharge will diminish as the level of the lake's surface falls, the time would of course be proportionately increased. However, it is sufficient for us to know that the pipe would run freely during the whole of the dry season.

Amount of Drainage available.

13. It may now be incumbent on me to show that the above supply of water will be available in all ordinary monsoons. Referring to the map of the Vehar valley, it appears that the extent of the surface drained by the nullah above the dam is 7 square miles, or 198,148,800 square feet. From the pluviometrical return for the last 34 years, it is found that the average fall of rain in Bombay during the monsoon months is 76 inches. Let us allow that of this 16 inches is wasted by evaporation, absorption, or other causes, and assume 60 inches or 5 feet to be the quantity conveyed by the nullah to the sea. We shall then have 975,744,000 cubic feet, or 6,098,400,000 gallons— six times the quantity held by the lake when full. From 12 to 18 inches of rain would probably suffice to fill the lake, and as the average fall in June is 22 inches, the waste-weir would be overflowed before the end of that month. There is also very good ground for supposing that the lake would continue full at least to the 1st of October. The fall of rain in Salsette is probably much greater than in Bombay, owing to the attraction of the high range of hills, so that the above calculations may be considered as being within the truth.

14. The price in London of cast iron pipe, 24 inches in diameter, laid and jointed, but not including trench excavation, is £3 10*s*. per linear yard. In this case the expense of trenching will be very slight, as the pipe need only be sunk just enough to protect it from injury, or, when passing over rock, might be laid on the surface, and covered over with a slight bank of earth, or of earth and dry stone facings. Very low freights would probably be obtainable, as the pipes might be shipped as ballast. On the whole, therefore, £4 per yard might reasonably be expected to cover all charges, so that 14½ miles, or 25,520 yards, at £4, give £102,080

Rough Estimate of Cost.

For constructions, viz. dam, waste-weir, delivery reservoir, and conduits..	15,000
Contingencies, &c..	2,920
Total..	£120,000

or Co.'s Rs. twelve lakhs, which may be considered a liberal estimate.

15. Considering the large item for the cost of the iron pipe alone, there would probably be no great difficulty in finding an English Contractor to undertake the supply and laying thereof, whereby not only favourable terms might be obtained, but the efficient performance of the work be secured at the same time.

Possibility of obtaining a Contractor.

16. During the monsoon, the water should be allowed to fill the tanks, for which purpose glazed earthenware pipes might be used with advantage, on the score of economy. The sluices, however, for regulating the flow of water through them, should be provided with racks and pinions to ensure their being opened and shut gradually, on account of the violent jerks to which pipes are exposed when the stream is suddenly arrested. The local drainage may then be dispensed with entirely, which, in the case of the Baboola Tank especially, will conduce in no small degree to the purity of the water in the tanks.

Distribution during the Monsoon.

17. But it would obviously not be the most advantageous mode of distribution to allow the water to run into the tanks all the year round, as it is there exposed to many causes of waste and deterioration. During the dry season the pipes communicating with the tanks should be closed, and a separate system of iron pipes established, to supply fountains or conduits in convenient situations about the Native Town. A few of these have been sketched on the general map of Bombay, showing also branch pipes to one or two of the piers, in order to afford a supply to the shipping in the harbour. Each of these conduits should of course be provided with a waste pipe, to convey the superfluous water to the nearest tank, and also with a pipe drain, communicating with some convenient sewer. These conduits might evidently be kept in full activity during the monsoon months also. The main pipe would of course require regulating

Distribution during the Dry Season.

sluices to adjust the flow of water to the precise quantity required for the conduits during the dry weather. It is, however, hardly within the province of a preliminary report to enter into detail regarding points which must be left to future arrangement, according to the local requirements of each district.

High Service.

18. Should it be considered desirable, at any future period, to organize a high service for supplying the houses of the more wealthy inhabitants of the island with water on their own premises, Nowrojee Hill will afford a very convenient locality for establishing pumping machinery, and, on the top, a reservoir, while the pressure pipes might be led in any required direction. Being close to some of the piers, coals might be landed and delivered at a very small expense for land carriage, and the whole establishment would be under close and efficient control.

Remarks on the Plans.

19. Before closing this report, I beg to offer a few remarks on the plans which accompany it, and which are as follows :—

I. A General Map of Bombay, Trombay, and Salsette, to give an idea of the localities, and also show the course of the pipe, with a general indication of the principal points of distribution by conduits. Respecting the latter, regard has been had only to the localities which stand most in need of this important element of health. The Esplanade, Girgaum, Byculla, Mahim, and the northern part of the island, are tolerably well supplied by their own wells, and need not therefore be taken into consideration at present.

The principal lines shown are—

1st.—A pipe to Mazagon, continued to the end of the pier.

2nd.—Another to the Musjid and Boree Bunders, continued to the Mint Tank in the Fort.

3rd.—One to the Jamsetjee Hospital, the Reservoirs at the corner of the Grant Road, and on to Commatee Poora, near the Race-course.

4th.—Lastly, to the new Reservoir now building in the Bhendy Bazar, continued to the Cooperage, whence a pipe already laid will convey the water to the European Barracks at Colaba. A branch pipe might also be laid from the Cooperage to the Apollo Pier for the shipping.

II. A map of the Vehar valley, showing the extent of country of which the drainage would supply the lake, comprised within the dotted line. It also shows more correctly than the general map, the approximate course of the pipe up to the point where it would join the railway line. A shaded blue line shows the manner in which the surplus water of the lake would return to the principal nullah by the smaller one, which passes under the Puspolee bridges.

III. An enlarged Plan of the Lake, showing the lines of which sections have been taken, along which the depth of water has been marked in Roman numerals. The numbered dots are the stations of the levelling staves. In some places the intermediate dot is the instrument station.

IV. Sections of the Lake. The upper line begins a little to the northward of Vehar, and continues along the road to a station marked 75 near Syee; it then turns off and follows the line of dots to the dam. The left hand section, on the 2nd line, takes up the road levels at the point 75, and continues them to a bench-mark opposite the 16th milestone from Bombay.

The next is from the same point, 75, to the base of the hill to the south-eastward of Syee. The third is a cross section of the lake near the bridge south of Vehar.

Below are the sections of the sites of the dam and waste-weir: the thick lines are drawn at the proposed surface level of the lake, but the top of the dam should be two or three feet higher.

V. Section from the Dam to the Reservoir. From the dam to the sign-post at C, the line is very nearly that of the pipe in No. II. From the sign-post to the railway the section is that of the road surface, less favourable than that of the course of the pipe would be, as the road has been taken some little way up the hills at D E, which need not be the case with the other. The hills shown in the railway portion of the section may be avoided, by taking advantage of the railway cuttings, so that from the dam to Koorla the pipe will have a continuous descent, and from Koorla to the rise at Nowrojee Hill will run along nearly at a dead level, without any vertical flexures. The rise at B can be avoided by keeping close to the bank of the nullah.

20. In conclusion, I beg leave to observe, that in stating the advantages of this project I have carefully endeavoured to avoid exaggeration, and trust that should it be carried into execution, the results will not disappoint the expectations now held out.

I have the honour to be, &c.

(Signed) A. DeLisle, Lieutenant,
On Special Duty, Salsette.

Bombay, 3rd March 1851.

LETTER FROM GOVERNMENT ON THE RECEIPT OF LIEUTENANT DeLISLE'S REPORT.

No. 1678 of 1851.

General Department.

To the Military Board.

Gentlemen,

I am directed by the Right Honorable the Governor in Council to acknowledge the receipt of your letter No. 1879, dated the 11th ultimo, submitting the report and plans prepared by Lieutenant DeLisle in illustration of Captain

Crawford's project for supplying Bombay with water from the island of Salsette.

This clear and concise report reflects great credit upon Lieutenant DeLisle, to whom you are requested it convey the acknowledgments of Government for the labour and attention he has bestowed on its preparation.

His Lordship in Council also desires that you will communicate to Captain Crawford the cordial thanks of Government for the efficient superintendence he has exercised over Lieutenant DeLisle's operations.

Government have no doubt that the data now furnished, though giving only general results, will yet be sufficient to satisfy the Honorable the Court of Directors of the feasibility of Captain Crawford's plan.

But in transmitting the papers to the Honorable Court, it seems to Government desirable that they should be accompanied by information on the following points, which I am accordingly instructed to request you will procure and submit as early as possible.

In the 8th paragraph of his report, Lieutenant DeLisle states that the quantity of water in the lake would be nearly doubled were the dam and waste-weir raised by 10 feet.

The total cost of the dam, waste-weir, delivering reservoirs, &c. is estimated (in paragraph 14) at £15,000. If constructed to the additional height, the cost would probably not be materially enhanced; and as the expediency of doing this at once is obvious, the Right Honorable the Governor in Council requests that an estimate may be prepared of the expense of building them to the height of 10 feet beyond what is provided by the present estimate. It should at the same time be shown how much more ground would be occupied by the lake if this addition were made to the height of the dam.

Again, in regard to the line of pipe. The present plan provides for a single line of 24-inch iron pipe, but it is possible that a double line of a somewhat smaller diameter might be considered preferable.

Government, therefore, desire that the cost of a double line of sufficient diameter to deliver somewhat more than the present plan provides for, may be roughly estimated; and as double pipes 24 inches in diameter may in course of time be necessary, the arrangements made for bringing the water beyond the dam should be such as to admit at any time of a change in the size of the pipes, without endangering the stability of the structure.

With reference, also, to the great expense of iron piping, Government would wish to be furnished with an approximate estimate of the comparative cost of a masonry conduit, of the same length and capacity as the proposed line of 24-inch iron pipe; also an estimate for a masonry conduit capable of delivering double the proposed quantity of water, or 200,000 gallons per hour throughout the year.

Government would also wish to be informed whether objections exist to the substitution of glass for iron pipe, as is now commonly used at home, in conveying water along a level. Should there be no objections to the use of glass, it is desirable that the cost of such pipe of the above size and capacity should, if possible, be furnished.

I have the honour to be, &c.

(Signed) J. G. Lumsden,

Secretary to Government.

Bombay Castle, 26th April 1851.

REPLY BY CAPTAIN CRAWFORD, SENT THROUGH THE MILITARY BOARD.

To the Secretary to the Military Board.

Sir,

I have the honour to acknowledge the receipt of your letter No. 3547, of the 5th instant, and its accompaniment, being copy of one from Mr. Secretary Lumsden to the Military Board.

I would beg particularly to bring to the notice of the Military Board that I do not possess data sufficient for procuring accurate and detailed estimates of cost. The survey that has been made was carried only to an extent sufficient to satisfy the authorities on the feasibility of the scheme as a hydraulic work, that is to say, the site of the proposed lake was accurately determined, its capacity ascertained, and its level above the point of delivery in Bombay decided. In addition to this, an estimate was framed of the quantity of 24-inch pipe which would be required, as this is the grand item of cost, and the one upon which the question of the adoption or otherwise of the plan would probably rest. No attempt was made to estimate with precision the subsidiary works; and when such is required, more time and larger means will be necessary to prepare the detailed and accurate drawings required for such a purpose.

It is therefore useless my attempting to state precisely what the cost of making this or that alteration in a plan, of which I have only framed an approximate estimate, would amount to. I may say, however, that raising the bund 10 feet extra would probably add 20 per cent. to its cost. The extra ground that would be covered by such raising would be comparatively small, as the hills surrounding the proposed site of the lake are very precipitous; and if a line, parallel to the present margin, were drawn at the distance of 100 feet outside it, along the eastern, southern, and western shores, this would nearly represent the extra ground that would be submerged. On the northern shore, however, where the slope of the country is more gentle, the margin of the lake would probably be extended some 400 or 500 yards up the valley.

On this subject, however, I would beg to remind you that there was an object in limiting the height of the proposed bund to 50 feet: 1*st*, that carrying it to such a height was sufficient to bring a small dip between two adjacent hills into use as a waste-weir, and as the ground throughout is of a rocky nature, it was far preferable to have the waste water flowing over the natural surface than pouring over the bund itself, or any artificial obstruction; 2*nd*, the bund of a height as at present proposed would pond back the water to the verge of the village of Vehar—an extra 10 feet to the bund would entirely drown the village.

With regard to paragraph 8 of Mr. Secretary Lumsden's letter, I would reply that there may be a certain advantage in bringing the water by two mains instead of one, as in such case an accident to the one would not cut off the supply of water during any necessary repairs to the other; but as far as economy is concerned, it is preferable to perform the service by one large main than by two of smaller diameter. Two pipes 17 inches in diameter would perform the work of one of 24 inches.* We will, however, take for comparison pipes 18 inches in diameter (as pipes of 17-inch guage are not usually cast), and we find, on reference to tables, that a double line of 18-inch pipe would be in proportion to a single line of 24-inch as 3 to 2 in weight of iron above. To this must be added the extra cost of laying and fitting the double line. So that in prime cost alone it will be necessary to add for a double line about 50 per cent. to the estimate of a single one of equal capability. The arrangements alluded to in the concluding portion of the 9th paragraph would of course be provided for when details of this nature come to be considered.

With reference to the subject of the 10th paragraph, I am not aware whether by the term conduit I am to understand a closed masonry pipe, capable of sustaining the pressure of a head of water, and thereby admitting of being laid in the ground, and following to a certain extent the irregularities of the surface, or whether I am to consider it an open masonry channel, supported on arches, and having a regular incline from the lake to the point of delivery.

If the former is intended, the only means by which it could be carried out in this country is on the plan of the aqueducts at Ahmednuggur, viz. by bedding a continuous line of whole round tiles in masonry. Allowing that tiles of a clear interior diameter of 5 inches could be procured, it would require 23 separate lines of such piping to equal, in area alone, the section of one pipe 24 inches in diameter; but when the irregular nature of the interior surface of these earthen pipes is considered, I very much doubt whether practically (in consequence of the enormous friction in the great length of 14 miles) there would be any delivery of water at all at the Bombay end.

* This is not strictly accurate, as no allowance is made for the greater friction which would occur with the two pipes.

At Ahmednuggur I found it a considerable saving to procure from Bombay 6-inch iron pipe, and substitute it for those of earthenware. The annoyance and expense that was caused by trees at very considerable distances striking their roots towards the masonry pipe, and, in spite of every precaution, working their way through to the water, was very great, and would be equally, if not more troublesome in Bombay. I can give no opinion of the applicability of larger earthenware pipes procured from home; I know practically nothing of their cost, merits, or demerits, as applied to extensive water-works: this is entirely a question for reference to England.

On the other hand, if an open continuous channel is required, it will be then necessary to build the whole, or nearly so, on a continuous row of arches, as of course it will be absolutely necessary to give it a uniform incline from end to end. An open masonry channel, with an incline of two inches per mile, and a sectional area of 18 square feet, say 6 feet broad and 3 deep, would give somewhat more than double the supply proposed, viz. 200,000 gallons instead of 100,000 gallons per hour. Such channel, to afford the incline at a uniform rate, must, from the nature of the country, be raised on a continuous line of arches. Without a most accurate survey of the ground throughout, and full and detailed drawings of the work, prepared for the special purpose of framing such an estimate, I could not even pretend to furnish anything trustworthy in the shape of an approximate estimate; when I mention, however, that from the section of the country I imagine that for about 12 miles of the line the arches would be at least 30 feet above the surface of the ground, this is sufficient, I think, for presuming that the expense of a work of such magnitude would far exceed the cost of carrying out the work by means of iron piping. I may also allude to the cost of purchasing the ground which would be covered by the arched aqueduct, whereas the iron pipe for a principal portion of its length, and the entire portion through the island of Bombay, would follow, and be bedded in the side cuttings of the railway.

On the subject of the 11th and concluding paragraph of Mr. Secretary Lumsden's letter, I am sorry that I have no information as regards glass pipes to offer, nor, from the newness of the article, have I been able to ascertain anything with certainty regarding their applicability to the work under discussion. I can procure no accounts of the size to which they are manufactured, their weight, cost, method of jointing, or in fact anything that will enable me to reply satisfactorily to the point.

Before concluding, I would mention that I have been favoured by Mr. Fowler, one of the Contractors for the Railway, with a small volume of recently published tables, and I find from them, that iron pipe of 24 inches is now cast with a thickness of only ⅝ inch, and that equal to a head of water of 312 feet, whereas we only require a head, at the outside, of about 100 feet. In Lieutenant DeLisle's estimate, the pipe was supposed to be 1 inch thick. Now substituting ⅝ pipe would reduce the weight required in the proportion of

8 to 5 nearly: this alone would make a very considerable difference in the estimate of the work. But in addition to this, I have lately been given to understand by Mr. Ker, one of the Railway Engineers, that Messrs. Fox & Co., the Contractors for the present building now constructed in Hyde Park, are at present employed in laying down throughout Paris malleable iron pipes, at a considerable reduction upon the cost of pipes of cast iron. This saving arises principally in consequence of the thinness to which a pipe of malleable iron can be safely reduced beyond one of cast iron, to fulfil the same requirements. It is also worthy of consideration, provided the applicability of malleable iron to our purpose is found advisable, whether galvanizing the material might not be advantageous, for the prevention of corrosion. I mention all these circumstances to show how necessary is a complete reference of the matter for full information to England. The points upon which I have been endeavouring to obtain further information have required some time, and having had other matter to occupy my attention will, I hope, excuse the delay that has taken place in replying to your letter.

I have the honour to be, &c.

(Signed) J. H. G. Crawford, Captain,
Engineers.

Bombay, 27*th May* 1851.

REPORT BY H. CONYBEARE, Esq., ON THE AMOUNT OF THE EXISTING WATER SUPPLY OF BOMBAY, WITH REFERENCE TO THE POPULATION, AND ON THE VARIOUS METHODS WHICH HAVE BEEN PROPOSED OR MIGHT BE ADOPTED FOR INCREASING THE SUPPLY, BOTH FROM SOURCES WITHIN THE ISLAND, AND FROM SALSETTE.

1. Towns can only be supplied with water from one or more of the three following sources—1*st*, from the water of rivers or running streams; 2*nd*, from deep spring or well water; and 3*rd*, from surface collection or rain water.

2. River water, with more of mineral impurities (which occasion hardness) than surface water, usually presents less of vegetation and animal impurity; it is, therefore, as a source of supply, generally preferable to surface collection, though greatly inferior to spring water. It is, however, certain that no river supply is obtainable for Bombay.

3. Spring water is incomparably the best source of the three. A recent authority on the subject states that "No other water is adapted for a beverage in the extreme seasons of the year [even in England], and it is preferable to every other water at any season. * * * It is not possible in the summer months to obtain water of the proper coolness, *and free from vegetation and animalcules*, except from springs." Rather the larger portion of the water at present used by the inhabitants of Bombay *for drinking purposes* is derived from wells, and it has yet to be shown that no supply of spring water, *commensurate with the wants of the whole population*, can be obtained, either in the island itself, or from the eastern coast of Salsette.* The circumstance of no adequate supply of spring water having been hitherto supposed to be available is no proof that none such exists. The General Board of Health has recently demonstrated the possibility of economically supplying London with deep spring water from sources (the Bagshot Sands) that had escaped the notice of the previous Parliamentary inquiries of 1810, 1821, 1827, 1828, 1834, 1840, and 1845, regarding the water supply of the metropolis.

* Since writing the above I have visited the eastern coast of Salsette, and satisfied myself that no adequate supply of spring water could be thence obtained, and that what there is lies at too low a level to be available for the supply of Bombay by gravitation. I am convinced that Bombay can only be adequately supplied with water by tracing the valley of the river Goper (of which valley the valley island of Bombay is a prolongation) up to its source near Vehar, and there constructing a series of reservoirs, in which the monsoon water falling over the central basin of Salsette may be collected and stored.

4. Of the three sources of water supply, surface collection is the most objectionable, "from its strong affinity for organic impurities," and from the difficulty of storing it in sufficiently large quantities, without exposing it to the action of the sun, vegetation, and other deteriorating influences. Wherever rain falls, a supply from surface collection is obtainable. *Water obtained from surface collection, as well as that of rivers, is unfit for drinking, until filtered.* A considerable portion of the poorer classes of the population of the Native Town of Bombay is dependent on surface collection, stored in open tanks, and hitherto unfiltered, for its supply of drinking water, and all classes derive their principal supply of water for washing and similar purposes from the same source.

5. The apparatus and appliances which are used in English towns for rendering water derived from each or any of the three abovementioned sources available to the wants of a large population, inhabiting an extended area, and also those essential for rendering any water except that of wells and springs sufficiently pure for drinking purposes, are, with trifling modifications, equally essential to the obtainment of the same ends in India.

In discussing, therefore, *seriatim*, the merits of the three sources from which towns are supplied with water, I shall, in order to afford a standard of comparison by which all that has been done or proposed towards increasing the quantity or improving the quality of the water supply of Bombay may be tested, describe in each case the apparatus and appliances whereby water obtained from each particular source is rendered available to public use in English towns.

6. I shall then describe the state of the water supply of Bombay, both from springs or well water, and from surface collection, and the extent and nature of the deficiency experienced towards the close of very dry seasons, and proceed to point out the means that have been, or might be adopted, for rendering our existing supply of spring water more extensively available than at present, or of obtaining an additional supply from the springs on the eastern coast of Salsette, and also the plan that should be adopted for improving the quality of the existing supply of water derived from surface collection, and the means by which the quantity, also, of each description of supply, might be increased, either from sources within the island or from Salsette, comparing the means adopted or proposed in each case with those in use under similar circumstances in European towns.

7. It is certain that no river or running stream exists sufficiently near Bombay to be available as a source of water supply to this town; but as there are other large towns in the Bombay Presidency where this is not the case, I shall describe shortly the works required for supplying a town with water from an adjacent river, taking the new works of the Grand Junction Water Company at Kew, the most recently constructed of those belonging to any of the nine water companies by which London is supplied, as an example.

8. The water is in the first instance conveyed from the river by a very large culvert pipe, laid in the bed of the former, with its opening, which is up-stream, barred across with a grating, to exclude all solid substances. This culvert pipe is carried under the bank of the river, and delivers its contents into a deep well adjoining, from which the water is pumped by steam power into slightly elevated reservoirs. The first and largest of these is a precipitating reservoir, in which the water deposits much of its impurity in the form of a sediment, and from this it glides through a small opening to the filtering reservoirs.

9. In these "the water rests upon, and permeates through a filtering bed 4 feet thick—consisting, 1*st*, of a surface of fine sand; 2*nd*, a stratum of shells; 3*rd*, a layer of garden gravel; and 4*th*, a base of coarse gravel. It thence falls through a number of ducts into cisterns. The water is now pure, and fit for use; but for "high service," and to enable it to find its way by gravity to the tops of the tallest houses in the highest parts of the district to be supplied, it is necessary that it should be first raised to a level considerably higher than any of these.

10. This was formerly effected by raising it by steam or water power to a reservoir situated on the nearest spot of sufficient elevation that was available; but in the neighbourhood of towns it was often impossible to find sites well adapted for reservoirs of the sort, and even where this objection did not exist, the water exposed in such open reservoirs to the action of the sun became rapidly contaminated.

11. The modern plan is to obtain the requisite head by pumping the water as soon as filtered up an enormous "stand-pipe," which presents the appearance of a thin, enormously tall iron column, rising in some cases between 200 and 300 feet above the ground, and having the appearance of being supported by 3 or 4 smaller columns clustered round it, which are really smaller main pipes, into which the water escapes from the summit of the large one, with a head which should, in all cases, be sufficient to throw a jet of water over the roofs of the tallest buildings in the town. From the four mains so surrounding the stand-pipe, the water descends at once into the conduit-pipe, from which it is distributed, by means of branch pipes of various sizes, to every street and every house in the district to be supplied.

12. The extent and cost of the pumping and distributary apparatus required for supplying water to any considerable town population is much greater than is generally supposed. The London Grand Junction Water Company is itself only one out of the nine establishments required for supplying the metropolis, and by no means the largest of them, its daily supply being only one-half as large as that of the East London Water Company, and less than one-fifth as large as that of the New Water Company. Yet for the distribution of its water to a town population amounting to little more than one-fifth of the population of this island, there are required 80 miles of service pipe, varying from 30 to 3 inches

in diameter ; and this is exclusive of the pipes required for house service. It must be remembered that Lieutenant DeLisle estimates the cost of only 14½ miles of 24-inch pipe at a lakhs of rupees. Lieutenant DeLisle's rate per foot for such pipes appears, however, to me, to be considerably in excess of the rate at which piping of sufficient thickness for the purpose might be landed in Bombay.*

13. The expense of raising water by single acting steam-engines, working expansively, is much less than would be imagined. Mr. Wicksteed, Engineer to the East London Water-works Company, states, as the performance of the most improved engines used at the works of that company, as follows :—

14. "One single pumping engine, made by Harvey and Co., upon the expansive principle, in 1837, working 24 hours per diem 7 days per week, mean power 95½ horses, quantity of water raised per diem 4,107,816 gallons, 110 feet high, cost of coals 12 shillings per ton. In the estimate for the cost, all charges for coal, labour, and stores are included, but no charge for interest upon outlay, or repairs of machinery and buildings; all other charges for working the engine are included. The estimate made upon the average of 4 years' working.

	s.	*d.*
Cost of raising 1,000 gallons 100 feet high	0	0·150
Or, cost of raising 80,000 gallons 100 feet high................	1	0 "

The cost of coal, labour, and stores, may be taken at Bombay at about double the London rate.

15. In the mining districts of Cornwall, where much attention has for many years been paid to the economical arrangement of pumping engines, even higher results have been obtained. Many engines in that county have for months together kept up a "duty" of from 90 to 120 millions of lbs. of water raised one foot high by the combustion of each single bushel of coal consumed. A bushel of coal equals 87$\frac{1}{10}$ lbs., and there are therefore about 25$\frac{7}{10}$ bushels in a ton. One gallon of water weighs 10 lbs. and half an oz., say 10 lbs. only. The work of the most improved Cornish engines may be therefore stated as follows :—When performing a duty of 90,000,000, they will lift 23,130,000 gallons of water 10 feet high; or 2,313,000 gallons 100 feet high, by the combustion of each ton of coal consumed; and when doing a duty of 120,000,000 they will lift 30,560,000 gallons of water 10 feet high, or 3,056,000 gallons 100 feet high, by the combustion of each ton of coal consumed.

16. Smaller sized engines will not work to the same advantage as larger ones. The following table is extracted from the evidence of Mr. Hocking, (one of the principal manufacturers of the Cornish pumping engine,) in the last Parliamentary Report on the Water Supply of the Metropolis :—

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* From a return made by the Grand Junction Water Company to Parliament, it appears that the cost of the works has been upwards of 52 lakhs (£522,295 4*s.* 9*d.*).

Cost of Pumping Water for the Supply of Towns, by Cornish Engines of various sizes, using Newcastle Small Coals at 12*s. per ton.*

Size of Engine.	Quantity of Water raised 100 feet high for 1*s*.
Horse-power.	Gallons.
230	87,997
180	80,436
135	74,862
100	67,848
65	61,549
40	54,905
25	43,214

N. B.—This estimate does not include interest on outlay, or the repairs.

17. Engines of this description of the largest size would cost, when set to work, about £50 per horse-power, the smaller one somewhat more; and the motion of this engine is so slow that there is scarcely any wear and tear of machinery, and the allowance for annual depreciation would be comparatively inconsiderable.

18. In some cases, where towns are supplied with the water of rivers or running streams, such water is brought by pipes or aqueducts from distant sources, situated at a height above the level of the town sufficient to force the water through the distributary apparatus without the use of steam power. This is called the gravitation system. By the adoption of this system, where practicable, the water supply is generally obtained nearer its source, and consequently purer, and freer from organic and mineral pollution than that of large rivers, running through populous towns, can be expected to be; and the constant cost of steam power for lifting the water to the requisite height is also avoided.

19. On the other hand, the adoption of this system is often rendered economically impracticable, by the enormous length of the aqueduct that would be required for intercepting any sufficiently considerable stream at a point where its level would be sufficiently high. For instance, the Croton Aqueduct, by which the city of New York is supplied with water, is 40 miles in length, which forms a serious addition to the cost of the distributary apparatus, which consists of 150 miles of mains, from 36 to 6 inches in diameter, exclusive of the high service, for which lead pipes of $\frac{5}{8}$-inch diameter, and weighing $8\frac{1}{4}$lbs. per yard, are provided, extending from the mains in the streets to the interior of each house supplied by the company.

20. I shall now proceed to consider certain questions and details which are common to all three sources (viz. rivers, springs, and surface collection,) from which towns are supplied with water. In each case the same question will arise regarding the particular system under which the supply is to be

distributed, and much the same purifying and distributary appliances will be required in each instance.

21. In each case either the intermittent or the constant system of supply may be adopted. Under the first, consumers are immediately supplied from small butts or cisterns, in or adjoining their houses, to which cisterns the water from the mains is only *periodically* laid on. Pure water exposed in a town atmosphere becomes so immediately contaminated by the absorption of gaseous and organic impurities as to be rendered in a few hours nauseous and unpalatable; and for these and other reasons the intermittent system of supply is universally condemned : it is never adopted in new works, and it is rapidly being replaced by the constant system in old ones. It will be therefore unnecessary to notice the system further.

22. Under the constant system of supply, the pipes remain always charged with water, and an unlimited supply is always at the command of the population, and available for the extinction of fire in every street in the town.

23. Under the constant system, the consumers may be "supplied from stand-pipes," or (in consideration of an additional rate) "supplied within their dwellings." The stand-pipes are upright pipes, inserted in the water mains at intervals, and furnished with cocks or taps, whence all in the neighbourhood can draw whatever water they require. The class "supplied within their dwellings" are provided with small branch pipes, extending from the water mains in the streets to the interior of their houses.

24. The water in the mains is rendered available for the extinction of fire by providing these mains with conical orifices at certain intervals apart, such orifices being closed by similarly shaped plugs, which can, at pleasure, be removed, and replaced by "stand-pipes," to which the suction hose of from 1 to 4 fire-engines may be attached.

25. Under either the intermittent or constant system, the supply may be either low service or high service. In the former case, either the water has not sufficient head to rise of itself above the ground-floor of the houses supplied, or, though there may be a sufficient head, those supplied within their dwellings may have the water laid on no higher than their ground-floor, and the inmates will consequently have the trouble of *lifting* all water required for use in the upper floor of their dwellings ; and this circumstance is, of course, calculated to limit the consumption of water.

26. From the above, it will appear that the conditions of a perfect system of supply are best attained when the constant system with high service is adopted, and when the consumers are supplied within their dwellings.

27. After describing in detail the application of the constant and high service systems, I shall proceed to consider the distributary apparatus, pipes, cocks, &c. essential in all cases; the proportion of each required for a given number of inhabitants; the average water consumption per head per day of a town population, and the proportion which the waste from leakage in the

distributary appliances bears to the quantity actually consumed; together with the ill effect of such waste in occasioning damp, and its result, endemic disease, and the consequent necessity that an efficient system of drainage should always precede the introduction of a liberal water supply.

28. I shall then proceed to describe the mechanical and chemical means by which water may be preserved from, and deprived of those impurities which water from all sources is liable to contract; the nature and effect on the human system of such impurities; their origin, and the natural processes by which water is purified from them; and the artificial processes, both mechanical and chemical, employed in imitation of those of nature, by which the same result is effected.

29. The advantages of high service are three-fold. In the first place, it promotes domestic and public cleanliness. The inmates of dwellings to each floor of which a high service supply is laid on have an unlimited supply of water available for all purposes in every corner of the house, without the trouble of procuring or lifting it; and it promotes public cleanliness, by affording (by merely screwing a nozel and length of hose into any of the water mains) a high-pressure jet too powerful for any amount of dirt to withstand. By the application of this jet the fronts of houses and windows can be frequently and cheaply cleaned, and the surface of paved streets and macadamized roads cleared much more cheaply, rapidly, and effectually than by scavenging.

30. Secondly, it affords, at a very small cost, a mechanical power, by means of which any person wishing for the service of a one or two-horse engine, either continuously, or for only an hour or two a day, may have it without trouble, risk, uncertainty, or skilled attendance. This use of water is rapidly extending. At Liverpool, Newcastle, and other towns, cranes for lifting goods into lofty warehouses by means of water-power have been introduced very generally and with great advantage, and the use of small rotatory water-engines for turning-lathes and similar purposes appears likely to become general. Several such machines were exhibited at the Exhibition.

31. Thirdly, high service affords great security against fire, by rendering available, at short intervals along every street, high-pressure jets of water of greater volume and height than any that could be thrown by a fire-engine, within two minutes of any alarm of fire being given, that is in one-tenth of the average time in which, under the most favourable circumstances, fire-engines can be brought to the spot, even in London.

32. The means by which a high service water supply is rendered available for the extinction of fire is as follows:—At intervals of from 50 to 80 yards apart, large open conical sockets are intersected in the main pipes running along each street, these openings being stopped by a conical metallic plug, called a fire-plug, fastened on to the end of an iron rod, extending from the pipe to the surface of the road, where it is covered over by a moveable cast iron flap. In case of a fire, this flap is lifted up, the fire-plug unscrewed and withdrawn, and an unlimited supply of water obtained immediately.

33. The fire-plug is replaced by a moveable pipe, called a connecting stand-pipe; the lower extremity fits into the conical socket of the water main, while its upper end is provided with four openings, to which the hose of four fire-engines may be attached, or from which, in case of high service, four hoses may be made to play with more effect than four fire-engines. If more than four engines require to draw water from one plug, the water from one orifice is allowed to escape into portable cisterns made of painted canvass, stretched over an iron frame, which folds up for convenience of transport, into which half a dozen engines may at once insert their suction hose.

34. In towns in which the high service is sufficiently high for the purpose, the use of fire-engines is superseded altogether. A few yards of hose, with a nozel attached, being screwed into each of the four orifices of the connecting stand-pipe, four jets of water, each of greater volume and greater height than can be obtained from a fire-engine, will be immediately applicable to the extinction of a fire in any of the adjoining houses.

35. It has been ascertained, that with proper arrangements a fire-plug may be knocked out, and the hoses and connecting stand-pipes attached and brought to bear in two minutes upon any house in which a fire occurs; whereas Mr. Braidwood, the Inspector of the London Fire Brigade, states that at London it takes on an average rather more than 20 minutes before an engine can be brought to the spot and set to work at a fire, and more than 30 minutes in other towns. Mr. Braidwood also states that assistance "to be of any use(to the house in which the fire originates) must be rendered within 5 minutes after the alarm is given," and that if the engines do not arrive before the fire gets head, "the injury done by the quantities of water required for the protection of the adjacent buildings, as well as for the extinction of the fire, is as great as the damage from the fire itself."

36. From experiments tried with high service at London and Nottingham, it appears that the height to which jets from the smaller mains of from 3 to 5 inches will rise, at the extreme points of delivery, is in general about half the height due to the pressure: thus a jet of 60 feet may be obtained with a head of 120 feet. In many English and Scotch towns, the water stands at a head of from 200 to 450 feet above the lower portion of the town supplied; and under these circumstances a jet of water may be obtained, greatly exceeding in height and volume the maximum attainable with a fire-engine. It is stated by Mr. Braidwood, that in London 26 men, working an engine of two 7-inch barrels, can only throw a $\frac{7}{8}$-inch jet 50 feet high.

37. The following Tables A and B contain the statistics of all the water companies regarding which I have been able to obtain authentic particulars. I have compiled them from official returns, and from the evidence published in the recent reports of the Metropolitan Sanitary Commission, and General Board of Health.

38. Table A gives most of the following particulars regarding sixteen

different water companies:—1*st*, the population supplied by each, and the proportion which those "*supplied from stand-pipes*" bears in each case to those supplied "*within their dwellings*" ; 2*nd*, the number of persons to each stand-pipe; 3*rd*, the number of persons to each fire-plug ; 4*th*, the mileage of distributary pipes laid down by each company; 5*th*, the number of persons to each mile of such pipes; 6*th*, the quantity of water distributed by each company annually to dwelling-houses, to large consumers, for street watering, for flushing sewers, and for extinguishing fires ; 7*th*, the quantity delivered per head to the population supplied by each.

39. Table B contains the financial statistics of the nine London Water Companies :—1*st*, the invested capital of each ; 2*nd*, ditto per head of population supplied ; 3*rd*, gross income from water-rate returns ; 4*th*, ditto per head of population supplied; 5*th*, expenses of management; 6*th*, ditto per head of population supplied ; 7*th*, net return ; 8*th*, ditto per cent. on invested capital.

40. The following are the results of Table A :—The population supplied by the sixteen companies in question is 3,208,937; the proportion that those supplied within the dwellings bears to those supplied by stand-pipes varies extremely. Some companies supply twenty-nine-thirtieths of their constituents "*within their dwellings*," while other companies supply four-fifths of theirs "*from stand-pipes.*" When a population is supplied from stand-pipes, the number of persons to each stand-pipe varies from 18 to 74, averaging 50 persons to each pipe. The number of persons to each fire-plug varies from 62 to 113, averaging 1 fire-plug to every 76 persons. The number of persons to each mile of water pipe laid down varies from 715 to 2,121, average 1,793 persons to each mile of water pipe.

41. The quantity of water *delivered* per head per day to the population supplied varies from 9 gallons to 45 gallons, averaging nearly 24 gallons : by far the greater proportion of this, however, runs to waste.

42. The results of Table B are as follows :—The capital invested in the works of the various companies varies from £1 12*s*. 3*d*. per head of the population supplied to £4 15*s*. 3*d*., averaging £2 5*s*. 9*d*. per head of the population supplied. The average water-rates paid to each company varies from 2*s*. 5*d*. per annum per head of population supplied to 7*s*. 10*d*. per head per annum, averaging 4*s*. per head per annum. The charges and expenses of management vary from 10*d*. per head per annum to 3*s*. 5*d*. per head per annum, averaging 1*s*. 8*d*. per head per annum. The net return on the capital invested varies from £1 14*s*. 4*d*. per cent. per annum to £6 14*s*. 3*d*. per cent., and averaging £5 2*s*. 7*d*. per cent.

TAB

Containing particulars regarding the Water Delivery

Name of Company.	Population supplied, estimated Persons per House 7·8.			No. of Persons to each Stand-pipe or Cock.	Proportio Fire-plug Populat
		No.	No.	No.	Proport
1 New River Company	Supplied within their dwellings.	630,294	650,000	54	1 to
	Ditto from stand-pipes & cisterns.	18,993			
2 East London Water Company	Supplied within their dwellings.	412,308	442,000	66	1 to
	Ditto from stand-pipes & cisterns.	297,414			
3 Southwark and Vauxhall Water Company	Supplied within their dwellings.	256,339	271,939	74	1 to
	Ditto from stand-pipes	15,600			
4 West Middlesex Water Company	Supplied within their dwellings.	190,944	190,944	..	1 to
	Ditto from stand-pipes	....			
5 Lambeth Water Company	Supplied within their dwellings.	176,787	182,488	55	1 to
	Ditto from stand-pipes	5,701			
6 Chelsea Water Company	Supplied within their dwellings.	161,834	163,768	32	1 to
	Ditto from stand-pipes	1,934			
7 Grand Junction Water Company	Supplied within their dwellings.	108,545	109,652	..	1 to
	Ditto from cisterns and tanks	1,107			
8 Kent Water Company	Supplied within their dwellings.	71,775	75,129	50	1 to
	Ditto from stand-pipes	3,354			
9 Hampstead Water Company	Supplied within their dwellings.	34,929	35,022	46	1 to
	Ditto from stand-pipes	93			
Paisley Water Company	Supplied within their dwellings.	6,000	29,690	39	....
	Ditto from stand-pipes	23,690			
Glasgow North of the Clyde Water Company	Supplied within their dwellings.	165,000	325,000	18	....
	Ditto from stand-pipes	160,000			
Ditto South of ditto, or Gorbal's Water Company	Supplied within their dwellings.	55,500	70,000	72	....
	Ditto from stand-pipes	14,500			

…tributary Apparatus of Sixteen Water Companies.

…ge of Pipes, exclusive of House Service.		No. of Persons to each Mile of Pipes.	Quantity of Water delivered Annually.		Quantity of Water delivered for all purposes per Head per Day of Population nearly.	
					For Domestic use	For all purposes.
Inches.	Miles.	No.	Gallons.	Gallons.	Gallons.	Gallons.
....	..	..	Dwelling-houses ....6,500,764,013 Large consumers.... 335,258,705 Street watering...... 45,410,900 Flushing sewers...... 12,906,570 Extinguishing fires.. 10,000,000	6,570,000,000	27	28
m 3 to 42	228	1,938	Dwelling-houses ....2,880,451,740 Large consumers.... 279,836,136 Street watering...... 15,466,000 Flushing sewers...... 23,000,000 Extinguishing fires.. 24,000,000	3,222,753,876	17	20
n 2 to 27	380	715	Dwelling-houses ....2,125,334,330 Large consumers.... 472,040 Street watering...... 43,200,000 Flushing sewers...... / Extinguishing fires... 26,000,000	2,195,006,370	21	22
m 3 to 6	150½	1,268	Dwelling-houses ....1,108,929,812 Large consumers... / Street watering ... 46,400,040 Flushing sewers...... 61,599,960	1,216,929,812	15	17
m 2 to 23	135	1,351	Dwelling-houses ..... 885,475,000 Large consumers..... 191,625,000 Street watering... ... 28,600,000 Flushing sewers ...... 10,500,000 Extinguishing fires.. 7,000,000	1,123,200,000	13	16
m 3 to 18	134	1,222	Dwelling-houses ....1,291,208,000 Large consumers.... 91,250,000 Street watering...... 36,000,000 Flushing sewers ..... 15,000,000 Extinguishing fires.. 5,000,000	1,438,458,000	21	24
m 3¾ to 32¼	80	1,370	Dwelling-houses ....1,111,814,901 Large consumers.... 96,260,029 Street watering...... 54,960,000 Flushing sewers.. ... 250,000 Extinguishing fires.. 25,900,000	1,289,184,930	27	33
m 1½ to 24	85	883	Dwelling-houses ..... 322,821,300 Large consumers.... 45,003,850 Street watering...... 22,520,000 Flushing sewers ..... 3,423,600 Extinguishing fires.. 180,000	393,948,750	11	14
m 3 to 12	26	1,347	Dwelling-houses .... 129,313,000 Large consumers..... 1,090,000 Street watering...... 15,768,000 Flushing sewers ...... 9,855,000 Extinguishing fires	156,026,000	9	12
....	..	..	No particulars are given	487,658,250	..	45
....	..	..	Ditto ditto	3,832,500,000	..	32
....	..	..	Ditto ditto	817,600,000	..	32

Name of Company.	Population supplied, estimated Persons per House 7·8.			No. of Persons to each Stand-pipe or Cock.	Proportion of Fire-plugs to Population.
		No.	No.	No.	Proportion
Stirling Water Company	Supplied within their dwellings.	3,180	10,305	..	....
	Ditto from stand-pipes	7,125			
Nottingham Water Company..........	....		35,000	..	....
Preston Water Company.............	....		78,000	..	....
New York Water Company	Supplied within their dwellings.	60,000	300,000	..	....
	Ditto from stand-cocks	240,000			
Philadelphia Water Company	Supplied within their dwellings.	120,000	240,000	..	Plug in every 400 feet.
	Ditto from stand-cocks	120,000			
		Total..	3,208,937	Average. 50	Average 1 to 76 near

TABL

Containing the Financial Statistics

No.	Name of Company.	Capital paid up.	Ditto per Head of Population supplied.
		£ s. d.	£ s. d.
1	New River Company	1,421,717 0 0	2 3 8
2	East London Water Company	745,781 0 0	1 13 8
3	Southwark and Vauxhall Water Company	435,247 0 0	1 12 0
4	West Middlesex Water Company	648,560 6 1	3 7 11
5	Lambeth Water Company	307,352 8 1	1 13 8
6	Chelsea Water Company	455,712 0 0	2 15 7
7	Grand Junction Water Company.....................	522,295 4 9	4 15 3
8	Kent Water Company..	202,104 13 6	2 13 9
9	Hampstead Water Company....	121,231 0 0	3 9 6
	Total Population 2,120,942	4,860,000 12 5	Total Average. 2 5 9

...age of Pipes, exclusive of House Service.		No. of Persons to each Mile of Pipes.	Quantity of Water delivered Annually.		Quantity of Water delivered for all purposes per Head per Day of Population nearly.	
					For Domestic use	For all purposes.
Inches.	Miles.	No.	Gallons.	Gallons.	Gallons.	Gallons.
....	..	..	No particulars are given	48,897,225	..	13
....	..	..	Dwelling-houses... ...... Large consumers..	248,200,000	..	19
....	..	..	Dwelling-houses..164,250,000 Other purposes ..113,150,000	277,400,000	57	9
...n 6 to 36	150	2,000	....		..	..
...n 12 to 22	115½	2,121	Particulars are not given......	1,825,000,000	..	20
	Average. 148	Average. 1,793	Total..	24,845,665,988		Average. 24

Nine London Water Companies.

...oss Income per ...ter-rate Returns.			Ditto per Head of Population supplied.			Expense of Management.			Ditto per Head of Population supplied.			Net Return.			Per Cent.		
£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
...36,296	0	0	0	4	2	55,582	0	0	0	1	8	80,714	0	0	5	13	6
...70,585	14	0	0	3	2	25,202	9	0	0	1	1	45,383	5	0	6	1	8
...36,396	16	0	0	2	8	12,000	0	0	0	0	10	24,396	16	0	5	12	1
...65,415	8	6	0	6	10	21,859	0	8	0	2	3	43,556	7	10	6	14	3
...22,446	17	9	0	2	5	14,877	16	5	0	1	11	5,569	1	4	1	16	2
...35,917	9	3	0	4	4	28,079	17	7	0	3	5	7,837	11	8	1	14	4
...43,387	8	9	0	7	10	12,537	7	6	0	2	3	30,850	1	3	5	18	1
...14,442	13	3	0	3	10	6,854	0	0	0	1	9	7,588	13	3	3	15	1
7,009	12	10	0	4	10	3,476	0	0	0	1	11	3,533	12	10	2	18	3
			Total Average.						Total Average.						Total Average.		
...31,898	0	4	0	4	0	182,468	11	2	0	1	8	249,429	9	2	5	2	7

43. Previous to the publication (in 1850) of the results of the late investigations of the Board of Health on the subject, much uncertainty existed regarding the quantity of water (in gallons) that should be supplied to a town per head of its population daily. This uncertainty was caused by the general impression that the quantity of water stated to be delivered to their constituents by the various English water companies was altogether inconsistent with the known habits of the population supplied, and that it exceeded the apparent amount of water consumed for domestic purposes by a very large though unascertained amount, the difference being supposed to be caused by leakage and waste.

44. The result of the investigations instituted by the Board of Health has shown that the waste is very much greater than was suspected; that in all cases it considerably exceeds the actual consumption; and that, in fact, "it may be truly stated that at present the large supplies furnished to towns are required, first *for waste,* and secondly for domestic supply."

45. The total quantity of water delivered by the nine water companies that supply London was ascertained to be 45 millions of gallons a day, but from careful gauging of the house drainage, it appeared that only two-fifths of this amount, or 18 millions, really entered into consumption, the remaining 27 millions being wasted by leakage. Of this 18 millions (being about 9 gallons per head per day) actually entering into consumption, it was ascertained that 5·7 gallons per head per day was the average domestic consumption of the best conditioned districts, provided with an unlimited supply of water laid on into the interior of their dwellings; the remaining 3·3 gallons being consumed by steam-engines, manufactories, the flushing of sewers, street watering, and the extinguishing of fires.

46. This result has been confirmed by similar experiments instituted in other large English towns, and it may now be considered as an ascertained fact, that the best conditioned town population, using baths and water-closets, with an unlimited supply of water always at their command, will not on *an average* consume more than between 5 and 6 gallons per head per day for domestic purposes. In Scotch towns, Glasgow for example, the inhabitants of which have a constant and unlimited "supply of the purest water always at their command," the average consumption of the population for domestic purposes was ascertained to be only eight-tenths of a gallon per head per day.*

47. The quantity of water consumed per head by the dwellers in towns appears to depend a good deal on the mode in which their water is laid on, and, as I have already mentioned, these modes are three in number: under the old intermittent system the water becomes so deteriorated by exposure in butts

* See Dr. Sutherland's report to the Board of Health: the larger portion of this daily eight-tenths of a gallon would, one would think, be required for the dilution of the whiskey daily consumed by the population.

or cisterns only periodically filled as almost to preclude its use as a beverage; and under these circumstances the consumption of water will of course be very small. When, however, the supply is constant, and at high pressure, the poorer classes of the population supplied have a constant and unlimited supply of water fresh from the mains always at their command, with only the trouble of turning the cock of any of the stand-pipes to be found in every street of the town; and under these circumstances the consumption might be expected to be much larger than in the last case. In towns supplied on the constant high service system there is another class of consumers, composed principally of the middling and higher classes of the population, who are saved the trouble of going to the stand-pipes, by having (in consideration of a special rate) the water laid on to the interior of their dwellings, to their water-closets, cisterns, and baths; and this class of course consumes considerably more water than either of the others. The experiments on the consumption of the two last classes gives an average of under 2 gallons per head per day for the classes supplied from stand-pipes under the constant system, and an average of between 5 and 6 gallons per day as the consumption of the class "supplied within their dwellings."

48. The following table is compiled from data contained in Dr. Sutherland's elaborate report to the Board of Health on the quantity and quality of the water supply, and the amount of actual consumption per head in various towns in Great Britain:—

Ascertained Average Daily Household Consumption of Town Population, having an unlimited supply of Water always at their command from Stand-pipes under the constant System.		Quantity actually flowing into the Mains, exclusive of the supply of Public Works, and all similar purposes.
	Gallons.	Gallons.
Glasgow North of the Clyde, supplied by Glasgow Water Company	0·82	. . . .
Glasgow South of the Clyde, supplied by Gorbal's Gravitation Water Company	1·14	32
Paisley	1· 4	45
Stirling	2· 0	13

49. Assuming the average consumption to be in all these cases even 2 gallons per head per day, the proportion of waste would be as follows:— 2 gallons per head per day would indicate a supply of 320,000 gallons as being sufficient, under the stand-pipe system of distribution, for the 160,000 people in Glasgow north of the Clyde, provided the quantity could be delivered without waste; whereas the actual quantity pumped into the mains for that proportion of the population is no less than 4,000,000 gallons, or more than twelve times the actual domestic consumption.

50. The amount (at 2 gallons per head per day) required for the domestic consumption of the 23,690 persons in Paisley supplied from stand-pipes would

be in round numbers 48,000 gallons, while the actual quantity sent into the mains is about 450,000, or nearly ten times the amount of the actual household consumption. Dr. Sutherland remarks, in conclusion, that similar discrepancies were found to exist elsewhere, and "that it must be borne in mind that these occur in populations having a constant and unlimited supply of water constantly at their command." He states that he was himself by no means prepared for the very low rate of actual household consumption (amongst the class supplied from stand-pipes) which the investigation brought out, although he had previously felt *that the habits and appearance of a large portion of the working population "did not afford any very strong indication of a liberal use of this prime element of health and convenience."*

51. The enormous amount of waste that occurs in even the best and most recently constructed water-works may be demonstrated in another way. For many hours of the night there is little or no consumption of water for domestic purposes, and manufactories; and if there was no leakage, the water pipes under the constant system of supply would remain charged all night, without requiring any addition to their contents; yet at the city of Glasgow water-works 3,000 gallons per minute were required to be pumped into the mains to keep them charged during the night. There are 1,440 minutes in 24 hours, and this amount therefore indicates a waste of 4,320,000 gallons a day in works supplying a town population of only 325,000.

52. The quantity which passes into the mains of the works of the Gorbal's Gravitation Water Company (which works are considered the most perfect of the kind in Great Britain) is stated by their Superintendent at 934.50 gallons per minute during the night hours, indicating a daily waste of 1,345,680, or nearly 18 gallons per head per day on the population supplied.

53. The enormous disproportion that the gross quantity of water supplied usually bears to the actual net consumption is attributed to leakage in the countless joints and fire-plugs of the many miles of the distributing water pipes, and to the enormous and continuous waste, not only from the stand-pipes, but also from water-taps or "stair heads," and within private dwellings: these latter sources of leakage are very numerous. There are 1,800 stand-pipes with ¾-inch taps belonging to the city of Glasgow water-works, and besides this a population of 165,000 supplied within their dwellings by probably not less than 80,000 taps.

54. Though expensive establishments are kept up for attending to the repair of these taps, and watching against all sources of waste, many sources of leakage escape detection: for example, I find in a recent report on the water supply of Liverpool, that Mr. McDonald, the Water Inspector in that town, recently discovered a wastage in a cellar which on a moderate calculation had been discharging at the rate of 42,000 gallons a day for the last 12 or 15 months.

55. Making, however, due allowance for these sources of leakage, the proportion of wastage stated to occur at present in all English and Scotch

water-works appears to me unaccountably large, and I do not doubt that now that the attention of water companies has been directed to the subject, engineering means will be devised for diminishing it to a mere fraction of its present amount.

56. The consumption per head per day of the class supplied within their dwellings is found to average about 5 gallons, the maximum in first class houses sometimes rising as high as 7 gallons. Mr. Newlands, the Borough Engineer of Liverpool, states:—"The result of a direct experiment as to the consumption of water for all purposes, made in a first class house, including washing, baths, and water-closets, was 7 gallons per head per diem.

57. "A like measurement was made of the supply to one of the Liverpool hospitals, and it was found to be 10 gallons per head per day; but it is only fair to state that the consumption in hospital is higher than for domestic use on account of the large comparative quantity required for baths, and the still larger amount consumed by the continuous washing required amongst sick persons."

58. The Liverpool work-house contains about 2,000 inmates, whose personal cleanliness is strictly attended to: the house is supplied with water-closets, baths, &c. The consumption in this house was found to be somewhat under 3 gallons per head per day.

59. In Stirling and Glasgow, the average consumption in the better class of houses, including washing and water-closets, was found to be little more than 5½ gallons per head per day. In the town of Bury St. Edmunds, the quantity of water consumed in many houses is accurately measured by Parkinson's patent water-meter, and the average consumption has been found to be, in a house of the first class, 6·88 gallons per head daily, and in houses of the middling class something less than 6 gallons.

60. The result of the "trial works" instituted by the Board of Health, to ascertain the quantities of water actually consumed in the metropolis, has given an average consumption of 5·7 gallons per head per day for the 1,200 houses (in Earl Street, near Regent's Park,) that were experimented upon.

61. From these experiments it may be safely concluded that the *average daily consumption for domestic purposes* of even the most cleanly town population, including washing, and the use of baths and water-closets, with an unlimited supply of water, under the most perfect system of distribution, can never be raised materially above 6 gallons per head per day.

62. The General Board of Health states "that from such inquires as they have made, they believe that a consumption of 6 or 7 gallons per head, or 50 gallons per house, by the labouring classes, would be *a great increase indeed* on the present actual consumption of water."

63. Regarding the injurious effects of the leakage of the distributing appliances on the sanitary state of towns in which it exists, the Board of Health remarks as follows:—"As applied to the excessive water supply, the term '*waste*' has been used; but if this large volume of water could only

be considered as so much wasted, it would represent a certain amount of loss in money alone; borne by the public, it is true, and consequently a grievance, requiring at the hands of the Legislature a corrective remedy. But the actual results are far worse: this water is not only waste, but a positive injury to the landlord as well as to the tenant; to the landlord by creating undue damp, and thereby injuring his property; to the tenant, by saturating the whole sub-soil with fluid refuse, tending to generate foul and highly dangerous gases; as also by rendering the basement floors, the walls, and yards unduly damp, producing all those ill effects known to exist in connection with swampy, undrained districts."

64. The Board states, that "on taking wide averages, the prevalence of epidemic disease is found to bear proportion to the state of drainage, and of the excess of damp where other conditions are similar." And this point is fully established by tables compiled from the Registrar General's returns.*

65. The experience of New York, and of many English towns also, which have been liberally supplied with water without the previous introduction of an efficient system of sewerage and house drainage, has fully proved, that under such circumstances an increased supply of water, by augmenting damp and decomposition, increases epidemic disease, and becomes a very serious sanitary evil, and there can be no question that it would be extremely unsafe to supply Bombay with water-works on the European system, without providing in the first instance a complete system of drainage.

66. The mode in which damp acts in affecting the sanitary state of a town population is described by Dr. Robert Angus Smith (the physician appointed by the General Board of Health to examine into the variation in composition of the air and water of towns) as follows:—"Water is necessary to the spontaneous decomposition of animal matters. * * * * Organic matter in contact with water constantly gives off an odour of some kind, and especially if heated, so that it would appear as if steam or vapour were capable of taking up much more than that which we call volatile matter. * * * *

67. "A certain amount of moisture is almost essential to the escape of odour from many bodies. It probably arises from two causes: the vapour of water *is a vehicle for organic matter*, and water favours decomposition in

* On dividing the metropolis into two great districts, the highest and the lowest, in relation to the Trinity high-water mark, we find that whilst in the highest districts, at an average level of 54 feet above high-water mark, the proportion of deaths from fever was in 1838 1 in 425, in the lower districts, at an average level of 11 feet only above high-water mark, the deaths from fever were 1 in 255. In 1832, the deaths from cholera in the higher districts were only 1 in 551; in the low lying districts they were 1 in 200. In 1849 in the higher districts the deaths from cholera were 1 in 347; in the lower districts 1 in 118. The last most severe visitation obverved a close relation to the differences of drainage level, for whilst, during the preceding attacks, the visitation was severest in some of the intermediate districts, on dividing the whole of the metropolis into three districts, the highest averaging 63 feet above high-water mark, the intermediate averaging 30 feet, and the lowest averaging 4 feet, we find that the deaths were in the highest 1 in 346, in the intermediate 1 in 256, and in the lowest 1 in 93.

bodies, so that as they decompose the vapour is given out. From whatever cause, it will be found that moisture rapidly facilitates the escape of odour. Mineralogists avail themselves of this when they breathe on a mineral, and then ascertain the smell. The moisture of an evening, or even artificial moisture, causes the flowers to give their scents, and the moist state of the atmosphere before or after the shower causes also a great fragrance in a flower-garden. But whilst this is caused, the same laws are operating for injurious effects wherever there is a reservoir of putrid matter, for then the exhalations are also abundant, and bubbles may be seen to rise from filthy water. It is not improbable that the state of the atmospheric pressure may cause this, as Mr. E. W. Binney has shown that the gases in coal-pits are caused to escape rapidly during a lowering of the barometer. Bodies that are moist will therefore give out more organic vapours. * * * Earth, if moist, will give out, not pure vapour of water, but water with organic matter in it.

68. "Organic matter may be lifted up into the air, and hot weather promotes it (the process). All vegetable solutions give out a certain amount of matter from them.

69. "The effect of wetness on the atmosphere of a town is very great: if we observe the smoke on a dry day we find that it rises, and if there be a little wind, it is carried out in distinct black lines, leaving the air below comparatively pure. If the day be dull and wet, the smoke, instead of being carried away, is poured out directly into the streets, and a spectator at a short distance sees a basin of black fluid, if the town be in a valley, or a heap gradually diminishing towards the circumference as it falls into the adjacent country. It may be replied, that the diffusion of gases would prevent this; but, again, it may simply be said that it does not prevent it. * * * Probably this is the reason of the very disagreeable state of our towns in damp gloomy weather; it is such weather as does not allow the town to be ventilated. The same does not occur on a thoroughly wet day, when the matter is carried fairly down into the streets, and a certain freshness is perceived."

70. Every one who has had occasion to pass the bridges over the main drain previously to its being arched over, during the evening or early morning, at which times the air is usually surcharged with moisture, must have remarked how greatly the ill odours arising from the sewerage were augmented at such periods; and the ill-smelling mist in which the New Town is often shrouded for an hour before and after sunrise affords an example of the effects of a low damp situation, and of imperfect ventilation in generating and retaining malaria.

71. The Board of Health, in their late report on the water supply of the metropolis, have most strenuously advocated the advantages of the constant supply system over the intermittent one, and the superiority of a supply delivered "within the dwellings" of the consumers, to a "supply from stand-pipes." The superior advantages of the systems advocated in each case can

be scarcely overstated; yet, when the Board of Health attribute the great water-waste that occurs in London to the prevalance of the intermittent system of supply, and the still greater water-waste of the Scotch works to the circumstance of their constituents being principally supplied "from stand-pipes," and not within their dwellings, their opinion appears unwarranted by facts, and even at variance with the water statistics published in the appendices of their own reports.

72. If the waste was greater under the intermittent than under the constant system, it might be concluded that the waste in the Scotch water-works (which are all on the system of constant supply) would be manifestly less than the waste in London, where the intermittent system is the rule (especially as the former not only adopt the system considered by the Board as least liable to waste, but are also the more recently and more perfectly constructed of the two). Yet the contrary is the fact; for according to the returns published by the Board of Health, the waste under the intermittent system at London does not exceed three-fifths of the whole quantity delivered, whereas in the Scotch towns it is stated at an almost incredibly larger proportion.*

73. Neither does the proportion of waste appear to be affected by the mode of distribution, whether from "stand-pipes" or "within the dwellings" of the consumers. The Gorbal's Water Company supply eleven-fourteenths of their consumers "within their dwellings"; and the Paisley Water Company only one-fourth, the remainder being in each case supplied "from stand-pipes;" yet the proportion of waste is in both towns about the same.

74. One great bar to the general adoption of the system of supplying consumers "within their dwellings," and with "high service," has been the difficulty experienced by the water companies in checking waste, and regulating the amount consumed when the water was delivered within the houses, and, therefore, practically beyond the supervision of such companies' officers. This difficulty might be overcome by the general introduction of water-meters, whereby the quantity actually drawn by each consumer might be registered, as in the case of the gas supply. Were this done, the water companies might charge by the quantity indicated by the water-meter, instead of so much a house. This plan would also much encourage the use of water as a motive power for small machines, mentioned in paragraph 30.

75. The use of water-meters would also be of great advantage in checking waste; it would be then the interest of consumers to see that no leakage occurred in the taps or joints of the house service, and by the application of large water-meters at intervals along the main pipes, and by comparing the indications of these periodically, and with the aggregate indications of the small meters, within the houses of the district such mains supplied, the amount and position of any source of leakage would be immediately detected. The patent water-meters of Parkinson of Bury are said to answer their purpose

* See ante, paragraphs 49, 50, 51, and 52.

well, and appear likely to come into general use. The Croton Aqueduct Water Company at New York have introduced another form of water-meter, which they fix to all the water services, charging consumers according to the indication of the meters as gas companies charge for the gas.

76. I shall now proceed, as proposed in paragraph 28, to describe the mechanical and chemical means by which water may be preserved from, or deprived of those impurities which water from all sources is liable to contract, the nature and effect on the human system of such impurities, their origin, and the natural processes by which water is purified from them, and the artificial processes, both mechanical and chemical, employed in imitation of those of nature, by which the same result is effected.

77. The impurities which water is liable to contract may be classified as follows:—1*st*, solid or "mechanical" impurities held in suspension; 2*nd*, dissolved impurities, mineral and saline; and 3*rd*, organic impurities, animal and vegetable, and the gaseous products of their decomposition.

78. *Solid Impurities.*—Running water usually abrades, holds in mechanical suspension, and carries along with it, the particles of earthy matter of which the soils or rocks forming its channel are composed. The quicker its flow, the larger the particles it can hold up. When the current subsides, and the water becomes still, the solid matter falls to the bottom, the larger particles first, and the water becomes clear. The water most free from solid impurities is that derived from springs, flowing over hard barren rocks. Iron and lead also occur in suspension, and vegetable and animal matter may be present in solid specks.

The methods of clearing water from solid or mechanical impurities are subsidence and filtration.

79. *Dissolved Impurities.*—The principal impurities of this class are described by Professor Clark in his evidence before the Health of Towns' Commission:—"The most material are earthy salts; that is, salts of lime and salts of magnesia. I call the earthy salts the most material, because it is the presence of earthy salts that gives rise to hardness. There is also usually present common salt, and sometimes bicarbonates of soda and potash; but none of these affect the hardness of water. The most important portion of the earthy salts may be reckoned the bicarbonate of lime. The whole salts present, whether earthy or not, may be distinguished into two parts,—according as they are neutral to test paper, or alkaline to test paper,—the neutral portion, and the unneutralized portion. The unneutralized portion consists entirely of bicarbonates—those of lime and magnesia, which are the earthy bicarbonates; and in some waters those of potash and soda, which are the alkaline bicarbonates. The neutral portion consists of the neutral salts of earths and alkalies, such as gypsum (sulphate of lime) and common salt. Salts of iron occur also occasionally in waters that are in use. Such salts impart an inky taste to the water, and they give a yellowish tint to linen that is washed by the water containing them. They, too, produce hardness."

80. *Organic Impurities.*—The contamination of water by vegetable and animal substances in a state of putrid decomposition, and by the minute forms of life bred among such impurities, takes place in various ways. The most obvious and abundant source of this class of ingredients is the sewerage and refuse of towns, and next in order may be ranked the contact with soils rich in organic matter. Among organic impurities may be classed offensive gases, such as carburetted, sulphuretted, and phosphuretted hydrogen; vegetable fibres in a state of rottenness; putrefying products of the vegetable or animal kingdoms; starch, muscular fibre, &c.; urea, and ammoniacal products; vegetable forms—algæ, confervæ, fungi, &c.; animalcules—infusoria, entomostraceæ, annelidæ or worms, &c."

81. The solid impurities held in suspension by running water are, for the most part, thrown down and parted with by the latter when it returns to rest, and are, therefore, seldom taken into the human system. But the ill effects attendant on the use of water containing dissolved impurities or organic impurities are numerous and frequent.

82. Of dissolved impurities, the most frequent in the water supply of towns are the salts of lime. These salts are chiefly objectionable in giving to water the well known quality termed hardness. Hardness occasions a great waste of soap in washing, renders the water unfit for cooking, or for making tea or other vegetable infusions, and produces derangements of the digestive functions, glandular obstructions, and calculary diseases. Magnesia is said by an eminent foreign physician (M. Graves) to be the characteristic ingredient of water in the districts where the diseases called *cretenisme* and *goître* (wens) abound. Soda, potash, and other alkaline substances render water vapid and unpleasant to taste; salts of iron in considerable quantity make what is technically called chalybeate water, and belong to the medicinal class.

83. By far the most prevalent cause of hardness in water is the presence of lime, sometimes as the sulphate, but far more usually as the bicarbonate. The presence of bicarbonate of lime in water is thus occasioned:—Water in its pure state (as rain water) imbibes with great avidity any organic or gaseous impurities that may be present in the adjacent atmosphere, and, amongst other products of decomposition, it so imbibes large quantities of carbonic acid gas, a proportion of which, about $\frac{3}{10000}$, is present in even the purest atmospheres. Should water so impregnated flow over a bed of limestone rock, (which is usually a carbonate of lime, and therefore insoluble in water,) or over any soil containing carbonate of lime, the carbonic acid will dissolve, and combine with a portion of such carbonate of lime, thereby forming the bicarbonate, which *is* soluble in water, and forms the peculiar salt of water flowing over chalk or limestone districts. The chemical process by which water is deprived of its hardness, when the latter is occasioned by the presence of the bicarbonate, (for water hardened by sulphate of lime is incurable,) is the converse of the natural process by which it acquires it.

84. "Professor Clark has devised a scale of hardness, which is now universally employed in the chemical description of waters. The hardening effect that would be produced by one grain of chalk dissolved in a gallon of water is one degree of hardness; in like manner four grains per gallon would produce four degrees of hardness; ten grains ten degrees; and so on. The degrees are expressed in numbers, thus 1°, 4°, 10°, 15°, or one, four, ten, and fifteen degrees respectively. When any other salt of lime is the hardening ingredient, the measure is still by grains of chalk: if a certain amount of sulphate of lime (gypsum) be dissolved in water, the effect is not expressed in grains of gypsum, but in the grains of chalk requisite to produce the same hardening effect." Water becomes perceptibly hard in washing when 5° of hardness is attained. The Board of Health found the average of 264 specimens of well and spring water examined to be 25°.86; of 111 specimens of river and brook water to be 13°.05; and of 49 specimens of surface drainage to be 4°.94.

85. "The scale of hardness increases with the consumption of soap requisite to form a lather. Professor Clark has made use of this fact in his process of testing for hardness—a process of extreme delicacy. It consists of the employment of a solution of soap of measured strength; and according to the quantity of solution requisite to form a lather of a certain duration, is the hardness of the water. By this test, the value of water for washing purposes, and for all other purposes where hardening matter is an objection, can be determined with great ease, and with a precision scarcely equalled by any process in chemistry. The employment of the definite scale of hardness, and of the soap test for measuring its amount, has tended more than any other circumstance to facilitate the determination of proper waters for the supply of towns."

86. The comparative effects of hard and soft water on the health of town populations have lately attracted much attention in England. "These effects," says Dr. Holland, "were perfectly well known in ancient times, and have continued to be recognized on the Continent. Every medical writer of eminence, from the days of Hippocrates downwards, has dwelt upon the sanitary distinctions of the two kinds of water"; and the medical evidence taken by the Board of Health and by the Sanitary Commission is quite conclusive on the same side of the question.

87. Dr. Sutherland, an eminent physician, who has given much attention to the subject, states as the result of his experience, that in certain susceptible constitutions, hard water tends to produce visceral obstructions; that it diminishes the natural secretions, produces a constipated or irregular state of the bowels, and consequently deranges the health; that he has known these complaints to vanish on his patients leaving for a time the hard water districts, and immediately to reappear on their return, and that such repeated occurrences had directed his attention to the fact.

88. Glasgow was formerly supplied with hard water—of late years a soft water supply has been introduced. Dr. Leech, of Glasgow, states, with reference to this change, that the comparative value of the new soft supply over the old hard supply had been matter of discussion at the Glasgow Southern Medical Society, of which he was president, and that it was the unanimous opinion of the medical profession, that great benefits of a sanitary kind had followed the substitution of the soft water. It had been observed that since this change urinary diseases had become less frequent, especially those attended by the deposition of gravel, and that as far as experience had gone dyspeptic complaints had also become diminished in number.

89. Dr. Cunningham, of Glasgow, gives testimony to the same effect.

90. Dr. Thomson, in his report on the well water of Glasgow, states that an excess of any form of lime in the food " is highly objectionable, as it is very frequently the cause of gravel and stone, and enters into the composition of many concretions which gather in the human system. So powerful is its influence, that when a person has been recovering from this painful disorder, a recurrence of the disease, in all its violence, has been occasioned by the presence of even a small quantity of lime in the water used to drink.

91. Dr. Wolstenholme, of Bolton, gives the following testimony :— " I have been acquainted with the character of diseases in Bolton for 35 years, and I have no doubt that gravel and calculous affections are less prevalent in the last few years than they were in the earlier period I speak of, viz. from the years 1815 to 1825. I attribute the improvement mainly to an ample and unlimited supply of pure soft water by the establishment of the Bolton water works in the year 1824, and partly to the diminution of drinking malt liquor to excess."

92. Mr. Robinson, surgeon, Bolton, has expressed similar views.

93. The General Board of Health state in their last report :—" It appears to be undoubted that the number of calculous complaints in the hospitals, as at Paisley, have greatly diminished, and that in the same ratio as consumption of soft water has increased."

94. The inferiority of hard water for cooking meats and vegetables, for making bread, and for making tea, has always been admitted. From experiments made by the " eminent cook" M. Soyer, and others, at the request of the General Board of Health, it appears that it requires one-fourth more time and fuel to cook vegetables or meat with hard water than with soft; that the former gives greens a yellow tint; that it does not open the pores of meat, like soft water; that it will not extract the flavour from vegetables or the juice or gravy from meat; that it is therefore ill-adapted for making soups and broths. " Instead of opening the meat," says M. Soyer, " it seems to draw it closer together, and to solidify the gluten; and I believe that the true flavour of meat cannot be extracted by hard water." It is also very inferior in making bread. In making tea with water of 16° (sixteen degrees) of hardness, (the

average of the London water,) and with the same water, after reducing its hardness to 3°, Dr. Holland found the quantity required to make an infusion of equal strength in each instance eighteen parts in the first case, and only ten in the second, showing that the tea went nearly twice as far with the soft water as with the hard. The results of M. Soyer's experiments on the effect of hard water in making tea corroborated those of Dr. Holland. M. Soyer was supplied by the Board of Health with solutions of lime-water of ascertained strengths, for the experiments, and was assisted by "the two most eminent tea-tasters in London."

95. The waste of soap attendant on the use of hard water in washing is enormous. On testing the comparative efficiency for washing of two waters of 5° and 15° of hardness respectively, the quantity of soap required in the first case was found to be 466 lbs., and in the latter 1,400 lbs., or more than three times as much (had rain water, or other perfectly soft water been used, the saving would have been proportionably greater); and 15° is one degree less than the average hardness of the London water.

96. Water hardened by carbonate of lime may be softened to a considerable extent by simple boiling, whereby a large proportion (sometimes as much as half) of the carbonate is thrown down, and forms a white crust on the bottom of the vessel used.

97. A chemical process for softening such water has been recently patented by Professor Clark, and is now generally used in manufacturing processes for which softer water is required than can be otherwise obtained on the spot. The same process is becoming very generally used by private consumers in London for softening the water required for domestic use, and there is no doubt that it will be shortly adopted on a large scale by all the London water companies in preparing the water supplied to their constituents.

98. Chalk and most other pure limestones consist of lime and carbonic acid. The latter can be driven off by heat, and the limestone then becomes quicklime. A pound of pure chalk, if burnt in a kiln, is reduced to 9 oz., the 7 oz. lost by the process of burning being carbonic acid gas.

99. Carbonate of lime cannot be dissolved in pure water; but if there be any free carbonic acid present in the water, as there always is in water that has been exposed in the slightest degree to the emanations of decomposing animal or vegetable matter, each 7 oz. of such carbonic acid present will combine with each 16 oz. of carbonate of lime, thereby forming the bicarbonate, which is soluble in water, like common salt. A pound of limestone or carbonate of lime so dissolved by 7 oz. of carbonic acid, in 560 gallons of water, would form a solution not sensibly different from filtered Thames' water.

100. It is clear that such water can only be deprived of the bicarbonate of lime it holds in solution by the introduction of something which, having a greater affinity for the carbonic acid than the carbonate of lime has, will

combine with and abstract such acid from the solution, thereby rendering the lime no longer soluble, and throwing it down to the bottom as sediment. This is the principle of Professor Clark's process, and the solution he uses for the purpose of rendering the bicarbonate of lime insoluble is called lime-water, and is prepared as follows :—

101. When a pound of carbonate of lime is burnt, 7 oz. of carbonic acid is driven off, and 9 oz. of quicklime remains. Quicklime is soluble in water, but these 9 oz. will require not less than 40 gallons for entire solution. Such solution is called lime-water.

102. Now, if this quantity (40 gallons) of lime-water be mixed with the 560 gallons of Thames' water I have described, the following fresh combinations will take place :—the 7 oz. of carbonic acid which had alone rendered the carbonate of lime soluble in the Thames' water will immediately—1*st*, abandon its alliance with the carbonate, which, being rendered insoluble by its abstraction, will forthwith separate from the water, and sink to the bottom, as a pound of chalky sediment; and 2*nd*, after having so abandoned the carbonate, the acid will combine itself with the 9 oz. of quicklime, which, by such alliance, will become carbonate of lime again, and, being as such insoluble, will also sink to the bottom. When the whole has settled, the result of the operation will, therefore, be 600 gallons of pure soft water, with a sediment of 2 lbs. of insoluble carbonate of lime at the bottom.

103. " If there be any mechanical or organic impurities in addition to the chalk, or any colouring matter, these are involved in the precipitate, and carried down along with it. In the case of the Thames' water, much more is removed than the mere chalk : organic compounds are withdrawn from solution, insects and animalcules are destroyed, and mud carried to the bottom."

104. For softening Thames' water for washing and culinary purposes, Dr. Holland uses oxalate of ammonia (prepared by dissolving 1 oz. Troy of oxalic acid in one quart of water, and adding as much carbonate of ammonia as will saturate it). This costs about 3*d*., and will soften more than 30 gallons of Thames' water; but if used in excess, it gives the water the taste of soot.

105. " *Organic Impurities.*—The contamination of water by vegetable and animal substances in a state of putrid decomposition, and by the minute forms of life bred among such impurities, takes place in various ways. The most obvious and abundant source of this class of ingredients is the sewerage and refuse of towns, and next in order may be ranked the contact with soils rich in organic matter. Among organic impurities may be classed offensive gases, such as carburetted, sulphuretted, and phosphuretted hydrogen; vegetable fibres in a state of rottenness; putrifying products of the vegetable and animal kingdoms ; starch, muscular fibre, &c.; urea, and ammoniacal products; vegetable forms—algæ, confervæ, fungi, &c.; animalcules—infusoria, entomostraceæ, annelidæ or worms, &c."

106. The water absorbs from the air with extraordinary avidity any gaseous impurities or organic particles that may be floating in the atmosphere: this is so much the case, that an analysis of water left standing for some time in any room or locality would furnish an analysis of the atmosphere of such locality.

107. By drinking water which has been exposed in an unwholesome atmosphere, the impurities with which such atmosphere abounds are thus introduced into the system, and often in a highly concentrated form; for the quantity of gaseous impurity which water can absorb is incredibly large. Professor Hoffman, a pupil of Liebig, and the Principal of the Royal College of Chemistry, states that 1,000 gallons of water at the common temperature will dissolve and absorb 46 gallons of oxygen, 25 of nitrogen, 2,500 gallons (two and a half times its own bulk) of sulphuretted hydrogen, (the most fœtid and dangerous of the ordinary gaseous products of decomposition,) 1,000 gallons of carbonic acid, and 500,000 gallons of ammonia. Besides these, it would absorb other dangerous compound gaseous products of decomposition, such as phosphuretted hydrogen, carburetted hydrogen, hydrosulphuret of ammonia, cyanogen, &c.

108. Water also absorbs with avidity the particles of decomposing organic matter which are always present in the atmosphere of crowded towns, which are given out by the lungs, and in the perspiration of animals, and which, when the latter are in a diseased state, are supposed to constitute miasma,* the infectious principle of endemic diseases.

109. The fact of water absorbing organic matter in a state of decomposition from the atmosphere is easily proved by the circumstance of a vessel of distilled or rain water, allowed to stand in a crowded room, becoming the abode of animalcules, for animalcules cannot exist in pure water, and their presence is always a certain proof of the presence of decomposing organic matter, which is their food, and essential to their existence. "Animalcules," says Dr. Angus Smith, "are now generally believed to come from the atmosphere, and to deposit themselves on convenient feeding places; that is, they only appear where there is food or materials for their growth, and they prove, of course, the existence of that continuation of elements necessary for organic life. At the same time, their presence is a proof of decomposing matter, as their production is one of the various ways in which organized structure may be broken up. Such a liquid must, of course, be an injurious substance, giving out constantly vapours of an unwholesome kind."

110. Another proof of the presence of organic particles in a crowded atmosphere is, that if the dew that collects on the glass windows of a crowded

* The commonly received opinion with regard to miasma is that it is animal matter, particularly gelatine in a state of decomposition, floating in the atmosphere, which, when inhaled, communicates a similar state of decomposition to the fluids of the human body, and that putrefactive decomposition is set up in the same manner as the fermentation of bread is excited by yeast. That is Liebig's opinion with regard to the nature of miasma.

room be scraped off and allowed to stand, and examined with a microscope, it is found to consist of a closely-matted mass of confervæ, "between the stalks of which are to be seen a number of greenish globules, constantly moving about, various species of volvox, accompanied also by monads many times smaller."

111. Organic matter exists in the air of ill-ventilated streets in quantities that admit of its being obtained from the air directly. Rogel and others have found organic matter in the atmosphere of towns, and Dr. Southwood Smith, in looking for matter which might produce fever, found an organic substance in the air of some of the streets of London. "These facts show," says another authority, "that the general notions entertained by persons as to the air of towns are not without the support of what is called scientific observation, although, at the same time, the effects on life are greater than chemists by any observations could have made out"; and the fact that the water will absorb whatever the air contains, and that Liebig has demonstrated that the analysis of water which had fallen through the air may be considered as a proximate analysis of the air itself, proves that the Native idea of attributing to a change of water the same importance that we do to a change of air is by no means an unfounded one.

112. The medical evidence taken by the Sanitary Commission regarding the ill effects of drinking water impregnated with organic impurities was unanimous and conclusive. It was stated by all the witnesses that diarrhœa and bowel complaint invariably resulted from the use of such water, and that during the prevalence of cholera "a very large proportion of the cases might be directly and indubitably traced to the use of such polluted water."

113. The General Board of Health report that "the evidence of the powerful influence of impure water in predisposing to the most violent attacks of cholera is indubitable : in all the well ascertained cases of this, the water had unquestionably been contaminated by the contents of the cesspools, sewers, or the like, having percolated into it. Throughout the country, examples such as we shall hereafter have occasion to refer to were so common, and the circumstances so marked to the popular apprehension, as to afford apparent ground for the popular belief in some places that the wells were poisoned."

114. The Registrar General's Report for 1850 also contains tables which prove that in the districts supplied with the impure and unfiltered water of the Lambeth Water Company, the mortality from cholera was greatly in excess of what it was in other districts otherwise similarly circumstanced.

115. In relation to the ravages of the cholera in the South-eastern Districts, Dr. H. Gavin states as follows:—"The connection between foul drinking water and cholera was established by irrefragable evidence. The cases where the connection was most clear were where the parties had been recently drinking water taken from pumps near to, and contaminated by the matter of cesspools ; but wherever the water was contaminated so as to be nauseous, diarrhœa was invariably present, and affected every person in the habit of

drinking such water. I am not aware of any valid exceptions to this law. The most aggravated instance of foul water developing cholera was where a thirsty navigator drank of the Hackney brook, (a common sewer,) and was almost immediately attacked with cholera, and subsequently speedily died. The cases next most marked were those of the 11 persons, out of 22 in number, whom I have already recorded as having perished in a certain square, consisting only of a few houses, where the water was contaminated with cesspool matter. A similar story I have related with reference to the first outbreak of cholera at Fulham. In Hackney, I have shown how that out of 85 inhabitants of one locality who drank of water contaminated with cesspool matter, every one had had, or then had more or less diarrhœa, and that to avoid its excessive filthiness, the whole of the inhabitants of that row were compelled to drink, and use for domestic purposes, the water which ran down the kennel. These are the more marked instances; but the cases where foul water led to the development of cholera were so numerous, that all the visitors under my superintendence united in their testimony as to the influence of such matter in the development of the disease. *I have traced in many instances the unsuspected cause of the development of cholera in the state of the drinking water.*"

116. There can be no doubt but that the use of impure drinking water is attended by the same ill effects in India as in England. I believe there are many districts in Bombay, as well as in London, in which the hitherto "unsuspected cause of the development of cholera might be traced to the state of the drinking water." A low and damp situation, and want of ventilation, have long been known to promote the development of cholera; but this disease often attains its greatest development in this country during the hot season, in which there is no such thing as damp, and in rural villages which are well ventilated. I believe that in such cases the cause will be found to lie in the increasing impurities of the village tanks as the hot weather advances. The small Native village of Byculla is, I think, a case in point. Though a country village, built on ground elevated some feet above high-water mark, it is one of the strongholds of cholera in Bombay, and I can only account for this by the circumstance of its inhabitants drinking the water from the adjacent tanks without filtration, when the advance of the season has caused such water to swarm with animalcules. I think that it should be required by legislative enactment that all tanks used in India for drinking purposes should be provided with filtering draw-wells.

117. I shall now proceed to consider the natural means by which water is purified from organic impurities, and the artificial processes in imitation of those of nature by which the same results are effected.

118. I have already shown how rain water absorbs from the air of towns or jungles deleterious gases, and particles of decomposing organic matter, animal and vegetable, which furnish the food and induce the presence of tribes of animalcules, whose ovæ are always present in the atmosphere; and how the

pollution of the water is thus increased, until in some cases the evolution of sulphuretted hydrogen and other poisonous gases becomes too great to be compatible with the existence of animalcules, or any form of animal or vegetable life.

119. Yet water even in this state of contamination may be rendered again pure and drinkable, by undergoing the natural process of slow filtration. It sinks into the ground, and in percolating through the soil or porous rock beneath, undergoes within a few hours a chemical change, after which it emerges into wells, or from springs, with all its dangerous gases completely destroyed, perfectly purified from the most impure substances, altogether free from all organic matter, and sparkling with carbonic acid gas (that gas which, being dissolved under compression by water, forms what is called soda water.)

120. The process by which these results are effected is analogous to that whereby the blood from the veins of animals is purified, and again rendered fit for its vital functions, by being brought into contact with oxygen in the extensive surface presented by the air cells of the lungs.

121. These filtering media are effective in oxidizing organic matter into nitric acid, and then dissipating such acid in proportion to the amount of surface their structure presents. "The large extent of surface presented by the more porous materials gives an increased facility for oxidation, or rather presents compressed oxygen, so as to be more effective." Thus animal charcoal is at once the most porous in its structure, and the most perfect in its action, of all the filtering media known.

122. The large proportion of organic matter which the water that falls in towns carries with it into the earth is, during its rapid percolation through the ground into the adjoining wells, oxidized into nitric acid. "The formation of this acid in such wells appears," says Dr. Angus Smith, to be "the effect of restricted oxidation, occurring as it does with such excess of organic matter; and although near the surface, still under hard pavement and soil, where there is little flow of water." These nitrates do not occur to any extent in purifying large bodies of water, nor do they occur in filtration through the rocks or sand, as in nature, but they occur in more close situations under streets and houses, and in undrained ground, according as it is saturated with animal matter. "We see that natural filtration, with abundance of room and free movements, dissipates the organic matter, and nitric acid too, if ever found."

123. The presence of nitric acid in the small proportion in which it usually exists in the wells of towns is not known to have any unwholesome effect, and the presence of any acid renders water more palatable. A few drops of any acid (sulphuric acid for example) are used by the workmen in chemical works, to improve the taste of the drinking water in warm weather. The presence of nitrates in town well water has at least one good effect—wherever it exists there is no animal or vegetable growth present.

124. There are two kinds of filtration. In the first species, which is called rapid filtration, the filtering media are very thin, as in the case of the filtering paper of the chemist, and the modes of filtering the drinking water usual amongst the Natives in India. The action of these rapid filters is purely mechanical—in fact only that of a very fine sieve. It makes the water clear, and to some extent purifies it, by excluding mud, and all solid impurities, mineral or organic, which were merely held in mechanical suspension by the water; but it does not deprive the water of any matter *dissolved in it*, or effect any chemical changes whatever.

125. In the other kind of filtration, the filtering medium is not a mere sieve, but a laboratory, in which the most important chemical changes and combinations are effected; and by passing through which, liquid solutions of the most impure description conceivable are rendered perfectly pure and wholesome—1*st*, by being oxidized by contact with the extensive "oxigeniferous surface of the porous filtering medium"; and 2*nd*, by the chemical action of the soil or humus of such medium in arresting, changing, and combining with almost every deleterious, saline, or organic impregnation that impure water can contain in solution.

126. Until lately, filtration was supposed to be a merely mechanical process, only capable of freeing water from substances which were not dissolved, but only mechanically suspended in it. Attention was first attracted to the chemical action of natural or slow filtration by the discovery that the water of the wells in towns contained chemical impregnations never found in wells in the country, and which were discovered to be due to the oxidation of the organic matter contained in the water permeating through the soil of towns. At the request of the Sanitary Commission, extensive experiments have been lately instituted by Dr. Angus Smith, Dr. Arthur Hassall, and Professor Way, regarding the chemical action of certain filtering media in purifying water from chemical and organic impregnations.

127. The experiments were tried with different filtering media, and with every description of impure solution. The apparatus employed were glass tubes of 1½-inch or more diameter, and from 12 to 18 inches in length, about two-thirds filled with the filtering medium, (sand, clay, animal charcoal, &c. &c.) of which the efficiency was required to be tested, and on the surface of which was poured the impure solution to be filtered.

128. The following are some of the experiments tried by Dr. Angus Smith:—The glass tubes were filled with sand, and some putrid yeast, which contained no nitric acid, was mixed with pure water, and poured on the sand, allowing it to filter through. The product of nitric acid was abundant. Charcoal was tried to the same end, but did not answer.

129. Ox-flesh was in this manner oxidized into nitric acid, *after allowing it to putrefy*. This result could be obtained by means of ordinary household filters, if the time allowed were long enough, and other conditions favourable.

The same was done on a smaller scale, by allowing nitrogenous organic matter to stand over spongy platinum.*

130. The following is an extract from Dr. Hassall's account of his experiments:—" Filtration is of two kinds—mechanical and chemical; sometimes both are in action at the same time, and this is generally the case when water passes through soils. I first directed my attention to the mechanical properties of filters, experimenting with the following substances, viz. coarse and fine bibulous paper, wool, sand, vegetable charcoal, animal charcoal, mild and strong clays. It is proper to state that the water employed as a test was green pond water, the colour of which proceeds for the most part from the presence of myriads of *infusoria*, of the genera *microglena*, *cryptoglena*, and especially

* " No doubt," says Dr. A. Smith, " this is a very important provision of nature for the prevention of the evil consequences of putrefaction: it is the complete destruction of all dangerous gases, and the perfect purification of the most impure substances. Whether it be advisable to drink water having much of this oxidized matter in it is another question. We see, however, in this, the two great agents of sanitary improvement at work for us—the air and the water acting through the soil; whatever goes through such an ordeal is made pure. The drainage of a country is therefore that which removes the evil effects of decomposition as well as the excess of moisture.

" The action of air and water on surface is then a powerful one, and probably is capable of doing many marvellous things with the substances given to it to treat. The effect produced on sulphuretted hydrogen is no less decided. A bottle of strong sulphuretted hydrogen was poured upon the sand filter, and sulphuric acid was the result, with sulphates formed of bases which it had washed out of the sand. Sulphuret of ammonium filtered through sand contains sulphuretted hydrogen no longer, and will not blacken lead, so powerful is this kind of oxidation.

" Water from a pump in a yard not far from me gave out a disagreeable smell of sulphuretted hydrogen, which filled the neighbouring houses. This I found the persons who used it were accustomed to filter and to drink. The sulphur was converted into sulphuric acid, and the water was actually made quite pure.

" These are no doubt some of the advantages of a filter; if so, we are then to consider that a filter acts according to its cubic dimensions, and not by its surface only. If the porous rocks have thus the power of oxidizing sulphur and nitrogen, we may then ask, have they not also the power of oxidizing carbon? Hydrogen is no doubt oxidized, the ammonia being broken up so as to form oxides, as nitric acid and water.

" We see that natural filtration, with abundance of room and free movements, dissipates the organic matter, and nitric acid too, if ever formed. The time allowed for filtration being so short, that is the time from the falling of the rain to the appearance of the pure water from the spring, we cannot suppose that vegetation accomplishes the purification, whilst there is no deposit of impurity apparent to account for the change. It seems to me that the action of the compressed air on the surface of bodies is sufficient to answer this question, and that this matter is removed by a process of oxidation. It was Saussure who showed that humus can unite oxygen and hydrogen; Liebig has shown that humus is constantly capable of combining with oxygen, and calls it a constant source of carbonic acid. When, then, we see water not very free from organic matter enter a rock, and come out free from organic matter, and sparkling with carbonic acid, leaving organic impurities behind it, we may safely conclude that the oxidation of the carbon has effected it: this, then, is a higher degree of purification than the oxidation of the nitrogen, which is probably allowed to go free. Processes such as these are going on constantly wherever water is filtering."

euglena. * * * * This water, which was passed through *fine and coarse bibulous paper*, retained a very evident green tinge, deeper through the coarse than the fine paper, and, examined through the microscope, was found to swarm with *infusoria*. Filtered through sand, it possessed an evident green colour, and contained multitudes of animalcules, some of large size. Passed through three different *patent filters*, it also came out retaining some colour and opacity, as well as numerous *infusoria*.

131. "After filtration through *vegetable charcoal* the water entirely lost its green hue, but possessed a certain degree of opacity, and, examined with the microscope, the smaller animalcules were to be detected in great numbers. Passed through *animal charcoal*, the water came out bright and transparent, without colour or opacity, and no animalcules could be discovered in it. Through *loam* the water was still perceptibly green, and contained the animalcules in great abundance. Filtered through *mild* and *strong clays*, the water was nearly as clear and bright as through the animal charcoal, without trace of *infusoria*. By filtration through clay and animal charcoal, the *infusoria* was so far removed that none could be detected by means of the microscope.

132. "The different filtering media were then tested by passing milk through them. (Milk owes its colour and opacity to microscopically minute globules of butter, the complete exclusion of which is the best test of a perfect filter.) Except from the animal charcoal and the mild clay, the milk as it escaped was observed to retain much of its colour and opacity, and this was the case even with that which came away from the vegetable charcoal and the patent filters; that, however, which flowed from the animal charcoal and mild clay, was nearly, but not quite as transparent as pure water, and on microscopic examination the globules of butter could not be detected."

133. Dr. Hassall then proceeds:—"I first passed some recent human urine through vegetable and animal charcoal, loam, and mild clay: passed through the vegetable charcoal, the urine still possessed some colour, and a faint urinous smell; through loam the colour was deeper, and the smell stronger; while through animal charcoal and clay the urine was as clear and as free from colour or smell as the purest water.

134. "Sewer water, holding in solution a large quantity of sulphuretted hydrogen, and of organic matter, emitting an odour in a high degree offensive, was passed through the following substances:—

135. "*Vegetable Charcoal.*—From this it came out free from smell, and colourless, yet evidently somewhat opaque: tested for sulphuretted hydrogen, this gas was not found.

136. "*Animal Charcoal.*—Through this the water escaped clear and brilliant, without the slightest opacity, and showing no traces, on the application of tests, of the presence of sulphuretted hydrogen.

137. "*Patent Filters.*—Passed through these the water passed with a

slight tint of colour and opacity only, but furnished evident traces of the presence of the gas in question.

138. "*Loam.*—From this the water came out in scarcely so pure a condition as from the filters, and also contained sulphuretted hydrogen.

139. "*Mild and Strong Clays.*—Through these the water passed as clear and transparent as through the charcoal, but yet was found to furnish distinct evidences of the presence of the gas. The sewer water, tested for sulphuretted hydrogen before being passed through a filter, gave with lead a dark brown precipitate; while after having been filtered through the patent filters, loam and clay, the colour of the precipitate was of a light brown.

140. "It is therefore evident that all the above filtering media are, to a greater or less extent, chemical; and that while some of them absorb the whole of the sulphuretted hydrogen, others retain only a portion of it. Most of the patent filters are made with a certain amount of animal charcoal, and hence their chemical properties. Now, although the water employed in these experiments was sewer water, yet the same proportional effects would follow the use of any water containing sulphuretted hydrogen. Again, Thames' water, known to contain sulphuretted hydrogen, was passed through the same media, and, when tested for the gas, it was found in all the filtered waters except those which had come through the animal and vegetable charcoal.

141. "Water highly saturated with carbonic acid was passed through the same media as the sulphuretted hydrogen. After filtration through animal and vegetable charcoal, a trace only of carbonic acid was to be discovered. The water filtered through loam and mild clay contained the gas abundantly, but yet in much less quantity than previous to filtration. After passing through the patent filters, the water gave distinct evidences of the presence of carbonic acid, but in less amount, apparently, than that from the loam and clay."

142. For the removal of sulphuretted hydrogen, charcoals, especially the animal, are best: animal and vegetable charcoal, loam, and mild clay, all remove the greater part of the carbonic acid present in water, the two latter abstracting, likewise, its carbonates.

143. The worst mechanical filters are in general the quickest filters, while the best are the slowest in their action: of the more perfect filters, animal charcoal is the quickest.

144. It is worthy of observation, however, that the absorbing power of substances for gases is to a great extent independent of size: thus coarsely powdered vegetable charcoal will take up gases equally well, if not better, than when reduced to a very fine state of division.

145. The following is an abstract of Professor Way's experiments:—

Having partially filled his tubes with the various filtering media under examination, he poured upon their surface strong solutions of different alkalies, and alkaline and earthy salts. He found that the first portion of the liquid which came through was absolutely deprived of them. Thus, for instance, a solution of caustic potash, or of ammonia, containing one per cent. of either alkali, was made to filter through 9 inches of a soil contained in one of the tubes just mentioned: from one to two ounces of liquid passed through quite pure, or free from the substances in question.

146. The time occupied in the percolation, when the depth of the filtering bed was 9 inches, was from 8 minutes to an hour or an hour and a half. In these cases the abstraction of the alkaline substances was complete. In order, however, to ascertain whether a sensible time was necessary for the effect, he forced the liquid in one experiment through the soil by means of a syringe, with precisely similar results, although the soil and the solution were in contact less than a minute.

147. These experiments were with substances *dissolved,* not merely mechanically suspended in water: the action described is therefore different from ordinary filtration. Professor Way believes it to be purely a chemical action, and that the different alkalies are absorbed in the relation of their chemical equivalents or combining proportions.

148. The alkalies potash, soda, and ammonia, in their caustic state, or in the state of carbonates, are absorbed by soils; in the case of all other salts of these alkalies, such as their sulphates, muriates, or nitrates, the *base only* is arrested, the acid of the salt passing through in combination with lime derived from the soil.

149. Besides the caustic or free alkalies, the soil had the power of removing from solution the carbonates of these bases, and that without introducing into the liquid any corresponding salt of lime. In the same way, lime, when dissolved in water, as it exists in *lime-water*, which is a solution of caustic or free lime, is entirely separated by filtration through a soil. "*Carbonate of lime, also, when dissolved in water by means of carbonic acid, is entirely removed by passing the water through an ordinary soil, or through a pure clay.*"

150. Besides experimenting on the filtration of water containing salts and other mineral impregnations, Professor Way's experiments extended to various organic solutions. He passed various animal and vegetable solutions, such as stinking cow's urine, sewer water, putrid human urine, the water produced by the steeping of flax, &c. through filter-beds of soil, and when passed through they were found to be entirely deprived of smell and taste, except an earthy smell derived from the soil. These solutions were highly offensive, and coloured, yet the liquid dropped from the filtering soil so colourless and inoffensive that it might be tasted without disgust.

151. As in the case of the absorption of potash, ammonia, &c. by soils, this deodorizing process can be effected without filtration, by simply stirring up the liquid and the soil together: when this latter subsides, the solution will be found colourless, and devoid of smell and taste. In the surface distribution of sewer water by jet or hose, all trace of smell disappears in half an hour

after the manure has been applied to pasture land. He attributes the effect of soils upon organic matters to the clay contained in the soils.

152. Professor Way further states, that by filtration of the water of rivers containing salts, giving hardness, and different animal and vegetable matters in solution through a bed of soil, he removed all these, (with the exception of those salts of lime before enumerated, and such other salts of lime as were formed from alkaline sulphates, muriates, and nitrates,) and produced comparatively pure water; and that in this way he reduced Thames' water of 15 degrees of hardness (15 grains of carbonate of lime in the gallon) to less than 2 degrees of hardness, and rendered it soft and pure.

153. It will be remarked in these experiments that sand is by no means the most powerful filtering medium *in proportion to its bulk*, and that in many of the foregoing experiments results were obtained with clay and animal charcoal filters far more perfect than could be produced by *an equal thickness of sand;* but it must be remembered that these experiments were tried with a thickness of only 9 inches of sand, and that in filters of the most recent construction for purifying the water supplied to towns, an aggregate thickness of 12 feet of filtering media is provided.

154. The following remarks of Dr. Angus Smith, regarding the efficiency of sand as a filtering medium, are worth quoting :—"The power of sand to purify water is really very great. I tried a few experiments upon it which I may as well mention. A strong alkaline solution of peat was made and passed through sand : the water came through clear, retaining only a taste of the earthy portion of the sand. The solution was strong enough to show colour through the twentieth part of an inch. Adding acetic acid to this ammoniacal solution until it becomes acid gives an acid solution of peat ; it is precipitated by some acids. This solution came through the sand equally clear. In both instances the matter was in perfect solution. As the action does not refer either to acids or alkalies, it seems probable that there is here an action independent of the ordinary chemical affinities; but as far as the purifying of water is concerned, it is enough to know that it is a fact that pounded bricks acted equally well, also oxide of iron and oxide of manganese.

155. "It would not be correct to say that sand is the most powerful filterer in proportion to its bulk ; it is too coarse generally to act, except when there are large quantities, and other substances purify the water, using much smaller quantities. It is, however, so general, and it is used in nature for purifying water so frequently, that it deserves most attention. The sand requires to be of considerable thickness, at least so that the water does not run too fast off, but at the same time nearly all the impurities removed will be found on the surface of the filter.

156. "In order to try the effects of filtration, I used strong sulphuric acid, in which pieces of wood had been soaked, so that it was exceedingly black, thinking by the strength of the acid to overcome all action which a filter

might have, but the acid came through very pure, and left the upper part of the filter with a dark film, where all the colouring matter had been deposited. The same was tried with muriatic acid, which had been rendered impure by some vegetable matter, and which did not deposit by any amount of mere standing: the acid came through brilliant.

157. "Percolation through a porous stratum is capable, in fact, of removing any amount of organic impurities from water, as the universal admiration of spring water sufficiently shows, and this removal of the organic matter, which is an objection to surface water, has generally been considered a sufficient compensation for the inorganic matter and hardness which it has acquired in the process, by going down to great depths, and remaining a long time. It is true, that to remove the last traces of organic matter seems to require that the percolation be continued a considerable length of time or space: it happens here, as in other cases, that the purity is according to the extent of the process of purification."

158. The most efficient filtering media for the bulk are animal charcoal and clay. Mr. R. Thom, an Engineer, who has paid much attention to the subject of water supply, used to mix animal charcoal "ground to the size of coarse meal" with the sand of the upper 6 inches of the filters constructed under his directions, but he states that he has subsequently found a species of friable trap rock (amygdaloid) a perfect substitute for the animal charcoal; and amygdaloid is the staple rock of Western India.

159. Clay, though experimentally equal to animal charcoal, is found inconvenient to use, as it is liable to muddy the water that passes through it. Burnt clay is, however, free from this objection, and stated to be otherwise equally efficacious. It is probable the amygdaloid owes its efficiency to its similarity to burnt clay.

160. I have given in a note the details and description of the self-cleaning water filter constructed by Mr. Thom, and those of the most recent filtering apparatus constructed at the Gorbal's Gravitation Company, on a plan suggested by Mr. Smith of Deanstone, and found to answer extremely well.* The

* The filtering apparatus by which the water of rivers is rendered fit for drinking purposes is precisely similar to that employed in purifying that obtained from surface collection; and the distributary appliances by which the water supplied from any source for town consumption is rendered available to the wants of the inhabitants of each house in the district supplied, and for the extinction of fire within it, are the same, whether the water be obtained from springs, from rivers, or from surface collection.

The filtering apparatus, by which the water derived from rivers or surface collection is rendered fit for drinking purposes, is variously constructed.

The following is the construction adopted by Mr. Thom, an Engineer of much experience in works for the water supply of towns (the date of his evidence being 1844):—

"*Mr Thom's Self-cleaning Filters* (1844).

At Greenock, Paisley, and Ayr "I have erected *self-cleaning filters*. The filter that I have erected at Paisley is 100 feet long and 60 broad, divided into three compartments, which may constructional details of the Gorbal's filter are shown in Drawing I. accompanying this report.

161. The microscope is now much used in England as a test of the purity of drinking water: "it displays differences in water that chemistry cannot detect."

This method has been successfully followed by the eminent microscopists Dr. Hassall, Dr. Lancaster, and Dr. Redfern.

either act together or separately at pleasure; so that when one compartment is cleaning the other two continue in operation. The site of the filters is on a piece of level ground, excavated to the depth of 6 or 8 feet, with retaining walls all round joined with cement, and puddled behind, so as to be perfectly water-tight. The bottom is laid about a foot deep, with strong stiff puddle, over which pavement is laid, cemented so as to be impervious to water. The whole of this bottom is then divided into drains or spaces, 1 foot wide and 5 inches deep, by means of fire-brick laid on edge, and covered with flat tiles of the same material, perforated with small holes, like those used in a kiln for drying oats. These holes are placed very near each other, and are rather more than a tenth of an inch in diameter. There is also a space of a quarter of an inch left open between the ends of the bricks, which support the perforated tiles, and their upper edges are little more than an inch broad, in order that there may be little or no space without holes, and nothing to prevent the water spreading equally over every part of the bottom of these drains. This is particularly necessary when the filters are cleaning by the upward motion of the water. The perforated tiles or plates are covered to the depth of an inch with clean gravel, about three-tenths of an inch diameter; this is to be followed with five other layers of gravel, each of the same depth, and each succeeding layer a little finer than the previous one, the last being coarse sand. Over this there is placed 2 feet deep of very clean, sharp, fine sand, similar to that used in hour-glasses, but a very little coarser; and about 6 or 8 inches deep of this fine sand, nearest the top, is to be mixed with animal charcoal, ground to the size of a coarse meal, each particle about one-sixteenth part of an inch in diameter. The proportion is one part of charcoal to 8 or 10 of sand. There is a longitudinal drain or pipe between the filter and the pure water basin, communicating with both, and on each of the openings between this pipe and the filter there is a stop-cock, to close the communication when necessary. There are also two drains to carry off the foul water when the filters are cleaning, and another to prevent the water from rising too high in the filter. When the filter is complete, its action is as follows:—The sluice and the valve are opened, and the water permitted to flow through the filter into the drain below, until it becomes quite clear. This will take two or three days when first set to work, unless very great pains is taken to wash the gravel and sand before they are put into the filter. The filter will now flow copiously for some weeks (longer or shorter, as the water may be more or less turbid on entering it); and when the quantity passing begins to fall off, the stop-cocks are shut, and the valves are raised. The water then enters *below*, and fills all the drains; and, having a head pressure of several feet, it will force its way *up* through the sand to the top, and in its passage raise the scales or particles of mud which have been deposited in the downward passage, and carry them into the foul-water drain below. If the sand at the surface is stirred by a fine-toothed rake, after the water has been thus raised above it, and a little additional water admitted on the top through the conduit, it will facilitate the operation of cleaning, as the mud is always deposited on the *very surface of the sand*. By this means the sediment will be carried off, and the water pass through quite clear again in a few hours; the valves should then be lowered, the stop-cocks opened, and the operation of filtering will again proceed as above described. The cost of this filter was under £600, and the quantity of water produced *regularly* every 24 hours is, on the average, 10,632 cubic feet. The expense

162. It is stated that the occurrence of the vegetable species and animalcules in question is an infallible proof of the presence of organic impurity in its worst stages, that is in the act of putrid decomposition, or in the course towards this consummation. These plants and animals feed upon the remains of other plants and animals, and cannot subsist upon mineral matter alone. Water is not perfectly pure if a single living being can live and procreate in it, and in proportion to the abundance of life is the amount of the impurity.

163. Moreover, in addition to the mere number of creatures that can be maintained on the foreign matters present in water, Dr. Hassall has pointed out the fact that " particular species of creatures belong only to certain degrees and circumstances of pollution, so that the occurrence of a single specimen of such species stamps the character of a water at once.

164. " There is a certain stage of pollution attained in sewer water which is fatal to animal life, and, consequently, where animalcules cannot be detected. The poisonous gases (sulphuretted hydrogen, &c.) which make part of the contamination complained of in polluted water are in this case too strong and too highly concentrated for any species of living beings to exist in the midst of them: dilution must take place before life can begin to appear."

165. The method of testing the purity of drinking water by the microscope is thus described in the " Quarterly Journal of Microscopical Science" for October 1852:—

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of a filter, therefore, to give a supply of water of the best quality *for family purposes*, to a town of 50,000 inhabitants, may be safely taken at £800. From often finding pure spring water in the moors, where the soil for many miles was composed of peat or moss, I suspected there was some substance in the earth which, by combining with the tannin or colouring matter, rendered the water pure; and this was proved to my entire satisfaction by a careful inspection of the minerals in the hills above Greenock. I there ascertained that the moss water, by flowing over or through a particular species of lava or trap rock, (amygdaloid, the most common rock of Western India,) became fine spring water. Since then, I have used the substance as a substitute for charcoal, with perfect success and much economy. A very large proportion of the hills above Greenock being composed of this substance, it may be had at a nominal price.—(For details and figures of this filter, see Cresy's Encyclopædia of Civil Engineering, page 1212.)

Mr. Smith of Deanstone's Filter.

At the works of the Gorbal's Gravitation Company (for the details of which see Drawing I.) the adoption of a filter on an entirely new plan, suggested by Mr. Smith, of Deanstone, has been attended by the best results. The construction is as follows :—" Three filters are provided—the uppermost composed of rough stones, from the size of a hen's egg and upwards, taken from the bed of a stream, where the water is allowed to rest as long as possible; and by the laws of gravitation these stones attract the light particles floating in the water, which are now seen to increase the size of these stones: it then passes into a second filter, made of coarse sand, or pebbles about the size of a common pea, and smaller, which intercepts the gross particles; and lastly passes to a filtering bed of fine sand; and the consequence is, that the water is not only perfectly pure, but the fine filter, which otherwise would have required washing once a week or so, works for six weeks or two months without the sand being removed to be washed and cleaned." These three filtering beds, and the pure water basin, are in duplicate, either set of which can be worked while the others are being cleaned.

"The mode of proceeding was to take half a gallon of the water to be examined, and, after allowing it to stand for a few hours, to decant the clear liquid from above till about half an ounce remained. A drop of this was taken up by a peppet, and examined under the microscope. It would appear from these reports, that in proportion to the absence of inorganic and organic matters in a state of decomposition is the water free from microscopic plants and animals. Great differences in these respects are presented by the water examined. Thus in the river Dee and the Walford water, scarcely a living organism was found, whilst in the Thames and New River waters above seventy species have been identified by the reporters."

166. The popular idea that all water contains animalcules is incorrect: the water of springs and deep wells is generally altogether free from any contamination of the sort. The specimens of water usually exhibited by the oxyhydrogen microscope, &c. are always taken from the *residue* of very *impure water*.

167. For drinking purposes it is prudent in this country to boil water, even though it has been already filtered: the heat of boiling water destroys the vitality of any ova which may have pased through the filter, and, by arresting decomposition, destroys any miasma the water may have absorbed. Thus water taken from jungle streams should always be boiled before drinking.

168. Dr. Hassall has found by experiments that the combined influence of light and air favour in a high degree the growth and development of the lower forms of animal and vegetable life, also that the influence of warmth is very great in producing the same results.

Thus it follows that to preserve water from such contaminations it should be protected from heat, light, and air, and that therefore all storage reservoirs should be covered, to prevent the growth of vegetation.

169. When water is stored in reservoirs of too large a capacity to be roofed, their depth should be sufficient to prevent the growth of vegetation from the bottom. From 10 to 15 feet is stated by Dr. Hassall to be the minimum found to answer these conditions in a temperate climate, and the deeper the better, " for the greater the depth of water, the less surface in proportion would be exposed to light, heat, and the circumstances favouring development."

170. Having now described the appliances whereby water derived from river or running streams (the first of the three sources of supply enumerated in paragraph 1) is rendered available to the wants of a town population, and also the contaminations, and the purifying and distributary apparatus common to all three such sources of supply, I shall now proceed to consider the two remaining sources, spring or well water, and surface collection or rain water.

171. *Spring Water.*—Spring water is rain water, that sinking into the ground, percolates and saturates some porous stratum beneath, which in some cases is called the water-bearing stratum: if this porous stratum rests on one of clay or impervious rock, on a section being made through both strata (as often

occurs naturally in valleys or undulating country) the water with which the porous stratum is charged gushes out, and is called a spring.

172. If there is no natural section, an artificial one may be made, by sinking a well through the porous strata until it reaches the depth at which the water stands on the impervious sub-stratum. In Bombay the water-bearing strata are moorum or laterite, and a littoral concrete, the former resting on a retentive stratum of rock, the latter usually on one of clay.

173. In some cases the arrangement of the various strata is such as to convey to one locality, in the shape of springs, water which has fallen as rain over a wide extent of country many miles distant. If the latter districts are at a higher level, such springs have of course a tendency to rise towards the same level; and if they are kept down, as is often the case, by the superposition of an impervious stratum of clay, on piercing through this to the water-bearing stratum below the water will gush up like a fountain. This is what is called an artesian well.

174. Some springs continue to flow all the year round; others become exhausted after a continuance of dry weather. Perennial springs are of course much more rare in countries where, as in India, a short rainy season is succeeded by many months of continuous dry weather, than in countries situated within the zone of constant precipitation, in which the rain fall is distributed over the whole year.

175. Spring water, when it can be obtained tolerably soft, and free from mineral impregnations, is the best source from which a town can be supplied with water. A recent authority on the subject writes as follows :—

176. "The greatest blessing that can happen to a town is to have an abundant supply of soft water from springs. Spring water being always free from organic impurity, having an even and admirably adjusted temperature throughout the year, and being well aired and of sparkling brightness, it requires only the addition of the quality of softness, and freedom from saline matters generally, to make it absolute perfection for every ordinary purpose of water.

177. "In every case of the public supply being from surface drainage or rivers, the springs and wells of the town should be religiously preserved, and made available for the drink of the population. This precaution was generally overlooked when the new method of extending pipe water to every house was first introduced in towns; but after a few years' experience of river supplies, attention is again directed to the preservation of the wells as the only sources of a pure and exhilarating beverage, unaffected by the vicissitudes of the seasons. It is not possible in the summer months to obtain a water of the proper coolness, and free from vegetation and animulcules, except from springs."

178. I have already stated that a considerable portion of the population of Bombay obtain their drinking water from the springs of our sandstone and

laterite formation, and that our existing supply of spring water is capable of being much extended; and I mentioned at the same time, as an instance of an extensive source of spring water having remained undiscovered for years in the neighbourhood of a great city, that the General Board of Health had recently demonstrated the practicability of economically supplying London with deep spring water from sources (the Bagshot Sands) that had escaped the notice of the previous Parliamentary inquiries of 1810, 1821, 1827, 1828, 1834, 1840, and 1845, regarding the water supply of the metropolis.

179. I shall now describe the works proposed for rendering this supply available to the wants of the metropolis, as an instance of the engineering works required when a town is supplied from spring water. Several small towns in England, Rugby for example, are already so supplied; but I have selected the works proposed by the General Board of Health for the supply of the metropolis as being on a larger scale, and having been recently designed. I shall first describe the formation in which these springs occur.

180. The Bagshot Sand formation covers a considerable area of land, about 20 miles distant from London.

The composition of this series is remarkably uniform: it is described as consisting of three beds—

(a) The upper portion consisting of pure silicious sands. These sands are from 200 to 300 feet in thickness.

(b) Beneath these sands is a retentive stratum of marsh and clay, varying from 5 to 15 or 20 feet in thickness.

(c) The lowest, consisting of white and pale yellow sands, purely silicious for the most part.

181. Over the areas of the upper and lower sands much rain water is absorbed as fast as it falls. That of the upper sand is thrown out, and collected over the surface of the retentive stratum *(b)*. At the junction of the two all the streams and streamlets take their rise, and this same retentive stratum, where denuded, supports the watercourses and ponds of the district.

Water also collects on the surface of the upper and lower sands, where argillaceous beds occur.

182. The water derived from these sands had previously been known to be remarkably soft, specimens of it varying from 3 to 6 degrees of hardness; but it was not supposed that it existed in quantities sufficient for the supply of the metropolis, without having recourse to the surface drainage as well as to the spring water.

183. In consequence of a report, however, made to the Board by the Honorable William Napier, who examined the ground at their request, which report set forth the abundance of spring water of not more than 2 degrees of hardness, and the greater part of it of less than 1 degree, the Board directed Mr. Rammell, one of their Engineering Inspectors, to make a fresh gauging of the springs.

184. The result of Mr. Rammell's gauging fully confirmed that of the Honorable William Napier. He found that the minimum available yield (during the driest weather) of the deep springs of the district might be estimated in round numbers at 61,000,000 gallons daily, of which quantity 51,000,000 have been ascertained by Mr. Napier not to exceed 1 degree of hardness, and the remaining 10,000,000 is considered by him to be under 2 degrees of hardness.

185. The means by which it is proposed to render this supply available to the wants of the metropolis are as follows:—"A series of earthenware pipes, of the aggregate length of 816,640 yards, and varying in diameter from 2 to 24 inches, are to be laid up to the very sources of the springs, and are to be so arranged as only to receive their least flow, the surface water being allowed to pass away without contaminating the source of supply. These pipes are to be laid at a depth of 4 or 5 feet, and carried to the outfall along the natural slope of the country, thus increasing to a trifling extent the distance, but avoiding works of masonry, and interference with the surface.

186. "From the system of pipes the spring water will be conducted through a large double brick culvert to a covered adjusting or distributing reservoir on Wimbledon Common, (containing 200,000,000 gallons, or 4 days' supply,) and thence iron mains will be laid down to connect such reservoir with the present street-water pipeage. A pumping engine will be placed near the reservoir to pump up to the requisite head the water required for high service in the most elevated districts of the metropolis.

187. "The estimated cost is as follows:—

Collection	£40,000
Conducting to service reservoir on Wimbledon Common, in a double brick culvert, 24 miles, at £7,000 per mile	168,000
Covered service reservoir to contain four days' supply, at 50,000,000 gallons per day	80,000
Estimate of expense of mains to connect the reservoir with the present street pipeage	200,000
Probable amount of compensation for mill-owners, irrigation, &c.	100,000
	£588,000
10 per cent. for contingencies	58,800
	£646,800

"This is exclusive of the expense of the pumping engine, and which it is supposed will swell the amount to about £725,000."

188. It will be remarked that this estimate does not include the cost of the street pipeage and distributary apparatus, as it is proposed to use those already laid down belonging to the existing companies.

189. There can be no doubt but that were the metropolis to be supplied *de novo*, the Bagshot Sands would be the best source of supply; but the capital invested in the works of the existing London water companies is so large (£4,860,000) that there is little probability of the plan recommended by the General Board of Health being caried into effect. In quantity the supply furnished by the present companies is ample, and by proper filtration, and the use of Clark's patent process for softening water, its quality might be rendered all that could be desired; and these essentials, as well as the adoption of the continuous and high service system of supply, and a system of charges regulated by the consumption of each consumer, as ascertained by water-meter, might be secured by legislative enactment.

190. *Surface Collection.*—I have selected the works of the Gorbal's Gravitation Water Company, near Glasgow, for an example of the engineering works requisite when a town is supplied with water by collecting in large reservoirs the surface drainage of any adjacent valley. It has been proposed to supply Bombay in this manner, by damming up (near Vehar) the head of the valley (that of the Gopur river, of which valley the island of Bombay forms the prolongation).

191. For supplying a town on this system, any valley or valleys debouching on such town should be traced upwards, until some natural basin is found at sufficient elevation above the town, in which a sufficiently large body of water might be collected (from surface drainage), and retained in storage reservoirs, by a moderate amount of embanking.

192. In determining the position of such reservoirs, the propriety should be kept in view of so arranging them as to admit of extension from time to time, as the demand might increase, by the construction of additional reservoirs on ground still more elevated, either in the same or adjoining valleys, whereby the additional supply could be drawn into the lower reservoirs, and thence into the filters. This is a matter of essential importance, when towns are rapidly increasing in population. By this arrangement, also, (see figs. 1 and 2, Drawing I.) the water settles, and deposits its sediment in the upper reservoir, and enters the filters in a comparatively pure state.

193. For securing these objects, as well as for accurately ascertaining the contents of the reservoirs, contoured surveys of the sites are of course essential. The reservoirs should be as deep as possible, in order to maintain the water at a low temperature, and to prevent the breeding of animalcules, and the growth of aquatic plants. The latter, at a less depth than 12 feet, are found "to grow and accumulate very fast," even in temperate climates.

194. In order to provide for the loss from evaporation, (amounting, even at Greenwich, to more than 5 feet a year,) and on account of the enormous waste from the leakage of the innumerable joints and cocks of the distributing apparatus, (which wastage usually far exceeds in amount the actual consumption,) the amount of water that has to be provided and delivered per each

consumer per year is very great. At Paisley, the delivery amounts to 45 gallons per head per day, or 16,425 gallons per head per year. At Glasgow, the delivery is 32 gallons per head per day, or 11,680 per head per year. In India, the rainy season is but once a year, and the capacity of the reservoirs must be therefore fully sufficient to contain *the whole year's* consumption and evaporation. In Great Britain, rain falls into the reservoirs constantly, and a much smaller proportion of storage room is sufficient. At Paisley, there is storage room for only about one-half of the annual delivery, and at the Gorbal's water-works for only about one-third.

195. The embankments should be puddled, and faced on their inner slope with rough stone.

196. Figs. 3 and 4 Drawing I. represent the contrivances by which the water is drawn from the upper to the lower reservoirs, without disturbing the sediment. The water is drawn from the lower reservoir at three different heights, through inlets in the tower. Fig. 5 exhibits the lower reservoir in connection with the tower, self-acting and regulating sluices, the filter, and pure water basins.

197. The filter and pure water or distributing basins should be roofed, to protect their contents from the deteriorating influences of light and heat: both filter and pure water basins should be in duplicate sets, to allow of one being cleaned while the other is at work.

198. By means of the self-acting sluices, the water in the distributing basins is always kept at the same height, whether the draft of the town be great or small.

199. In Scotland it is found necessary (for keeping the water cool) to lay the pipes at a depth of at least 8 feet below the surface. In India the depth should be greater.

200. The population supplied by the Gorbal's Gravitation Water Company is 75,000, and the cost of the works (exclusive of house service) was £110,000, or £1 9*s*. 4*d*. per head. The cost of the Paisley water-works was £1 10*s*. 6*d*. per head. The average cost of the works of the nine water companies supplying London was £2 8*s*. 7*d*. per head. (The larger the number supplied by a single set of works, the smaller will be the cost per head.) The cost of superintendence to the Gorbal's Water Company (supplying a population of 75,000) is £900 per annum. Of the Paisley Water Company, supplying 40,000, £600 per annum.* The works of the Gorbal's Gravitation Company have been pronounced the most perfect, and the most economically constructed in Great Britain. The accompanying sketches are from the plans of Mr. Gale, the Engineer by whom they were constructed ; similar works have been or are being erected, for the supply of nearly thirty other Scotch towns. The Gorbal's reservoirs are 5¾ miles distant from Glasgow : the proposed Vehar reservoir would be 14½ miles from Bombay.

201. Before discussing in detail the project for supplying Bombay with

* This low rate for superintendence is due to the works being on the gravitation principle ; there are no steam-engines to attend to.

water from Vehar, I shall in the first instance proceed, as premised in paragraph 6, to describe the state of the water supply of Bombay both from springs or well water and from surface collection, and the extent and nature of the deficiency experienced towards the close of very dry seasons; and then proceed to point out the means that have been or might be adopted for rendering our existing supply of spring water more extensively available than at present, or of obtaining an additional supply from the springs on the eastern coast of Salsette; and also the plans that should be adopted for improving the quality of the existing supply of water derived from surface collection, and the means by which the quantity also of such description of supply might be increased, either from sources within the island, or from Salsette, comparing the means adopted or proposed in each case with those in use under similar circumstances in European towns.

202. To illustrate this portion of the subject, I have prepared the accompanying skeleton map of the southern portion of Bombay. (Drawing No. II.) The physical conformation of this portion of the island is generally described in the columns of letterpress printed at the bottom of this map.

203. The geology of the southern portion of the island, as far as relates to its water supply, is briefly as follows:—

From Fort George northwards to Mazagon, the water-shed of the eastern side of the island is composed of a mass of trap rock, varying from 16 to 80 feet in height above high-water mark. The wells in this portion of the town (which comprise the suburbs of Mazagon, Oomercarry, Mandvee, and the eastern portion of the Fort,) are generally mere reservoirs of rain water. Springs are occasionally met with, but the majority of them are very brackish immediately after the rains, and become quite salt before the end of the hot season.

204. The trap formation I have mentioned has its line of water-shed very close to the harbour margin, and after gradually declining towards the west for about 350 yards, it again dips beneath the surface, and is overlaid by a porous stratum of moorum or laterite; this is in its turn being covered up by a thin stratum of stiff clay, known as the lagoon formation.

205. The moorum formation is very porous, and the rock on which it rests is generally impervious and retentive: the moorum is consequently a water-bearing stratum wherever it attains any depth. From being generally below high-water mark, and having been until the present century continually overflowed at high water, it is in many places so impregnated with salt as to render the water stored in it of little use. The salt is, however, being gradually washed out of the lower portion of it, and the upper has always contained sweet water. Along the bottom of the eastern escarpment of the Malabar Hill ridge, from Chowpatty to the Breach, this moorum formation contains the best wells in the island.

206. In the Market, Dhobee Tulao, Girgaum, and Chowpatty Sub-divisions, the retentive clay stratum known as the lagoon formation sinks below the surface, and is overlaid by a highly porous formation of littoral concrete. This

contains (for so shallow a formation) an enormous quantity of water, and is riddled with wells: these wells are not sunk quite down to the lagoon formation, for fear of reaching salt water. In Candywadee Lane, near the north extremity of the Dhobee Tulao Sub-division, I last year sunk a large well through the littoral concrete and lagoon formation into the moorum beneath, and found the water in great quantity, and perfectly fresh; this, however, was probably an exceptional case.

207. In sinking wells in many parts of the island (particularly at Mazagon, Byculla, and the New and Old Town Districts,) though springs are to be expected, it is quite a lottery whether those reached will be salt or fresh: there are many instances of two wells in the same garden, and within 40 yards of each other, containing, the one good water, and the other water too salt to use. Sometimes the salt is merely an impregnation in the soil, which becomes washed out after the well or tank has been drawn for a few years, and the water then becomes sweet. Salt springs are very troublesome in sinking wells about Mazagon, and along the eastern side of the island, but I am not aware of any having been met with in sinking the few wells that have as yet been dug along its western coast.

208. On the accompanying plan, the public wells are represented by black dots: their number and position is reduced from actual survey, but their size exaggerated, for the sake of distinctness. The tanks and Fort Ditch are also shown in black, but their size is not exaggerated.

209. The private wells are not shown. There are few good Native houses without one; but of course such private wells share the defects of the public ones in the same neighbourhood. Native houses of the first class have sometimes extensive reservoirs beneath them, in which the rain water collected from the roofs is preserved, and it is to be regretted that this practice is not more general.

210. The wells in Colaba are with one or two exceptions in trap rock, like those of the Old Town, and are generally little more than reservoirs of rain water, drying up (if drawn upon) as the season advances.

211. In point of number, the wells and tanks of Bomby are amply sufficient, if they were but available to public use all the year round; but they are not so. For some time after the monsoon the supply of water continues abundant in quantity in all the wells and tanks, and, except in the latter, of good quality; but as the season advances, the majority of the wells, and many of the tanks, dry up, and the water remaining in the latter becomes too contaminated with organic impurities to be used with impunity for drinking purposes without filtration; and I believe that this impure state of the water in the public tanks occasions a considerable amount of disease and mortality, which might be prevented by providing each tank with a filtering draw-well.

212. Water is always abundant in the wells in the littoral concrete of Chowpatty, Girgaum, and the Oart Districts, in those on the east side of the

Esplanade, and in many wells in the Fort; but towards the end of the dry season the Old Town and New Town Districts mainly depend for their supply of water on under-ground aqueducts, which convey the spring water of the Oart Districts to reservoirs at Duncan Road, Poydownee, and Musjid Bunder; and this scarcity of water occasions much inconvenience; yet at the close of the worst dry season there is no part of these districts more distant than 400 yards in a direct line from some abundant and unfailing source of supply. This is the present limit of the deficiency in seasons of scarcity.

213. In such a dry season as that of 1850, the poorer classes in the New and Old Town Districts have to go further for their water than usual, and the wells in use are often inconveniently crowded. The water sellers reap an abundant harvest. Under such circumstances they draw water gratuitously from the public wells in the Oart Districts, and sell it at an unwarrantable price to those of the upper and middling classes whose private wells have dried up.*

* The failure of the monsoon in 1850 occasioned a scarcity during the hot season of 1851 more severe than any that had occurred since 1824. The following return of the state of the water supply of the various Police divisions of the island on the 1st of June 1851, which I forwarded to the Board at the close of the hot season, when the scarcity was at its worst, will show the proportion of sources of supply to population under the most unfavourable circumstances:—

	Population.	No. of Wells and Tanks of Sweet Water still in use.	No. of Wells and Tanks of Brackish Water.	
A Division.				Exclusive of the Esplanade wells under charge of the Garrison Engineer, which supply the A, B, and C Divisions to a considerable extent.
Fort..........	75,864	20	2	
Lower Colaba..	6,467	8	3	
Middle Colaba } Upper Colaba }	3,878	8	2	
		3	..	
Total..	86,209	39	7	
B Division...............	233,345	3	5	
C Division.				
New Town .. } Old Town .. }	136,345	1	..	
		23	1	
Total..	136,345	24	1	
E Division.				
Mazagon	5,203	2	1	
Parell..........	4,894	6	..	
Sewree	2,485	6	..	
Mount	1,243	1	1	
Commattee Poora and Tarwaree..	38,204	..	..	
Total..	52,029	15	2	

The scarcity of 1851 led to a considerable increase in the number of perennial sources of supply.

214. I shall now proceed to point out the means that have been or might be adopted for rendering our existing supply both from springs and from rain water more extensively available, and of better quality, than it is at present, and the means by which its quantity might be further increased, both from sources within the island and from Salsette.

215. From my account of the existing state of our water supply, and from the accompanying map, it will appear that our tanks and wells are very numerous, and yield a supply sufficient for the present demand for some time after the monsoon; but that the evil to be provided against is the rapid diminution of the number of available sources of supply as the season advances, and that the objects to be kept in view in expending money on improvements of this class is, not to add to the number of tanks and wells that at present fail in the hot weather, but to increase the number (at present far too small) of *sources of supply continuing available to the close of the hot season*, and to improve by filtration the quality of water in our tanks.

216. The means that have been or might be adopted for increasing the number of perennial sources of supply in the districts at present worst off for water are as follows:—

217. 1*st.*—By bringing in through pipes the spring water of the Oart Districts to a greater extent than at present. The recently constructed reservoir at Poydownee, supplied through nearly a mile of pipes from the spring water of the Esplanade, is a very important improvement of this class, and by similar means the spring water of the Oart Districts might be brought to any part of the Native Town where water is required.

218. 2*nd.*—By converting wells and tanks at present drying up towards the close of the hot season into perennial sources of supply, by deepening and by roofing them; by the latter measure the amount (averaging nearly 10 feet in depth annually) at present lost by evaporation would be saved, and the water kept cooler, and preserved from the contaminating influences of light, heat, and air.

219. No opportunity is neglected of increasing the capacity of the existing tanks, and the improvements thus effected of late years have been very considerable (the capacity of the Baboola Tank has been thus increased 4,688,000 gallons since 1st January 1850); but none of our wells or tanks have as yet been roofed, and I think it most desirable that all the former, and such of the latter as are of moderate size, should be so covered. The large wells I constructed during the last season in Girgaum Back Road and Breach Candy Road were vaulted over, with the exception of an opening for drawing from, and it would be an improvement if these openings were also roofed over.

220. 3*rd.*—The population deriving their usual supply from tanks at present failing a few weeks before the close of the monsoon might be saved the inconvenience of going further off for their water, by constructing close to these tanks water-tight, covered reservoirs, lined with cement, and filled from such

tanks during the height of the monsoon, and then closed till the tank dries up four or five weeks before the next monsoon sets in. I believe a reservoir might be constructed for Rs. 6,000 or 7,000 capable of holding (provided there was no loss from evaporation or leakage) a five weeks' daily supply for the largest number of persons at present drawing by hand from any single public tank. No such covered reservoirs have as yet been constructed.

221. *4th.*—The quality of the supply from tanks is at present execrable, even during the monsoon. This does not arise from the source of the water being objectionable, for most of the tanks derive their supply principally, if not entirely, from the surface drainage of rural districts, and even that is not admitted till the first dash of the monsoon has thoroughly washed the contributing area. I hope that ere long arrangements will be made which will enable us to dispense with the surface drainage of the town districts altogether in all the tanks. I think that such a change would be desirable; but from a microscopic comparison of the water of the variously supplied tanks, I can state that no material improvement in the character of the tank water can be expected to result from it. I believe that the present rapid contamination of the tank water is solely due to its exposure, in shallow stagnant reservoirs, to the heat and light of a tropical sun, and to its absorption of the gaseous impurities and floating organic particles with which the air of filthy and ill-ventilated towns is always contaminated.

222. The following drawing exhibits the details of the appliances by means of which the springs of the littoral concrete formation may be rendered extensively available to the wants of the other town districts, also the details of covered wells or storage reservoirs, wherein water might be retained and protected from loss by evaporation, and the contaminating influence of light, heat, and air; also those of filtering draw-wells, whereby the stagnant water stored in uncovered tanks would be freed from all organic impurity, and rendered perfectly fit for drinking purposes, and for the supply of the adjacent population.

223. Water from the springs in the littoral concrete formation of the Fort, Esplanade, and Oart Districts, is already conveyed through pipes to several localities which are destitute of springs. Thus the harbour side of the Native Town is principally supplied with drinking water from a reservoir at Musjid Bunder, to which water is carried through pipes from an elevated reservoir on the Fort Esplanade, up to which the spring water of the adjacent wells is raised by bullock power. The Colaba Barracks are similarly supplied through more than a mile of pipes from wells also on the Fort Esplanade.

224. The New Town is principally supplied from similar draw-reservoirs, situated at the junction of the Grant and Duncan Roads, and supplied through pipes from wells in the Oart Districts, at the expense of the estate of the late Framjee Cowasjee, to whom the Poway Estate in Salsette was made over in inam on condition of his keeping up these wells.

225. The largest apparatus of the kind yet constructed is that I erected

last season at the cost of Rugoonath Ramlall, for conveying the spring water of Framjee Cowasjee's Tank (excavated in the littoral concrete of the Esplanade) to a large draw-reservoir in the centre of the worst supplied districts of the Native Town. Drawing III. exhibits the details of this work.

226. In all works of this kind hitherto constructed at Bombay, the water has been raised by bullocks to elevated reservoirs (by means of an ingenious contrivance called a moat), from which it descends by gravity through a line of pipes to the draw-reservoir in the distant locality to be supplied. There is a heavy expense attendant on keeping up these bullocks, and it is certain that they might be dispensed with, provided the draw-reservoirs were made so much lower in level than the source whence the water is supplied as to allow of the latter descending to them by gravity through a siphon pipe. Such an arrangement is shown in fig. 1 Drawing IV.

227. In this figure, A is supposed to be a well in the littoral concrete of the Esplanade, (such as Ramlall's Well, near the Church Gate,) in which the water stands at a level of 4 or 5 feet above high-water mark, and D a deep reservoir in the trap formation of the Fort, (like that near the Fort Vegetable Market,) excavated to a depth of some 40 feet from the surface, or 25 below high-water mark. The bottom of such a reservoir will be therefore about 30 feet below the usual level of the water in Ramlall's Well. It is evident that if the siphon pipe A, B, C, D, is perfectly air-tight, and be once filled with water, the water will continue to flow through it from Ramlall's Well into the Vegetable Market Reservoir, until it stands at the same level in both; and that any water drawn from the latter will immediately be replaced from the former.

228. Such a siphon would be set to work as follows:—Its extremities would be closed by miter valves at A and E. At the highest point of the siphon there are two such pipes, C and D, capable of being closed at pleasure by air-tight cocks. These cocks are opened, and the siphon is then filled through the pipe B by means of a funnel, the air escaping through pipe C. When all the air has escaped, and the siphon is quite filled, the superfluous water will begin to run out at the air pipe C. The cocks at B and C are then closed, the siphon is air-tight, full of water, and ready for work: all that is required to set it going is to open the valves at A and D.

229. Large siphons of this description have been used with success in many parts of Europe; all that is required for their certain action is that the pipes of which they are composed shall be joined together by perfectly air-tight joints. In Europe, a glass tube like the water-gauge of the steam-engine boiler is sometimes added at the highest point of the siphon, by means of which any accumulation of air in the tube can be at once detected: to get rid of this air, the valves at the extremities of the siphon are closed, the cocks B and C opened, and the air is then driven off by pouring in a little more water through B; B and C are then closed, and A and D opened, and the siphon goes on working again.

230. When the difference of level is so great as it would be in this case, the momentum of the water running through the siphon pipe would be sufficient to force up by means of a self-acting hydraulic contrivance called a ram, a portion of its volume in the form of a fountain. The diagram fig. 2 Drawing IV. represents a siphon arrangement of this description put up at the Polytechnic School at Paris.

231. In the figure A, L, C, G is a siphon transporting water from A to G. On the long branch G B is a ram's head, with two valves at C of flowing and ascension, and above them a reservoir of air; a cock is placed at G, and a valve at K, which opens and shuts by means of a lever, the extremity of which is fixed at L when this valve is open.

232. To work the siphon, the cock G and the valve K are shut; water is poured through the pipe D; the air escapes by the same pipe both out of the vertical branch G B, and that inclined to the horizon D L, the pipe D being closed by a plug; the cock G and the valve K are opened; the water which flows through the siphon from A to G shuts the flowing valve C, opens the ascension valve E, and escapes at M in a jet of water, or raises itself in the ascension pipe served on the air reservoir above C.

233. Drawing V. represents one of the vaulted wells I constructed during the last season; the roof is not yet added. Drawing VI. is an example of a small covered tank, such as it is proposed to form out of a quarry containing springs of sweet water recently purchased for the purpose at Mazagon.

234. When tanks are too large to be covered, the water they contain being unprotected from the deteriorating influence of light, heat, and air, rapidly becomes (even while the rain continues to fall) the abode of swarms of animalcules, and of decomposing organic matter; and when the water is once in this state, it must undergo the process of slow filtration, through a filtering medium some feet in thickness, before it can be habitually drunk with impurity. All such open tanks should therefore be provided with filtering draw-wells, and the public should not be permitted to draw water except from these wells.

235. The rapidity with which rain water stored in open tanks becomes contaminated in this town is extraordinary. An establishment is kept up for removing what is called " vegetation" from the tanks: during the late monsoon the public tanks were covered with such vegetation, and it was accordingly skimmed off. The form of this matter was that of floating green slime; from its bad smell I suspected that it was not of vegetable origin, and on examining it with a powerful microscope I found it to consist of an aggregation of myriads of a little green animalcule called the *Monas grandis*. After keeping it in a glass of water two days, the water became a deep opaque purple, and extremely offensive even at a considerable distance.

236. This was in the beginning of September, and by the close of the hot weather, the amount of decomposing animal matter in the tanks becomes enormously increased, and generally before the close of the hot season the

evolation of the gaseous products of such decomposition has become too great to be compatible with the existence of life in the water. Bubbles of sulphuretted hydrogen rise everywhere—a proof that the water is already fully saturated with the utmost proportion of that poisonous gas (according to Professor Hoffman as much as two and a half times its own bulk) that water is capable of holding in solution. All the fish in the tanks die, and labourers are employed "to remove dead fish from the tanks."

237. The conventional form of an Indian tank of moderate size is the very worst conceivable, for preserving water in a state of purity. An Indian tank of this class has, when empty, very much the appearance of a graving dock, and is almost as costly. The lines of "alters" (as they are called in the case of a dock) and its flights of steps, being all of cut stone, are not only costly, but seem purposely designed for exposing a maximum amount of heat radiating surface to the volume of water they enclose, and for retaining a minimum amount of water at a maximum cost of masonry.

238. The sides of a tank should be perfectly perpendicular from top to bottom, and depth is of far more importance than total capacity. The deeper a tank is, the smaller will be the proportion which the surface exposed to evaporation and contamination bears to its total capacity.

239. There should never be any steps down into a tank: the water should be drawn as from a draw-well. Steps are objectionable for two reasons: they are the cause of a great amount of contamination to the water, and they increase the labour of those using the tank. Were the sides of a tank perpendicular, there would be no need for steps.

240. If any one observes the poorer classes drawing water from a tank furnished with steps he will see that each person stoops down and washes his or her water-pot in the tank before filling it, scrubbing the soot, &c. off the outside with their hands; and when it is considered that ten or twenty thousand pots are so washed daily in the Baboola Tank, it is evident that the aggregate amount of contamination due to this cause must be very considerable.

241. If the water was always taken from the tanks as it is from draw-wells, the amount of labour to those drawing would be only one-third of what it is where steps are used. Labour or work consists, and is expressed in so many pounds lifted so many feet high in a given time: when drawing with a rope the work done is merely lifting the weight of the full water-pot from the level of the water in the well to the surface of the ground; but if the person wanting the water has to go down to it by steps, he has in going up the steps again to lift his own weight the same height as he lifts the water; and if he weighs twice as much as the full water-pot he carries, his labour, that is to say the amount of the weight he lifts, is three times as much as it would be in drawing the same quantity of water by a rope, while remaining himself at the surface of the ground.

242. Drawings VII. and VIII. are examples of filtering wells in open tanks. The first (the filtering well in the Gowalla Tank) is an example of all that is

required when the tank is excavated in a porous stratum, and wells of this class are not uncommon. The second (the proposed filtering well in the Baboola Tank) shows the arrangement necessary when such tanks are excavated in rock.

243. Under such circumstances, the site of the proposed filtering draw-well is first rendered the deepest portion of the tank, and an excavation is formed, if necessary, lined with cement, in which a supply of filtered water may be retained for some time, even if the tank dries up before the monsoon; and the well is then built up with double walls 4 feet apart. Each wall is 2 feet thick, and constructed of accurately fitted blocks of a permeable stone, such as filtering sandstone, or the littoral concrete of Versova. The interval of 4 feet between these walls is filled up with fine sand, and the whole thickness of the filtering medium is therefore 8 feet, a thickness sufficient to support the drawing platform of the well which is connected with the road by a causeway, bridge, or gangway.

244. From the description I have given of the present state of the water supply of Bombay, it will be seen that some districts of the island are always well supplied with water, and that there has never, even in the worst season, or in any district, been an absolute want of that necessary of life in quantities ample for drinking or cooking, but there has at times been a very inconvenient scarcity in many districts, the poorer classes having sometimes to go twice the usual distance for their drinking water, the washermen being compelled to go 8 miles out of town, and great difficulty being experienced in obtaining water for watering the streets.* But, on the other hand, it may be stated that the number of perennial sources of supply has been greatly increased since 1850, and it is difficult to assign a limit to the increased supply which may be afforded from the springs of the Oart Districts to the waterless portions of the town by the multiplication of such works as the Poydownee reservoir.

245. I am of opinion that works of this class should be multiplied as far as possible, that existing tanks should be deepened, provided with filtering wells, and roofed, whenever of practicable size; and I believe that these improvements might readily be carried to an extent which should render the existing population of Bombay as well off for water in May as they are at present in October. But I do not think that this is all that will content, or even suffice the inhabitants of such a city as Bombay is likely to become within twenty years of the opening of an extended railway communication into the interior; and I do not think it is all that ought to content the inhabitants of the island even at present.

246. It is true that by the means I have described the supply from existing sources might be rendered during the hot months equal to our present supply in October, and that the latter is equal to our present demand; but a

* There is always a want of water in cases of fire, and this must be so in any town, however perfectly supplied from wells and private reservoirs, that has not water pipes always charged under every street.

supply on the English scale, with stand-pipes in every street in the proportion of one to every 50 or 100 inhabitants, by means of which the inhabitants would have an unlimited supply of fresh water always at their command within 50 feet of their doors, without any further trouble than turning a cock, would enormously increase the present demand and consumption, and the effect of such increased consumption, if accompanied by a thorough system of drainage, would be greatly conducive to public health and cleanliness.

247. We ought to have water pipes, fire-plugs, and public fountains in every street, and a thorough system of drainage, to carry off the increased consumption of water which would then be sufficient to prevent the accumulation of deposit in the sewers. Whenever Bombay is enlightened up to the point of forming proprietary water and gas companies, and submitting to water and gas-rates, it will become necessary to search for a source from whence a supply of at least 20 gallons per head of the population may be obtained daily throughout the year. At least this is always considered the minimum rate for a town supply in England, even though previous to the introduction of such supply the town had been well supplied from wells.

248. The questions that will then arise are, what is the nearest and best source from which such a supply can be obtained? Supposing the use of the *spring water* of Bombay to have been carried as far as possible, could not a sufficient supply *from surface* be obtained and *stored* within this island from the 78 or 80 inches of rain annually falling on the 21 square miles of its surface? If not, we must go to Salsette, first, to endeavour to discover a sufficient supply of *spring water*, and if spring water is not found to be available in sufficient quantities, we must have recourse to surface collection.

249. The high and rugged interior of Salsette must undoubtedly contain many valleys and ravines at a considerable elevation above Bombay, by damming up which, a sufficient supply might be collected from surface drainage; and the nearest and best adapted of these valleys should be sought for, its capacity tested by accurate *contoured* surveys, and an estimate framed of *all the works, reservoirs, sluices, purifying and distributary appliances,* whereby such supply might be rendered available to the wants of our population, and to the extinction of fire.

250. Before proceeding to point out how far Lieutenant DeLisle's water surveys and estimates answer these conditions, I shall consider what prospects there are, in the first place, of obtaining and *storing* a supply amounting to 20 gallons per head per day from surface collection within the island itself, and in the second, whether there is any possibility of obtaining the supply of *spring water* from Salsette. If these two expedients fail, a supply from surface collection in Salsette must of necessity be resorted to.

251. Twenty gallons per head daily for a population of half a million would require an annual total of 3,650,000,000 gallons; but our population already considerably exceeds half a million, and is increasing; so I will take a round

number, 4,000,000,000 gallons, as the minimum amount required (after deducting evaporation) for supplying Bombay with water as English town populations are supplied.

252. The average rain fall of Bombay is about 78 inches = 6.5 feet; there are 6.23 gallons in a cubic foot, and 27,878,400 square feet in a square mile. The total amount of water falling on each square mile is therefore $27,878,400 \times 6.5 \times 6.23 = 1,128,935,808$ gallons: the rain water falling on three square miles (only one-seventh of the area of the island) would therefore be nearly sufficient to give 20 gallons a head a day to our present population. The surface of Bombay is about 21 square miles, and the total amount of rain water falling on it annually is more than 20,700,000,000 gallons.

253. It is therefore evident that the amount of rain water falling annually at Bombay is many times larger than the population can ever require. But the same may be said in the case of almost every town: the difficulty always is to find some valley or ravine well adapted for storing the amount required; and it is certain that there is no valley or ravine within the island of Bombay in which the 4,000,000,000 gallons required (after deducting the loss of evaporation) could be stored. No water supply on the English scale is therefore obtainable from sources within the island, and whenever such is required recourse must be had to Salsette.

254. I fear that there is little probability of obtaining from Salsette an adequate supply of *spring water;* but I am not prepared to say that no such sudply is obtainable. The spring water capabilities of Salsette should be most thoroughly investigated before recourse is had to surface collection.

255. Captain Crawford, in paragraphs 13 and 14 of his letter No. 108, of the 16th May 1846, to the Board of Conservancy, on the subject of the water supply, mentions a locality near Koorla as "deserving of the closest investigation." With reference to this point, he says:—

"In proceeding along the road from Koorla, and about 2 miles from that village in the direction of Tanna, there is a range of hills on the right, which terminates in some curious spurs and knolls. These spurs include some valleys, which, from a hurried inspection, I believe to be large natural reservoirs of water. In many parts the herbage is yet green and fresh on the surface. One or two old wells have 12 or 15 feet of beautiful cold spring water in them. In one place I saw a hollow, merely scraped in the surface for watering cattle at, and full of water. In another spot, even in this dry season, water was still trickling on the surface, to say nothing of local reports, which, although often exaggerated, have generally some foundation in truth, and which reports state the water to be very close to the surface. In fact, I look upon this place as something of the same character of ground as that around Ahmednuggur, and in which are constructed the well known aqueducts of that town. Should the ground prove to be what I imagine it, but which can only be ascertained by trials with the boring rod in various parts, the plan to be adopted would be much the same as that of the Ahmednuggur aqueducts." And Captain Crawford then proceeds to describe a system of collecting pipes, &c. similar in principle to that by which it is proposed (see ante paragraphs 3, 185,) to supply London with water from the Bagshot Sands.

256. On the opposite side of the ridge, where Captain Crawford observed the springs on the harbour coast of Salsette, and along the line of the railway, a line of springs occurs, extending from Koorla to the north of Bandhoop. Cursetjee Cowasjee Ashburner, who owns the large distillery at the latter locality, informs me, that being distressed for want of water in carrying on his works, he some years since sunk a covered collecting conduit, 1,500 feet in length, 4 feet wide, and 3 feet high, generally 12 or 15 feet below the surface, along the side of the hill range passing close to his works, which conduit has on the average continued to supply him ever since with about 100,000 gallons of excellent spring water daily.

257. There is unquestionably a large amount of excellent spring water obtainable in Salsette; but from the conformation of the island I believe that the springs would be found to be to a great extent local, and not distributed over an area sufficiently large, or at proper levels for the supply of Bombay by gravitation; and should this be found to be the case, after thorough examination, boring of the strata, and gauging of the springs, recourse must be had to surface collection from Salsette as the source of supply.

258. I have already stated, that when it is intended that a town should be supplied with water by collecting in large reservoirs the surface drainage of any adjacent valley, the valley or valleys debouching on such town should be traced upwards, until some natural basin is found at sufficient elevation above the town, in which a sufficiently large body of water might be collected in storage reservoirs by a moderate amount of embanking.

259. The only valley debouching on Bombay is that of the river Gopur, (as Hamilton styles it in his Indian Gazetteer,) which rises in a basin of hills near Vehar in Salsette. The valley island of Bombay is in fact a prolongation of that of the Gopur river, and Hamilton in his Gazetteer states that the water of that river, when in flood, used formerly to enter Bombay between Mahim and Sion, and traverse the length of the island on its way to the sea. The head valleys of the Gopur are therefore the spots to be first examined in search of sites for storage reservoirs sufficiently capacious for the supply of Bombay, and the height of the hills and the depth of the ravines in which this stream takes its rise would appear favourable to the probability of finding among them a site or sites suitable for the purpose.

260. Lieutenant DeLisle has traced up this valley to its source in the basin of hills near Vehar, about 14 miles distant from Bombay, and there, at the level of 69½ feet above the plinth of the Church Gate of the Bombay Fort, he proposes to construct a dam 50 feet in maximum height, whereby a large portion of the surface drainage of an area of 7 miles will be ponded up. The quantity

of water so ponded up he estimates roughly (for his surveys being preliminary, no contoured plans were made,) at 157,100,000 cubic feet, or in round numbers 1,000,000,000 gallons.

261. From this lake at Vehar, through an inlet 20 feet above the bottom of the dam, Lieutenant DeLisle proposes to convey the water through a 2-feet iron main to the Great Indian Peninsula Railway, the line of which it will thence follow to Bombay. The estimated cost is as follows:—For construction, viz. dam, waste-weir, delivery reservoir, and conduits, £15,000; for 14½ miles of 2-feet iron water main £102,080; contingencies £2,920; total £120,000, or twelve lakhs of Company's rupees. This estimate does not include the cost of regulating sluices, of filtering beds, or of the miles of pipes forming the distributary apparatus, whereby alone a water supply can be made available to the wants of a town population; and the cost of such distributary appliances always forms the largest portion of the total cost of water-works for the supply of towns.

262. I shall now consider how far the project is likely to fulfil the expectations held out in Lieutenant DeLisle's report, as regards the quantity and quality of the water supply it would afford, and how far the data supplied by that officer's report and plans are sufficient for determining approximately the expense of rendering such supply available (by distribution) to the inhabitants of Bombay.

263. To ascertain the net *available* contents of such a tank as that proposed at Vehar, the amount of the mean annual evaporation of the locality must necessarily be deducted from the depth of water which the bund is calculated to retain; but it does not appear that any allowance is made for evaporation from the tank in Lieutenant DeLisle's report. In paragraph 13 it is indeed assumed that of the 76 inches of rain that falls on the surface of Salsette, "16 is wasted by evaporation, absorption, or other causes," and that "the remaining 60 inches are conveyed by the nullah to the sea"; but nothing is allowed on account of any wastage of the waters of the lake by evaporation subsequently to the 1st of October; and by this omission the available annual yield of the lake is made to appear at least double what it would actually be if (as I think there is no reason to doubt) the mean annual evaporation of India is correctly stated in the scientific publications on the subject.

264. The mean annual evaporation of even the neighbourhood of London (as ascertained at the Royal Observatory of Greenwich) amounts to as much as 5 feet; that of Calcutta is stated in the Journal of the Asiatic Society of Bengal, Part I. Vol. XVII. to be 15 feet per annum; and as the mean annual temperature of Bombay is higher than that of Calcutta, there is every reason for supposing that the evaporation of the former locality would at *least* equal that of the latter.

265. The adoption of the Calcutta standard of annual evaporation (15 feet) would reduce the maximum depth of the lake from 50 feet to 35 feet, and

would consequently* diminish its *available* contents from 157,100,000 cubic feet to 53,885,300, or nearly two-thirds, and were an annual evaporation of only two-thirds of the Calcutta standard allowed, the supply would still be diminished from 157,100,000 to 80,435,200, or very nearly a half, or in round numbers to 500,000,000 gallons.†

266. This is only an eighth of the quantity (4,000,000,000 gallons) I have shown to be requisite for the supply of Bombay, according to what is considered in England the minimum scale on which town populations should be supplied with water. On referring to the Table A (see ante paragraph 42) it will be found that the average delivery of the sixteen water companies, of which the statistics are given, is 24 gallons per day per head of the population of the towns supplied. It must be remembered that even in the best and most recently constructed works the greater portion of the amount delivered is wasted (see ante paragraph 44).

267. The deterioration of rain water, collected and stored under circumstances similar to those of the proposed reservoir at Vehar, is thus described in a recent standard work on the subject :—

" Water falling on a growing soil, and running off the surface to lie in stagnant ponds, is in very favourable circumstances for being tainted with vegetation and animal life. Water-plants will spring up, and feed numerous tribes of animalcules, and each pool will be a constant scene of vitality. In such a state the water is usually unfit for drinking; the palate instantly discerns a disagreeable taint, and no one will use it who can do better."

268. I have shown that in temperate climates a minimum depth of from 12 to 15 feet is requisite, in storage reservoirs, to prevent the growth of water plants, and the consequent extensive development of organic impurities. When full, the average depth of the Vehar reservoirs (according to Lieutenant

* The capacity of similar solids or voids being as the cubes of any one of their dimensions.

† The Board of Conservancy considers that I have greatly over-estimated the probable loss from evaporation in thus fixing it so high as two-thirds of the ascertained evaporation at Calcutta (see ante paragraph 264) ; and they state that they have been informed that the evaporation at the Colaba Observatory had been ascertained to average but little more than one-fourth of an inch (·26 inch) per diem. I am, however, assured by the gentleman who conducted these Colaba Observatory experiments, that they related to " atmospheric evaporation" solely, and were conducted in vessels carefully shielded from the action of the sun, and from any exposure to the highly evaporating influences of currents of air.

Evaporation is three-fold :—1*st*, atmospheric evaporation, or that due to the temperature and hydrometric state of the atmosphere ; 2*nd*, solar evaporation ; and 3*rd*, that due to the drying action of currents of air. The first is the only species of evaporation that can be accurately decided by experiments on a small scale, as small vessels exposed to the sun and hot currents of air get themselves too much heated to give the water fair play. We cannot tell, therefore, what is the total evaporation of water to be expected from all three causes at Bombay, but we may be certain that it is considerably more than that ascertained to be due to only one of them, and I have only added for both the unmeasured causes together one-third the ascertained amount of atmospheric evaporation.

DeLisle's plans and reports) would be about 7¼ feet only,* and under these circumstances, a luxuriant growth of aquatic plants would be unavoidable; and even were the average depth of the tank doubled, a filtering bed would be absolutely essential, to render the water stored under such circumstances of fit quality for drinking purposes.

269. Lieutenant DeLisle calculates on obtaining a head of water of 100 feet through an inlet 20 feet higher than the bottom of the dam; but the highest head really obtainable, after allowing for the regulating sluices and filtering apparatus, (see Drawing I.) will be 8 or 10 feet below the bottom of the dam, and this would reduce the height of the head to about 60 feet above the plinth of the Church Gate, a height sufficient to keep the pipes always fully charged, and sufficient for fountains in most parts of the town, but not sufficient for any real high service. After allowing for the friction of the pipes, such a head would only yield in the town a jet of about 30 feet in height above the level of the plinth of the Church Gate.

270. Lieutenant DeLisle proposes that the water should be conveyed from the Vehar reservoir to Bombay through a 2-foot main: this would not be sufficient for supplying the population of Bombay with 20 gallons per head per day. In such matters, practical experience is a much better guide than theory, and the Grand Junction Water Company find a main of 30 inches in diameter none too large for an annual delivery of 1,200,000,000 gallons only, yet their main conduit is not half the length, or liable to half the friction that one from Vehar to Bombay would be; and their head of water is upwards of 200 feet above the lower portion of the town, which of course would cause a much more rapid flow along the main than the head of 60 feet obtainable from the Vehar reservoir could do. The Gorbal's Gravitation Water Company have deemed a 2-foot pipe, with a head of 220 feet, necessary for the supply of a present population of 75,000. I should not recommend a smaller diameter than 41 inches for a main 14 miles long, for supplying a population of 500,000 or 600,000 from a head of only 60 feet at the rate of 20 gallons a day.†

* The surface of the lake being (by measurement on Lieutenant DeLisle's plans) 21,349,925 square feet, and the contents (by Lieutenant DeLisle's report) 157,100,000, the average depth *when full* is consequently 7.358 feet.

† This would be the diameter by required Hawksley's formula, even supposing the delivery to be equally distributed over the 24 hours of day *and night*.

Hawksley's formula for determining the diameter of a pipe of given length, to deliver a given quantity of water, under a given head, is as follows:—

Let q = the number of gallons to be delivered per hour.
l = the length of the pipes, in yards.
h = the head of water in feet.
Then d, the diameter of the pipe, will $= \frac{1}{15} \sqrt[5]{\frac{q^2 l}{h}}$

271. It would be desirable to ascertain, at least approximately, the cost of rendering a supply of water, brought from Salsette, available to the wants of the inhabitants of Bombay by the distributing appliances which are indispensable in all water-works, but of which (from its preliminary nature) no mention is made in Lieutenant DeLisle's report. In all English water-works the expense of the distributing apparatus forms by far the greater portion of the cost of the whole : of course the amount of this item would vary considerably with the extent to which the water supply is in the first instance diffused over the town, but regulating sluices and filtering reservoirs (which latter are allowed to be indisputably essential to any water supply) must necessarily be constructed in the first instance, and the branch mains, with all provisions required for further extension, must also be then laid down.

272. Assuming the amount of water required for the supply of Bombay at 4,000,000,000 gallons, would it be possible to collect, and obtain storage room for this quantity, or (assuming storage room for a nine months' supply to be sufficient) for nine-twelfths of it, in the neighbourhood of Vehar?

273. Lieutenant DeLisle estimates the extent of area draining into the nullah at Vehar at 7 square miles, and he considers that about three-fourths, or 60 out of the 76 inches of rain annually falling on this area, may be reckoned on as available, the remaining fourth being dissipated by absorption, evaporation, &c.

274. The largest proportion of the total rain-fall found to be available, under the most favourable circumstances, in the Scotch water-works, is two-thirds, and it would not be safe to calculate on a larger proportion in this country. The quantity of rain falling annually on each square mile in Salsette may be taken in round numbers at 1,199,000,000 gallons: two-thirds of this would be about 752,700,000 gallons, or, for 7 square miles, about

In this case $q = \frac{4,000,000,000}{365 \times 24} = 456,621$ gallons per hour.
$l = 25,520$ (yards).
$h = 60$ (feet).

Then, $q^2 = 208,502,737,641$; $q^2 l = 5,320,989,864,598,320$; and $\frac{q^2 l}{h} = 88,683,164,409,972$.

The 5th root of which $= 615$ (inches) nearly, 1-15th of which (41 inches) will be the diameter required.

The delivery, instead of being equally distributed over the 24 hours, would, in reality, take place principally during the twelve hours of daylight, and a larger pipe than 41 inches would therefore be essertial were Hawksley's formula quite correct ; but the recent experiments on the flow of water in pipes carried on at the experimental works of the Metropolis Commission of Sewers has proved, that under favourable circumstances the delivery of water in pipes is one-quarter greater than it would be according to Hawksley's formula.

The formula for determining the hourly flow (in gallons) of water through a pipe of given diameter, and length, under a given head, is the converse of the above, as follows :—

$$q = \sqrt{\frac{h}{l}(15\,d)^5}$$

5,396,000,000 gallons. The available rain-fall of the district draining into the nullah at Vehar would be, therefore, sufficient to the supply (4,000,000,000 gallons) that would be required for the delivery of 20 gallons a head a day to the population of the island.

275. But is sufficient storage room for this quantity, or even for a nine months' supply, (3,000,000,000 gallons,) obtainable in the neighbourhood of Vehar? The capacity of the reservoir proposed by Lieutenant DeLisle is stated by that officer to be in round numbers 1,000,000,000 gallons; and supposing the loss from evaporation to be only two-thirds of the amount of evaporation at Calcutta, that quantity would be reduced to 500,000,000 gallons; but Lieutenant DeLisle says, that by raising the dam 10 feet the capacity of the reservoir would be doubled, *i. e.* rendered equal to 2,000,000,000 gallons.

276. From this, the loss from evaporation must, of course, be deducted, but it would be less in proportion, as the greater volume of water would keep down the temperature, and check evaporation. I think it probable, moreover, that the amount of evaporation ascertained at Greenwich and Calcutta, being the result of the evaporation of comparatively small quantities of water, may be found too high for such a large volume as the contents of a reservoir containing thousands of millions of gallons. On the whole I consider it probable (as far as an opinion can be formed without *contoured* plans of the site), that by raising the height of the dam (60 feet) the available contents of the proposed reservoirs might be increased to 1,500,000,000 gallons, after allowing for evaporation.

277. This would be equivalent to a four and a half months' supply. The only way by which the remaining months could be provided for would be "by the construction of additional reservoirs on ground still more elevated either in the same or adjoining valleys, whereby the additional supply could be drawn into the lower reservoirs, and thence into the filters; and it appeared to me, from a cursory examination of the ground, that the ravine through which lies the path from Vehar to the Kennery Caves is well adapted to the construction of a series of such subsidiary reservoirs, which would admit of being increased in number one above the other as the demand for water increased; but of course contoured surveys are essential to the accurate ascertainment of the capabilities, not only of this ravine, but of the site of the proposed main reservoir.

278. My conclusions and recommendations regarding the Vehar project are therefore as follows:—

1*st.*—That Lieutenant DeLisle's surveys have demonstrated the practicability of ponding up, by a dam of the maximum height of 60 feet, (10 feet higher than that estimated for,) situated about 14½ miles distant from Bombay, a body of water apparently sufficient (as far as can be ascertained without contoured surveys) for the supply of Bombay at the usual rate (20 gallons per head per day) at which the water supply of English towns is calculated, for four and a half months out of the twelve, and that there appears a probability of its being found practicable to obtain a considerable additional amount of storage room, by the construction of a series of subsidiary reservoirs in the valley leading to the Kennery Caves; but that accurate contoured surveys of the Vehar basin and the adjoining ravines are essential to the accurate ascertainment of the capabilities of the whole locality, and that such contoured surveys ought to be undertaken.

279. *2nd.*—That owing to their preliminary nature, Lieutenant DeLisle's plans and surveys afford no sufficient data for determining even approximately the cost at which a supply of water from Vehar could be made available, through the usual medium of a system of street pipeage and stand-pipes, to the wants of the population of Bombay, and that as soon as careful contoured surveys shall have determined the water-storing capabilities of the Vehar basin and its neighbourhood, it is desirable that detailed plans and estimates should be made of the probable cost of rendering such supply available to the wants of the town of Bombay, by the same appliances as are used for rendering a supply from a similar source available to the wants of Glasgow by the works of the Gorbal's Gravitation Water Company, and in all similar cases in Great Britain.

280. It may be objected to such recommendations and conclusions that the proposed supply is in addition to all existing sources of supply, and that I therefore exaggerate the wants of the place in assuming that so large an amount as 20 gallons per head per day ought to be provided.

281. In answer, I would refer to the table (A) I have given (paragraph 42) of the statistics of all the water companies regarding which authentic information is obtainable, and to the engineering evidence regarding the supply of towns taken by the various Parliamentary Commissions on the subject, to show that 20 gallons per head per day is the minimum that any engineer or practical man acquainted with the subject has ever recommended in designing water-works for any town; and that the average delivery of all the water companies of which authentic particulars can be obtained is 24 gallons per head per day, and in the more recently constructed works half as much again; and that these supplies have for the most part been recently introduced to towns which were previously supplied by well water much better than Bombay is supplied at present, inasmuch as they had no dry season in which these wells failed.

282. I am certain that no English engineer at all conversant with the subject of water supply would, in designing works for the supply of Bombay, calculate the amount required under existing circumstances at less than 20 gallons per head per day*: if it was considered inexpedient to supply the whole

* The Board of Conservancy have recorded an opinion that I have greatly over-rated the additional quantity of water required at Bombay, in fixing it so high as 20 gallons per head per day. My assertion, however, regarding what English engineers would consider requisite is fully borne out by the estimates for the water supply of Calcutta that have been since published in No. X. of "Selections from the Records of the Bengal Government." These estimates

of the quantity in the first instance, the complete works should nevertheless be estimated for, and whatever portion of them was executed in the first instance should be constructed with a view to the ultimate provision of a delivery of at least 20 gallons per head per day to the whole population. There is no reason whatever why the supply to a town of half a million inhabitants, and within the tropics, should be less than the average supply to third and fourth-rate Scotch and English towns, and there are many valid reasons why it should be greater.

283. It may be expected that I should say something regarding the probable cost of supplying Bombay with drinking water on the English scale of supply. I regret that no sufficient data at present exist for doing so. The works of the Gorbal's Gravitation Water Company cost £110,000 for a population of 75,000, and they are considered the most perfectly and economically constructed in Great Britain; but the cost would have been much less per head if the number supplied had been larger; and the same Company have now a bill before Parliament for constructing an additional reservoir, which will increase the number they can supply from 75,000 to 230,000, the probable additional cost of which *is stated* at £25,000 only, which would reduce the cost per head of the number supplied from £1 9*s.* 4*d.* to 11*s.* 9*d.*

284. Perhaps we may say, therefore, that under the most favourable circumstances, the works for supplying a population of a quarter of a million might possibly be constructed in Great Britain at 10 shillings (5 rupees) per head.

285. As regards cost of construction, Bombay possesses advantages and disadvantages as compared with England: owing to the extraordinary density of our town population, the mileage for distributing apparatus, street pipeage, &c. requisite in Bombay, could be greatly less than would be required for a town of the same population in Europe, but what pipes were required could not be provided and fixed in Bombay at nearly so low a rate per foot as in England. Our distance from the proposed reservoirs at Vehar is considerably more than double that of Glasgow from the Gorbal's reservoirs, and in India (as I have shown in paragraph 194) a much larger proportion of storage room would be required than is sufficient in England. This would of course add very considerably to the cost of the reservoirs.

286. The rainy season does not usually begin till after the 10th of June, and there is seldom any rain to speak of after the 10th September. The minimum storage room absolutely essential would therefore appear to be nine months' supply; but this would leave no margin for deficient monsoons, or unusually hot fair seasons; besides, it would not do to draw the reservoir quite

(of which I have given an abstract in the postscript to this report) are by Mr. Simms, C. E., Consulting Engineer to the Government of India, by Mr. Hawksley, C. E., Engineer of the Nottingham Water-works, and a high authority on the subject of water supply, and by Captain Young, of the Bengal Engineers; and all these gentlemen concur in rating the additional requirements of the population they propose to supply at 30 gallons per head per day. Yet a glance at the maps of Bombay and Calcutta will show that the existing sources of supply are at least five times more abundant in the latter town than in the former.

to the bottom. Lieutenant DeLisle only proposes that the reservoir he estimates for at Vehar should be drawn to three-fifths of its depth. Altogether I should not recommend a less provision than storing room for the whole twelve months' supply, *i. e.* for 4,000,000,000 gallons, after deducting for evaporation.

287. Whenever detailed estimates are prepared of the cost of water-works and distributary apparatus for the supply of Bombay from Salsette, returns should be collected of the amount at present spent by the upper and middle classes of the population of Bombay in paying bheesties, &c., and of the proportion of such amount which might reasonably be expected to be saved to the consumers by a system of pipe supply: water-rates to two or three times the latter amount might, I think, be reasonably calculated on, for the increased supply would create a greatly increased demand.

288. I doubt, however, whether the great bulk of the population could ever be induced to pay water-rates directly. The lower classes at present pay nothing to bheesties: all the water they require is brought by their women from the nearest wells; the average distance of their houses from such wells is trifling, and might readily be made still more so; and I believe that both sexes would be unwilling to pay, even if they could afford it, for water being brought to their very doors. The men would probably think that the occupation of drawing water kept the women out of mischief, and the women would miss the gossiping with all their neighbours which the meeting at the well daily affords them.

289. If, after ascertaining as accurately as is possible the probable cost of complete water-works for the supply of Bombay, and the probable returns in the shape of water-rates on the capital so invested, the Court of Directors were of opinion that the case was one in which they would be justified in guaranteeing a return of 4 per cent. to any chartered proprietary company that would undertake the work, I believe that the capital required might be raised without difficulty.

290. On the 10th of June 1852 an extract (paragraph 64) of a despatch from the Honorable the Court of Directors, No. 8, dated the 31st of March last, was transmitted to the Board of Conservancy, stating that it was desirable that in considering the question of the supply of water at Bombay special attention should be given to the means of providing water for extinguishing fires, and requesting that the Board would submit any suggestions they might be able to offer on the remark at the close of such paragraph; and by resolution 5 of the Board's meeting of the 16th of June, such extract was forwarded to me for my opinion, and with a request that I would report on the matter in connection with the question of the supply of water to Bombay. I shall now proceed to do so.

291. The number of fires annually occurring in Bombay is very small compared with the numbers of our population: the average of the last five

years has been under 50 fires per annum, while the average number at London during the same period has been more than sixteen times as many, or above 800. With sixteen times as many fires, the population of London is only four times that of Bombay; the proportion of cases of fire to population is therefore four times as great in London as at Bombay.*

* The following is a statement of the number of fires that have occurred in Bombay during the last five years :—

1848	33
1849	43
1850	50
1851	50
1852	31 up to 19th Nov.

In London the number of fires is increasing ; the average of the last seven years has been 790 per annum, and for the seven preceding years only 623. Since 1845 the number has never been below 800; last year it was above 900.

The following is an abstract of a very elaborate table of the causes of fire in the metropolis from 1838 to 1849, inclusive, compiled by Mr. Baddeley :—

"The total number of fires that occurred from 1833 to 1849 inclusive (a period of seventeen years) was 11,305. In these seventeen years the annual number of fires appears to have nearly doubled, the number in the first year of the series (1833) having been only 458, and of the last (1849) being 838. The annual rate of increase appears to have been tolerably uniform. The amount of the increase is out of all proportion to the increase in the number of houses that has taken place during the same period, and is to be attributed solely to the increase of incendiary fires occasioned by the more general introduction of house insurance.

"The causes of the above fires, as far as they can be ascertained, have been as follows :—

Total number of fires from all causes that occurred during the seventeen years ending 30th December 1849	11,305

Of which were traced to the following causes the following number :—

To candles, various accidents with	2,876
To flues, foul, defective, &c.	1,273
To gas	780
To stoves, defective, overheated, &c.	626
To linen, drying, airing, &c.	509
To accidents of various kinds, for the most part unavoidable	452
To fire-heat, application of, to various hazardous manufacturing processes	440
To fire sparks	339
To shavings, loose, ignited	339
To carelessness, palpable instances of	309
To furnaces, kilns, &c. defective or overheated	263
To tobacco smoking	239
To children playing with fire or candles	238
To spontaneous combustion	228
Wilful	211
To lucifer matches	188
Suspicious	125
To fires kindled on hearths, and other improper places	120
To ovens	117
To drunkenness	84

292. The rarity of fires in Bombay can be readily accounted for. In the tropical climate of Southern India, fire is required for no other purposes than cooking, and Native cookery requires a very scanty amount of fire, and that for a very short time. The fuel employed is very expensive, and there are no chimneys or flues. A few sticks, or pieces of dried cow-dung, are collected and lighted on a little clay hearth, and the pot of rice is boiled, the thin unleavened cake baked on an iron plate, and the fire allowed to go out till the next meal. Another reason for the rarity of fires is that house insurance is almost unknown at Bombay. (See paragraphs 339, 340.)

293. Under these circumstances, the breaking out of a fire is necessarily of rare occurrence; but when a fire does break out it is generally far more destructive than it would be under better arrangements, for the three following reasons :—

294. 1*st.*—Because, owing to an insufficient Building Act, very laxly enforced by the Court of Petty Sessions, houses are allowed to be constructed of inflammable materials, and with projecting balconies of light wooden trellis-work, excellently adapted for spreading fire from one house to another.

295. 2*nd.*—Because there is no fire brigade in Bombay, and whenever a fire breaks out, the mob of amateur firemen, Native policemen, sailors, lascars, and thieves, who assemble, with and without fire-engines, under the idea of putting it out, being altogether without organization or training, are really in nine cases out of ten of far more harm than good. The fire would generally go out without their assistance just as soon as with it, and the damage to adjacent property would be infinitely less.

296. 3*rd.*—Because there is generally a very scanty supply of water, and the amateur firemen assembled make that little go as short a way as possible.

297. The remedial measures whereby the risk from fire might be diminished are—1*st*, precautionary, by the enactment and *stringent enforcement* of a proper Building Act, which would prevent houses being built in an inflammable manner; 2*nd*, by the organization of an efficient fire brigade, with its head quarters at some central point; and 3*rd*, by increasing the supply of water available for the extinction of fires.

To lamps	76
To fire-works	70
To apparel ignited on the person	69
To lime, slaking of	61
To hot cinders put away	56
To fumigation, incautious	49
To hearths, defective, &c.	24
To reading, working, or smoking in bed	22
To gunpowder	22
Unknown	1,080
Total from all causes in the seventeen years	11,305

298. I will cite two examples, which both occurred in the Fort, and within 100 yards of each other, of the insufficient enactments of our Building Act, and the lax manner in which the Court of Petty Sessions enforce it. One of the most destructive fires that has occurred in Bombay for many years was that which, breaking out in a low shed in which spirits were kept, consumed the British Hotel in the Fort, with the adjoining warehouses. Had the provisions of the Londom Metropolitan Building Act been in force and *enforced* at Bombay, this fire would have done no farther damage than burning down the shed in which it originated.

299. The latter was one of a few low houses, not above 20 or 25 feet in height, that immediately adjoined the British Hotel, which, as well as the line of warehouses next it on the north, was a very lofty building. When the firebroke out (by the bursting of a cask of spirits), the flames streamed up the side wall of the British Hotel, and lapped a light wooden trellis-work balcony, or veranda, half way up it; the drapery of the window and the wooden ceiling of the room within caught fire from the burning balcony, and the whole hotel, with the warehouses to the north (filled I believe with piece goods), were consumed.

300. By the London Metropolitan Building Act, no external projections of the sort are allowed to be construced *of any materials except stone and metal*, and had this restriction been enforced at Bombay, the British Hotel could not have caught fire on the occasion I have mentioned. The low house adjoining the other side of that in which the fire originated was saved.

301. I will now adduce an instance of the insufficiency of our existing Building Act to the prevention of risk from fire, and of the laxity with which its provisions are construed by the Court of Petty Sessions.

302. Article V. Regulation III. of 1815 repeats the enactments of Article XVIII. Regulation III. of 1812, against the use of inflammable materials in building, and confirms it as follows:—" And whereas by Article XVIII. of the said Rule, Ordinance, and Regulation, the construction, both within the walls of the Garrison, and the limits of the Native Town, of all houses, sheds, or huts, whether of tatta, or cudjans, or of other materials than stone or brick, with tiled roofs, is prohibited, therefore, for the better enforcement of the said Article, it is hereby ordained, that any person constructing any such house, shed, or hut, *with any other materials than stone or brick, with tiled roofs*, shall for every such offence forfeit or pay to the Court of Petty Sessions a sum not exceeding 100 rupees, over and above the expense of demolishing such building; and which said building, erection, or erections, the said Court of Petty Sessions are hereby expressly instructed and authorised to demolish and remove, in such manner as they shall deem most expedient for the public benefit and convenience; the materials of which such building may be formed being hereby declared to be forfeited to, and to become the property of, the Court of Petty Sessions, who are hereby authorised, and directed, either to sell the same and carry the amount produced by such sale to the credit of the Police Fund,

or to apply the said materials themselves towards repairing the roads of the island, as may be most expedient."

303. The new Building Act (XXVIII. of 1839) repeals the former Acts, but its intentions, as regards the prohibition of inflammable materials in building, appear to me to have been the same. The new enactment on the subject is as follows:—

"*Article VIII. Act No. XXVIII. of* 1839.

"And it is hereby enacted, that *no cudjans or other inflammable materials* shall be made use of in the external roof or walls of any building without the Fort walls of Bombay, in any place or place within the islands aforesaid, to be declared by the Governor of Bombay in Council, by proclamation in the Government Gazette; and that every person offending herein shall, on conviction before the said Court of Petty Sessions, be punishable by fine not exceeding 500 rupees."

304. In defiance to the provisions of the latter article, as I understand it, a building about 60 feet long, and about 40 feet in width, and height, was erected in the Fort of Bombay, about six months ago. The sole material employed in its construction was planking of American white pine (one of the most inflammable descriptions of timber known). The plank walls were double, with an air space of about 18 inches between. The roof was of similar planking, pitched to render it water-tight. The building was intended to keep ice in, but such destination did not render it less likely to take fire, as the ice was merely in a heap on the middle of the floor; and the damp chaff placed as a non-conductor between the double plank walls is as liable to spontaneous combustion as damp hay.

305. This inflammable construction almost touches three large and very valuable buildings—the office of Messrs. Leckie and Co., the Scotch Church, and the Supreme Court House. The insurers of the first of these immediately gave notice that they would not renew the insurance, and I was requested to bring the matter to the notice of the Court of Petty Sessions, as the Court's Surveyor. I accordingly on the 26th August last charged the owner with having made use of an inflammable material in the external walls and roof of a building within the Fort of Bombay, contrary to Article VIII. Act XXVIII. of 1839, paragraph 299, but the case was dismissed, on the grounds that white pine planking, though unquestionably an inflammable material, *in reality* was not *inflammable within the meaning of Act XXVIII. of* 1839, because it was deemed somewhat *less* inflammable than the *only one inflammable* material (cudjans) that was particularly specified in such Act, and because it was a "legal maxim" that prohibitary enactments of this class could not be held to apply to articles at all *less* objectionable than *the one or more particularly specified* in the wording of such enactment.

306. I conceive, that in enforcing enactments of this class their spirit and intention should be regarded rather than the finikin verbal technicalities, which,

on account of the importance of the interests therein at stake, are deemed to be essential in the case of the upper Courts.

307. On this case being dismissed by the Court of Petty Sessions, Messrs. Leckie and Co. appealed to Government, as it was understood (erroneously I believe) that the building had been erected under their special sanction. On this Government referred the matter to the Chief Engineer, (Colonel Waddington,) who also gave it as his opinion that the building was a dangerous one. The building, however, has not as yet been removed, nor am I aware that it is intended to remove it.

308. During the first three years of my residence at Bombay, no fire of any importance occurred at which I was not present, and I can therefore state from personal experience that it is impossible to conceive a scene of greater confusion than a Bombay fire presents. There are generally a great many more engines present than there is water for, and what water there is is not made the most of: there is no order or arrangement whatever—any one who gets hold of an engine and two or three bullock loads of water thinks it necessary to show his zeal by having such engine worked vigorously (for the few moments the water lasts) at any point of the blazing building, without discretion. I have often seen streams of water (when water was sorely wanted) wasted against a dead wall, where it could do no manner of good; but the more usual fault is to pump away into the heart of the fire of a hopelessly inflamed building, instead of attacking the outskirts of the flame, and thereby endeavouring to confine it within the house already doomed, and to prevent its spreading to the adjacent buildings.

309. There are generally large parties of sailors present, who are led to attempt to pull down houses, to create a gap to prevent the spread of the fire. Such attempts usually lead to much unnecessary damage of property, and are always useless, for the frame houses of Bombay are always too strongly constructed, and burn too quickly, to allow of the demolition before the fire reaches them by any agency except gunpowder. I have never yet seen an attempt to pull down a house during a Bombay fire successful, and such attempts are often a mere wanton destruction of property, undertaken for mere destructiveness, and love of excitement.

310. As a case in point, I may mention what occurred at one of the many fires that have taken place in the Mazagon Timber Yard. There was a small insulated house at the verge of this yard, with a little garden intervening. The house was, I think, at one time really in danger, but pulling it down, even if practicable, could have answered no useful end, for it was insulated, and would not have spread the fire further. However, a party of sailors was led upstairs to try and demolish it, and they certainly exerted themselves to the utmost in smashing every piece of wood-work not impervious to their axes. The next day's newspapers commented on the wanton destruction of property that had so taken place, but the owner got no redress.

311. At Bombay fires, there is usually no want of engines, or of willing hands to work them. The engines, however, generally arrive on the spot (as is the case in most towns) too late to save the house in which the fire has originated; but, under proper arrangements, I believe the fire might almost always be prevented (notwithstanding the scarcity of water) from spreading to the adjoining houses, as it very often does. There is at present no order or organization in the means employed for the extinction of fire at Bombay: half a dozen different people are seen giving contradictory orders, and every one who gets hold of an engine misapplying it as his fancy leads him. I have no hesitation in saying that the majority of fires I have been present at in Bombay would have stopped just as soon without the attendance of the engines and the accompanying mob, and that the damage done to the adjacent property would have been infinitely less had they been absent.

312. The first thing to be done by the person in charge on reaching a fire is to see whether the building in which it has originated is past saving or no; and this any one accustomed to such matters can generally tell at a glance. At the same time, assistants should be despatched to examine the side and rear of the house on fire, and to report immediately regarding the means of getting fire-engines in; the extent of the fire on each side; the number and position of the openings in the wall of the burning house through which danger to the adjoining houses is to be apprehended; and the circumstances of the adjoining houses as regards their liability to catch fire from such openings, or from the roof eaves of the burning house. The engines should then be disposed, and the supply of water husbanded accordingly. The Police should bar access to the street above and below the fire, and keep back all not actually employed in working the engines. An intelligent officer should be charged with the arrangements for facilitating the supply of water: a good map of the town would show where the nearest wells were situated, and if any were within a reasonable distance, chains of men should be formed to pass the full and supply water buckets backwards and forwards between the fire and the wells. This is a very common expedient in England, and as it is a far more rapid mode of transmission than the bheesties' bullocks, it is strange that it should never have been adopted in Bombay.

313. The officer in charge of the arrangements at a fire should distribute the fire-engines about the building, entrusting each, with particular instructions, to an intelligent subordinate; and an assistant should constantly visit the different engines, to see that such instructions are punctually followed.

314. Fire-engines cannot throw a jet to a greater height than 50 feet; when a large building is thoroughly alight above this height, there is little chance of saving it—at any rate the evil is beyond the reach of the fire-engine in the street. If the fire is not too far gone to render such a course unwarrantably hazardous, the best thing to do in such cases is to have a chain of men extended up the stairs to the part on fire, for handing full buckets up,

and empty buckets down; and if, in addition to this, a light portable engine was always brought, which might be lifted up the stairs to use the water supplied by the chain of men, many fires might be extinguished that are beyond the reach of the heavy engines. The Phillip's patent portable fire annihilator would also be very useful under such circumstances.

315. Portable engines would be also very serviceable to carry up to the upper windows of the adjoining houses, which command the eaves or other dangerous portions of the burning house, and the tanks of such little engine (if the height was not too great, might be kept full, by hose extended from the large ones below.

316. If the house in which the fire has originated is past saving, (as is often the case before the engines arrive,) the principal object to be kept in view will be to prevent the fire spreading to the adjoining houses: each side of the burning house must be closely watched; but the principal danger is of course to be apprehended on the side from which the wind blows.

317. Nearly all the water obtainable should be accumulated and carefully husbanded on this side. The most powerful of the engines with their tanks ready filled should be placed so as to command the eaves and openings of this side; and whenever the flames burst out from any such opening, in a manner to threaten the adjoining house, the nozles of half a dozen engines should be immediately directed on this one point, and this will always be found sufficient to drive the fire back for some time from a point of such limited extent. Directly the flames are driven back, the engines should be stopped, and the water again husbanded till danger manifests itself from some other opening. To direct the engines against a dead wall, or into such a mass of flames as a hopelessly ignited house presents, is a mere waste of water; the faster such a house burns the better, for when once its roof has fallen in the fire is confined within its walls, and the adjacent houses are comparatively safe.

318. The following is a statement of the number of engines at present kept up in Bombay, and of the establishment maintained for taking charge of them. Some private engines, regarding which I have been unable to obtain particulars, are not included :—

In whose charge, and where.	No. of Engines.	Establishment.	Annual Cost of Establishment.
			Rs. a. p.
Director of Fire-engines.			
Bombay Green............ 14 Gun Carriage Manufactory.. 2 Mazagon Powder Works.... 2 Parell Government House.. 1 Marine Lines .... 1 Boree Bunder Native Lines. 1 Government Cooperage .... 1 Staff Lines .... 1 Fort Custom House........ 1 Commissariat Stores 1	25	Director of Fire-engines Rs. 60; one English Assistant Rs. 50, with Rs. 30 for house rent, and Rs. 15 for horse allowance; Office establishment Rs. 30, with Rs. 15 for stationery; two Tindals at Rs. 9-8-0 each; one Syrang at Rs. 20; and 34 Lascars at Rs. 6 each per mensem; contingent charges per month Rs. 43-14-6.....	5,842 14 0
Superintendent of Police.			
Bhendy Bazar .... 1 Commatee Poora .... 2 Musjid Bunder .... 2 Mazagon Police Office...... 1 Mahim Police Office........ 1	7	6 Tindals at Rs. 7 each, and 53 Lascars at Rs. 5 each for fair season; 4 Tindals and 34 Lascars at the above rates respectively for monsoon. 5 Lascars out of these go every day on board the Police Hulk, and each receives remuneration, Rs. 1 in the fair season, and Rs. 2 in monsoon. Monthly cost for fair season Rs. 312, and for monsoon Rs. 208; contingent charges per month Rs. 13............	3,484 0 0
Colaba Land and Press Companies.			
Grant Buildings.......... 2 Cotton Screws............ 2	4	4 Lascars at Rs. 7 each per mensem.............	336 0 0
Dock Yard.			
Fort.................... 6 Mazagon 1	7	No establishment; but 2 Lascars out of the Dock Yard establishment look after them occasionally..............	......
Munguldass Nathoobhoy Sett.			
Sheik Memon Street 1	1	2 Lascars at Rs. 6 each...	144 0 0
		Annual Total..	9,806 14 0

319. It will be seen that there is no lack of fire-engines at Bombay, as far as mere number is concerned, but unfortunately they are of different sizes, and when it is wanted to join several lengths of suction hose to reach a well, it is often found that the hoses at hand will not fit each other. This might be

partially remedied by providing each engine with short lengths of connecting hose, by which the different sizes might be joined together.

320. It will be also seen that on the Director of Fire-engines' establishment, the number of lascars is only 34 for 25 engines, or less than one and a half lascar per engine, while on the fire establishment of the Superintendent of Police the number is 53 for only 7 engines, or nearly 8 lascars per engine, being more than five times the proportion allowed in the former establishment. I am not aware of any reason for this difference, but the maintenance of so large a number of lascars appears to me an unnecessary expense. Fires are so rare at Bombay, that few of the lascars get work to do (at fires at least) more than once a fortnight, and under such circumstances workmen naturally become lazy, and incapable of any real work when called upon. I have observed that the engines are always more vigorously worked by labour obtained on the spot (although at present such labour is I believe unremunerated) than by the lascars. On occasions of borrowing engines for emptying public wells I have always found the lascars lazy, querulous, and inefficient, and have considered it preferable to hire labourers to work the engines than to employ them. If the number of lascars were diminished, and the European establishment increased to the extent of the saving thereby effected, a much higher degree of efficiency would be obtained than under the existing arrangements.

321. Not having a proportion of the engines horsed is a very false economy, for in cases of fire an early arrival on the spot is everything ; 6 engines horsed, maintained in good order, handled by trained men, and posted in some central position, would be worth three times as much as the 44 at present maintained on an inefficient footing.

322. There are few fires a single bucket full of water would not have extinguished if judiciously applied at the commencement. A light apparatus on the spot is therefore always of more utility than a heavy engine at a distance ; there should, therefore, be light engines, merely for immediate use, kept at the different Police stations, in the Dockyard, and other public establishments; but it must be remembered that an engine is of no use without water, and whenever an engine is kept up for the security of a public building in Bombay, it is desirable to have two or three water hogsheads on wheels, kept always full, to afford such engine an immediate supply at any moment, otherwise this light engine will be of little use. The heavy engines will probably arrive as soon after the alarm as the bheesties.

323. A city containing a population of above half a million, and so large an amount of valuable property as Bombay, ought unquestionably to possess a fire brigade, and the head quarters of such brigade should be in as central a position as possible. The most central position from the Fort and Native Town would be Fort George ; and the best material for a fire brigade at Bombay would be the company of European artillery always quartered there. One or two

non-commissioned officers from the regiment of artillery might be trained to the special duties incidental to the extinction of fire, and might remain permanently attached to the garrison; the change in the gunners merely would be of no consequence, as a trained artilleryman would always, under proper direction, be an efficient fireman.

324. I think that six engines would be sufficient to have constantly horsed, and each engine should have two water hogsheads on wheels (always full) attached to it, to supply water until the bheesties got up. A first class engine requires 26 men to work it; but for merely working the handles, a large proportion of untrained labour is always admissable. The horses required for this purpose might also be lightly worked on other Government purposes for which bullock draft is at present employed, such as the carriage of stores between the Gun Carriage Manufactory and the Arsenal, or they might be used as bullocks are, I believe, at present, in drawing the guns out to the garrison parade ground, when salutes are required, or on the occasion of brigade parades.

325. A difference of time of five minutes in the arrival of assistance at a fire may make many lakhs' difference in the amount of damage done: in one case the fire will be nipped in the bud, in the other it will have attained a head which will baffle all the force that can be brought against it. To secure the early arrival of engines on the spot, two things are necessary—1*st*, that the alarm should be communicated to the central station with the utmost practicable rapidity, that is to say by the electric telegraph; and 2*nd*, that by a proportion of the engines being always ready, and efficiently horsed, assistance may be brought to the spot in the shortest possible time after the alarm is given.

326. The use of the electric telegraph in connection with fire establishments is rapidly extending. In the principal towns of the United States, systems of electric telegraphs have been constructed, by means of which notice of the breaking out of a fire is immediately telegraphed to all the fire-engine stations. The arrangements for the purpose are as follows:—

327. "A town is divided into certain districts. In each district one or more electric telegraphs are placed, communicating with a central station. From this central station wires diverge to all the principal establishments where fire-engines are kept.

"As soon as a fire breaks out, information is sent to the central Police station. From this central station communications are instantly despatched by telegraph to all the fire-engine stations. These engines start immediately to the scene of the fire. Assistance is thus despatched forthwith, and no delay arises from uncertainty as to the exact locality of the fire."

328. The construction of a line of electric telegraph from the Mazagon Police Office to that of the Fort, with a branch to the Mombadavee and Null Police Station, and another to Fort George, would be by no means a costly improvement. Lines of electric telegraph are now completed on some of the

Continental lines of railway, at the rate of £11 (Rs. 110) per mile. The line itself, as generally laid down on the Continent, consists of nothing more than a *single* thick iron wire,* such as is used for wire fencing, supported on posts, these supports being the principal expense.

329. In Bombay, such posts might in the town itself be dispensed with, and the wire supported along the walls and weather boards of the houses. The expense of the apparatus at Fort George, Mazagon Police Office, the Null and Mombadavee Police Chowkey, and the Fort Police Office, need not be more than £15 or 20 each, or £100 for the whole. The indications of Brequest's telegraph (the one generally used in France) are so simple in their action, that a European Constable would learn how to use them in a few hours. They consist of two indicators or revolving vanes, placed side by side, which can each be made to rest in any one of eight different positions in the circle. In collocation they are therefore capable of transmitting 8×8 or 64 *primary* signals, and each such signal might stand for the name of a particular street. In case of any disturbance, such telegraph might be also useful for Police purposes. It is found worth while to employ the electric telegraph on communications of much more trifling length than this. The Directors of the Bank of England have lately caused to be erected throughout their buildings a system of electric telegraph, to communicate between the different departments of that establishment.

330. I shall now proceed to consider the means by which a larger supply of water might be rendered available for the extinction of fire.

331. It is of the greatest importance that the source of supply should be as near as possible to the fire. The public sources of water supply are few compared with the number of private wells within the tenements of the inhabitants; it is therefore desirable that in cases of fire the nearest private wells should be made available to its extinction.

332. This end might be secured by enacting that all such wells should be registered, and that a board should be affixed to the outside of each house possessing one, stating the distance of the well, and its, depth in feet: this would be a guide for the length of suction hose required for reaching the water. It should be further enacted, that whenever a fire occurs in the neighbourhood, the owner of the adjacent well should allow a European Constable to bring in and insert in the well a sufficient length of suction hose to reach from the street to the water, the height of the water in the well being measured before and after pumping from it, and the owner either remunerated on account of the water used, or such amount replaced by water carriers, at the public expense. If the insertion of a leather hose in a well was considered objectionable, on religious grounds, gutta percha or vulcanized India rubber might be substituted ; the objection formerly made to the use of leather in the valves of pumps might be similarly obviated.

* This is the type that has been followed by Dr. O'Shaughnessy in his India electric telegraph.

333. Another way of rendering the existing water supply more available than at present in case of fire, would be to have the water carts used for watering the roads (which exceed 100 in number) left at night full of water in convenient situations, where the bullocks that draw them, and the drivers, might be also housed. By such an arrangement a supply of water for commencing with would always be rendered available in much less time than it takes to get any bheesties to work.

334. But after all, the only efficient arrangement by which a sufficient supply of water can be rendered at all hours available to the extinction of fires breaking out in the town, is the laying down of a system of pipes always charged with water, and extending to every street.

335. It has been proposed to obtain this desideratum by pumping up salt water by steam power from the sea face of the town to some elevated reservoir, from which a supply might be diffused by a system of pipes, and be rendered available to the extinction of fire, street watering, &c. in every street of the town. The objection to such a project is its enormous expense, as compared with the benefits it offers.

336. From the table I have given (ante paragraph 42) it will be seen that the cost of laying down the street pipeage is always the principal part of the expense of supplying towns with drinking water, and that the proportion of water used for the extinction of fire, street watering, and sewer flushing, is always extremely small, as compared with the amount required for domestic purposes. It is therefore evident, that it would never be worth while to go to the expense of laying down a system of street pipeage except for the primary object of diffusing a supply of good water for domestic uses. The extinction of fire is merely an incidental application of pipes laid down for a far more important purpose.

337. The most perfect examples of the arrangements by which risk from fire may be diminished is exhibited in the arrangements adopted for that purpose in rebuilding Hamburgh. After the destruction of that city by fire, it was rebuilt chiefly under the direction of Mr. William Lindley, the Engineer, and, as he has avowed, so far as he was allowed, on the principles developed in the reports of the Metropolitan Sanitary Commission. "In those arrangements," say the Committee of Health, "were included works for the total abolition of cesspools, a complete apparatus for the delivery of water into houses, and for the removal of all sewer or soil water. In respect to fires, the arrangements for surface cleansing by the high pressure water jet have been successful, not only in effecting the immediate extinction of purely accidental fires, but they have further afforded means of checking the crime of incendiarism for the sake of insurance money."

338. Mr. Lindley's answers to the Board's queries regarding the provisions against fires adopted in Hamburgh as rebuilt are as follows:—

" Is the jet used at Hamburgh for watering the streets?—Yes; the charge has been 1*d*. per foot of frontage per annum.

" What provision is made with the new system of works which you have laid down for the prevention of fires?—The mains are large,—from 6 to 20 inches diameter,—constantly charged at high pressure, being supplied from the one extremity by two Cornish engines, and at the other level from a high summit reservoir, kept constantly filled. Throughout the whole length of the pipeage are placed, at intervals of 40 yards, fire-plugs of 3 inches diameter in the clear.

" How soon can a jet be applied?—In two minutes. The men who get paid by old custom for the use of their engines will come although they are not wanted, but the power of eight engines may be anywhere applied as quickly as the hose can be screwed on and introduced inside the house where the fire is.

" Have there been fires in buildings in Hamburgh in the portion of the town rebuilt?—Yes, repeatedly. They have all, however, been put out at once. If they had had to wait the usual time for engines and water, say 20 minutes or half an hour, these might all have led to extensive conflagrations.

" What has been the effect on insurance?—The effect of the rapid extinction of fires has brought to light to the citizens of Hamburgh the fact that the greater proportion of their fires are the work of incendiaries, for the sake of the insurance money. A person is absent; smoke is seen to exude; the alarm of fire is given, and the door is forced open, the jet applied, and the fire extinguished immediately. Case after case has occurred, where, upon the fire being extinguished, the arrangements for the spread of the fire are found and made manifest. Several of this class of incendiaries for the insurance money are now in prison. The saving of money alone, by the prevention of fires, would be worth the whole expense of the like arrangements in London, where it is well known that similar practices prevail extensively."

339. The statistics of London fires prove that the general adoption of house insurance has occasioned a startling amount of incendiarism. In London the proportion of houses insured is considerably under 50 per cent. of the whole number of houses, and with fair play the number of fires of houses insured would be therefore less than the number of fires in uninsured houses; but instead of being less, it is actually enormously greater, the number of insured houses burnt being more than four times as many as the uninsured fires. This startling result has led to the revival of the practice of holding Coroner's inquests on fires, with a view to determine their cause; and the detection and punishment of a considerable number of incendiaries has been the result of such inquiries.

340. The following is from the last report of the General Board of Health on the subject of water supply:—

" From a return made by Mr. Braidwood of the houses and properties destroyed in the metropolis, in the three years ending in 1849 inclusive, it appears that the total number was 1,111; of contents destroyed (which, being generally insured separately, should be kept distinct,) there were 1,013: of these—

	Insured.	Uninsured.
Houses......	914	197
Contents	609	404
Total....	1,523	601

"The proportion per cent. of the uninsured to the insured would be :—

		Insured.	Uninsured.	Total.
		Per cent.	Per cent.	
Houses......	1,111	82·3	17·7	100
Contents	1,013	60·1	39·9	100
	2,124	71·7	28·3	100

"The frequency of fires led Mr. Payne, the Coroner of the city of London, to revive the exercise of the Coroner's function of inquiring into the causes of fires most usefully. Out of 58 inquests held by him (in the city of London and the borough of Southwark, which comprise only one-eighteenth of the houses of the metropolis,) since 1845, it appears that 8 were proved to be wilful; 27 apparently accidental, and 23 from causes unknown, including suspicious causes. The proportion of ascertained wilful fires was therefore 23 per cent., which gives strong confirmation to the indications presented by the statistical returns as to the excess of insured property burnt above uninsured.

"The increasing frequency of destructive fires at Liverpool about five years ago led to a close inquiry into their causes by Mr. Rushton, the Magistrate, when he was led to the conclusion that a considerable proportion of them were wilful, the offence having been committed to conceal extensive depredations on warehouse property."

341. There is not at Bombay the same urgent occasion for such inquiries as there appears to be at London, but I think they would be valuable in this island, in leading to the ascertainment and record of the most common causes of fire. I am much puzzled to account for the extraordinary liability of particular localities to fire. For instance, fires have for some time occurred almost annually in the two blocks of houses adjoining the Green Market, and I am not aware of any peculiarities in the use or construction of these houses that could have led to such a result.

342. The number of fires annually occurring in Bombay is so small, as compared with our population, that at first sight it appears to admit of question

whether the money value of the property they destroy is of sufficient amount to warrant either further outlay or any further legislative provision, with the object of rendering the risk from fire still smaller than at present.

343. I should answer this question by pointing out that though the causes occasioning the breaking out of fires are much fewer in India than in England, on the other hand the inflammable nature of our buildings, and the want of all organized means for the extinction of fire when it does occur, renders a general conflagration a much more probable contingency in Bombay than it has been at London any time since the great fire of 1666.

344. Certain predisposing causes must exist before any great conflagration or great pestilence can occur in a town, and in the city of Bombay these causes are all present, and all increasing. It is true that such causes have been so present for many years without either pestilence or conflagration having *yet* occurred, but that does not at all prove that no danger exists, or relieve those in authority from the responsibility of making due provision for the safety of the community. The history of all such visitations clearly proves that all these causes may exist in a town, remain unaccountably inoperative for a long period of years, and then suddenly (from some concurrence of circumstances, or aggregation of predisposing causes, the mode of action of which we cannot clearly trace,) start into action, and carry off at a blow a third of the inhabitants of the city attacked, or destroy an equal proportion of their habitations. Prior to the rebuilding and improved ventilation of London, occasioned by the great fire, the plague was as common in London, and seems not to have been more destructive than the visitations of cholera have *hitherto* been at Bombay; but in 1665, it suddenly blazed up, and swept off a third of the population of the place in a few months, as cholera *has done* in some instances in India, and as it will probably *yet do* some day at Bombay, unless more attention is paid to the sanitary improvement of the town than at present.

345. The great fires of London and Hamburgh were without precedent in both those cities. *Since* the destruction of the latter town by fire, its inhabitants have taken measures, in rebuilding it, which render the recurrence of such an event an impossibility; but how much loss of life and treasure would have been saved if *they had taken the same precaution a few years earlier!*

H. Conybeare,
Superintendent of Repairs.

Bombay, Superintendent of Repairs' Office, 22nd December 1852.

POSTSCRIPT.

1. It has occurred to me that a short abstract of what has subsequently been published by the Bengal Government on the subject of the water supply of Calcutta would be a useful addition to the foregoing report. It will at any rate show what is considered, by high civil engineering authority, to be the probable cost per head of providing and distributing a supply of water to an Indian presidency population.

2. The compilation in question (No. X. of "Selections from the Records of the Bengal Government") was published in 1853, and consists of a report on the establishment of water-works to supply the city of Calcutta, by F. W. Simms, Esq., C. E., Consulting Engineer to the Government of India, dated the 27th of February 1847; of estimates for water-works for supplying the European quarter of Calcutta, framed in 1852 by Mr. Hawksley (the Engineer to the Nottingham Water-works, and a high authority on such matters,) in conjunction with Brevet Captain Young, of the Bengal Engineers; and of a memorandum from Dr. Pearson, the Presidency Surgeon at Calcutta, urging on Government the necessity of adopting a plan for supplying Calcutta with pure water, and an improved system of drainage,—estimating the cost of the necessary works at 70 lakhs, and proposing that a loan, to be called the Calcutta Improvement Loan, should be raised for the purpose, the interest of which should be paid by an additional house assessment.

3. Mr. Simms' report was called for by Sir T. H. Maddock, Governor of Bengal, and is dated 27th February 1847. The source of supply he recommends is the river Hooghly near Pultha Ghaut, a point above the influence of salt-water, and 18 miles above Fort William at Calcutta, measured along the centre of the river.

4. At this point the water is to be taken through a suction pipe from about the centre of the river, and pumped up by steam-engines into two slightly elevated reservoirs, from which it descends by an aqueduct 13½ miles in length, running along the Barrackpoor road to Ballygatchea, the northern suburb of Calcutta, where the water is to be delivered and purified, and whence its distribution through the city is to take place.

5. Such must unquestionably be the general outline of any practicable plan for the water supply of Calcutta; but the cost of executing such plan will depend—1*st*, on whether the whole, or only a portion, of the city is to be supplied, or rather on the number of the population which is to be supplied; and 2*nd*, on how many gallons per day is to be provided per head of the population to be supplied.

6. As regards the 1*st*, Mr. Simms considers that the whole city should be

supplied; and after citing all the data obtainable on the subject, he shows that the total population of Calcutta at the present time "may be assumed, with sufficient accuracy for practical purposes, as numbering 230,000 souls," or rather less than half the population of Bombay.* *2ndly*, he considers that this population should be supplied at the rate of 30 gallons per head per day: the total daily consumption for a population of 230,000 would be, therefore, 6,900,000 gallons daily, and the works required for the obtainment and distribution of this quantity of water he enumerates as follows:—

7. *Works at Pultha Ghaut.*—Two circular reservoirs, 1,000 feet diameter, and 12 feet deep, and containing about 9,000,000 cubic feet of water each, the bottom of such reservoirs to be raised 12 feet above the present level of the ground, and a steam-engine of 200 horse-power to be provided, with the necessary pumps for raising the water from the river to the reservoir.

8. *Aqueduct.*—For the conveyance of the water from the Pultha Ghaut reservoir to the centre of distribution at Ballygatchea, 13½ miles distant, Mr. Simms recommends an open conduit, running along the Barrackpoor road, as he considers an iron main pipe would be too expensive an expedient.

9. *Works at Ballygatchea.*—"The water brought down by the aqueduct should be capable of being turned into either of the duplicate basins at this place, and from thence pumped into extensive filters, where it would be freed from its impurities, and rendered fit for use. After filtration the fluid would pass into one or more reservoirs, capable of containing at least one week's supply. From thence the water would be forced by steam power into mains leading through the city, with a pressure that would deliver it into elevated cisterns in each house." Two engines of 150 horse-power each would be required for the purpose.

10. *Distributing Mains and Pipes.*—From the centre of distribution at Ballygatchea, three mains are to diverge, traversing the city parallel to each other and to the general course of the river; of these the "Eastern Main" would run along the Upper and Lower Circular Roads; the "Western Main" along

* In 1821, four Assessors were employed to make a Census of Calcutta, and they returned the total number of inhabitants at 179,917; shortly after, the Magistrates made a report, in which they estimated the fixed residents at 230,552, which conclusion they arrived at from knowing the number of houses of each class, and allowing a certain number of inmates to each house. *Secondly*, the same authorities by other means make the fixed residents amount to 205,600. In 1837 the Superintendent of Police made a Census, (given in Mr. Simms' Appendix,) whereby the population were shown to be 229,714, nearly agreeing with the Magistrates' calculation of 16 years before; and on reference to the assessment book it is found that the number of houses and huts had been stationary during the interval. Mr. Simms considers that no increase has since taken place, and few persons have had the opportunities of arriving at correct conclusions on the subject which Mr. Simms must have enjoyed in preparing his elaborate surveys of the city of Calcutta.

Captain Young, of the Bengal Engineers, estimates the population of the "European Quarter" of Calcutta in 1852 as follows:—Europeans and Eurasians 11,000; Mahomedans and Hindoos 90,000; total 101,000.

the Shaum Bazar Street, Chitpore Road, Cossitollah Street, and along the Chowringhee Road to the Lower Circular Road, to the south-east extremity of the midan; while the "Central Main Pipe" would pass between these, along Tuntunah Bazar, College Street, Wellington Street, Wellesley Street, and Wood Street or Camac Street to the Lower Circular Road. The aggregate length of these mains would be 14 miles, 5 furlongs, and 23 yards.

11. From these main arteries would diverge the smaller mains required for 70 miles 4 furlongs and 19 yards of street, and 57 miles of lane, making a total of 142 miles, 1 furlong, and 42 yards of mains of different sizes.

12. Mr. Simms estimates the cost as follows:—

Works at Pultha Ghaut and Ballygatchea, and aqueduct, the whole 13½ miles	£159,861
Distribution by mains and pipes through the city, 142 miles, 1 furlong, 42 yards	510,336
Total outlay in the first instance	£670,197

Exclusive of "*house* service," which must be paid for by the landlords.

PROBABLE INCOME.

13. All houses to be compelled to pay water-rates as follows:—

Supplied by Water laid on within the Dwellings.	
6,000 two and three-storied houses, averaged at per mensem Rs. 8	Rs. 48,000
9,000 one-storied houses, average Rs. 4	36,000
Supplied from Stand-pipes in the Streets.	
51,000 huts, average each 4 annas	12,750
Per mensem	Rs. 96,750

Or in round numbers £116,100 per annum.

Deduct working expenses, estimated at Rs. 55,480 per annum, Rs. 60,317 will remain for profit, being an interest of about 9 per cent. on the capital.

14. In addition to this, Mr. Simms estimates the cost of the house service pipes, cocks, and cisterns, required for the delivery and receipt of the water in the houses to which water is laid on, at 25 lakhs; this is, however, in all cases a charge on the landlords. If it is to be done by the water company, there must be an equivalent increase in the capital of the company, and in the rates levied on the class of houses so supplied.

15. In 1852, Captain Young, of the Bengal Engineers, then on furlough to England, submitted Mr. Simms' report to Mr. Hawksley, Engineer of the Nottingham Water-works, and a high authority on the subject of water-works, and from the data, &c. furnished him by Captain Young, Mr. Hawksley prepared the following rough estimates of the cost of supplying a portion of Calcutta, (the European quarter,) containing a population of 100,000, (about

a fifth of the population of Bombay,) with 20 gallons per head daily (Mr. Simms' estimates having been for supplying 230,000 persons with 30 gallons daily).

16. The plan is the same as Mr. Simms', but on a smaller scale, (the amount of water delivery being only as 3 to 7 when compared with Mr. Simms',) and it is estimated at lower rates. As in Mr. Simms' plan, the water is to be raised from the river at Pultha Ghaut, and delivered to Calcutta from Ballygatchea.

17. The estimate is as follows :—

1st.—Engine power at Pultha :	
Three engines of 20 horse-power, with pumps, buildings, sluices, &c. &c., costing in England £105 per horse-power, say in India £210 per horse-power	£12,600
2nd.—Three subsiding and regulating tanks, each capable of holding 1 tide of water = 1,500,000 × 3 = 4,500,000 gallons, say each 60 yards square and 3 yards deep, 10,000 yards of surface, at 10*s*	5,000
3rd.—Thirteen and a half miles of 48-inch conduit, 9 inches thick, brick-work, 12*s*., cutting and filling 8*s*., puddling, &c. 13½ × 1,760 × £1	22,760
4th.—Four filter beds, each to filter 100,000 gallons per day, say each 40 yards square, 40 × 40 × 4 = 6,400, at 15*s*	4,800
5th.—Two pure water tanks to receive the filtered water, and to be arched over to protect it from solar influence, dust, &c., each to contain 1,000,000 gallons, say 50 × 50 × 2 = 5,000 yards, at 20*s*	5,000
6th.—Two hundred horse-power, as before, at £210	42,000
7th.—Sixty miles of pipe, at £800	48,000
	£140,160
Including contingencies	160,000
Add value of land, if not provided by Government*	12,818
	£172,818

(Signed) T. Hawksley.

" C. B. Young, Capt., Bengal Engineers.

18. Captain Young estimates the returns from water-rates at £15,475 per annum for the population of 100,000 supplied, and the working expenses at £4,000 per annum.

19. The Calcutta Municipal Commissioners, in communicating to Government on the subject of the estimates of Mr. Simms, and of Messrs. Hawksley and Young, fall into the extraordinary error of comparing the two schemes as

* The value of the land required is estimated by the Calcutta Revenue Board at £12,818.

if the scope of each was identical: they say that "the two plans differ in no essential except that of cost"; and they state that Messrs. Hawksley and Young's estimate provides "for the same identical work as Mr. Simms'."

20. A glance at the two estimates will show that this is not the case. Mr. Simms' estimate is for supplying the whole city of Calcutta, Messrs. Hawksley and Young's for only supplying a portion of that city, containing a population of 100,000 only; the daily water delivery provided for in Mr. Simms' estimate is about 70,000,000 gallons, whereas the other estimate provides for only 30,000,000 daily.

21. Mr. Hawksley is, however, a much higher authority on the subject of water-works than Mr. Simms, and his estimates have the advantage of having been framed five years later; in fact, at the date of Mr. Simms' report, the principles of water supply were (comparatively speaking) very imperfectly understood. We may therefore accept Messrs. Hawksley and Young's scheme as the most reliable of the two, and proceed to compare the cost per head of the supply as estimated by those gentlemen with the rate exhibited in the returns made to Parliament by the nine water companies that supply London.

22. Messrs. Hawksley and Young's rough estimate for the supply of a population of 100,000 persons, exclusive of house service, amounts to Rs. 17,23,189, including the cost of land, but exclusive of engineering superintendence and many other incidental charges, which would probably raise the total to little under 20 lakhs. We will, however, take it at only Rs. 17,20,000, and this will be £1 14*s.* 4*d.* per head of the population supplied. This rate is a very moderate one for a water supply raised by steam power from a river. Of the nine London water companies, the cost of the most expensive (the Grand Junction Company) has been at the rate of £4 15*s.* 3*d.* per head of the population supplied, the cost of the cheapest (the Southwark and Vauxhall Water Company) £1 12*s.* per head, and the average cost of the nine £2 5*s.* 9*d.* per head. Messrs. Hawksley's and Young's rate for Calcutta is, therefore, nearly as low as the lowest in London: taking local circumstances into consideration, a much higher rate might have been anticipated, for it must be remembered that all the piping, steam-engines, and other machinery have to be brought from England, and that the expense of working steam-engines at Calcutta must be at least twice as great as in London.

23. The expenses of management and working of the nine London water companies ranges from 2*s.* 5*d.* to 7*s.* 10*d.* per head of the population supplied, averaging 4*s.* Captain Young estimates the working charges at Calcutta at only 9½*d.* per head, a rate which seems to me impracticably low for any water works not on the gravitation principle,—*i. e.* that employ steam power at one or more points to raise the water to a proper level.

24. Let us now see what is the bearing of these Calcutta reports on the water question at Bombay, as regards the quantity to be supplied daily to each individual, and the cost of such supply per head. Mr. Simms calculates the requirements

of Calcutta at 30 gallons per head per day for *all purposes*. Mr. Hawksley and Captain Young calculate the daily requirements of a population of 100,000 at 2,000,000 gallons for house consumption, and 1,000,000 gallons for public purposes (street watering, sewer flushing, fire extinction, &c.,) making a total of 3,000,000 gallons daily for a population of a lakh, being at the same rate as Mr. Simms', viz. 30 gallons per head per day; and a glance at the map of Calcutta will show that the existing sources of supply in that capital are much more abundant than is the case at Bombay. These subsequently published Calcutta estimates confirm, therefore, what I have said in paras. 281 and 282 of the foregoing report, " that 20 gallons per head per day is the minimum that any engineer or practical man acquainted with the subject has ever recommended in designing water-works for any town"; and again " that I was certain that no English engineer at all conversant with the subject would, in designing works for the supply of Bombay, calculate the additional amount required under existing circumstances at less than 20 gallons per head per day." It may therefore, I think, be conceded, that the main conduit, and all other portions of the proposed Bombay water-works, that would not admit of future addition, should be constructed, in the first instance, of capacity at least adequate to the supply of 20 gallons per head per day for a population of half a million; for though the census may possibly have over-rated our present population in stating that it is so high as this already, there can be doubt that the extension of railways and electric telegraphs from the port of Bombay into the interior will, before very long, augment enormously both the business and the population of the place.

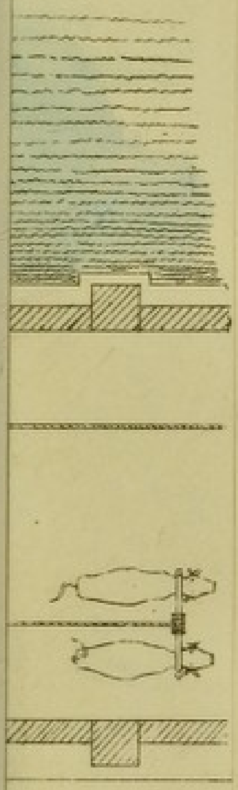
25. In paragraph 283, after stating that the cost per head would diminish with the increase of the number supplied, and citing cases in point, I said that under the most favourable circumstances it would perhaps be possible to construct works for the supply of so large a population as ours at as low a rate as Rs. 5 per head, and at this rate our Bombay water-works would require a capital of 25 lakhs (£250,000).

26. This appears a large amount in the aggregate, but the cost per head, Rs. 5, is very trifling, as compared with the benefit which would be conferred even on the poorest cooly by the introduction of an unlimited supply of good water. The interest of Rs. 5 at 5 per cent. is only 4 annas a year, or 4 pies a month; and I believe that there is scarcely a sweeper in Bombay who would not think the benefit of an abundance of good water cheaply purchased by a monthly payment of 4 pies for each member of his family. To collect such small sums as these would be of course quite out of the question; but I think that a general water-rate, which would press either directly or indirectly on all classes, would be considered a hardship by none, and that were a low *general* water-rate sanctioned by Government, the principal difficulty to getting an English joint stock company to undertake the work would be removed.

27. I think, moreover, that a very large bonus might be collected as an additional inducement to an English joint stock company. I understand that the

NG. III.

is raised fron

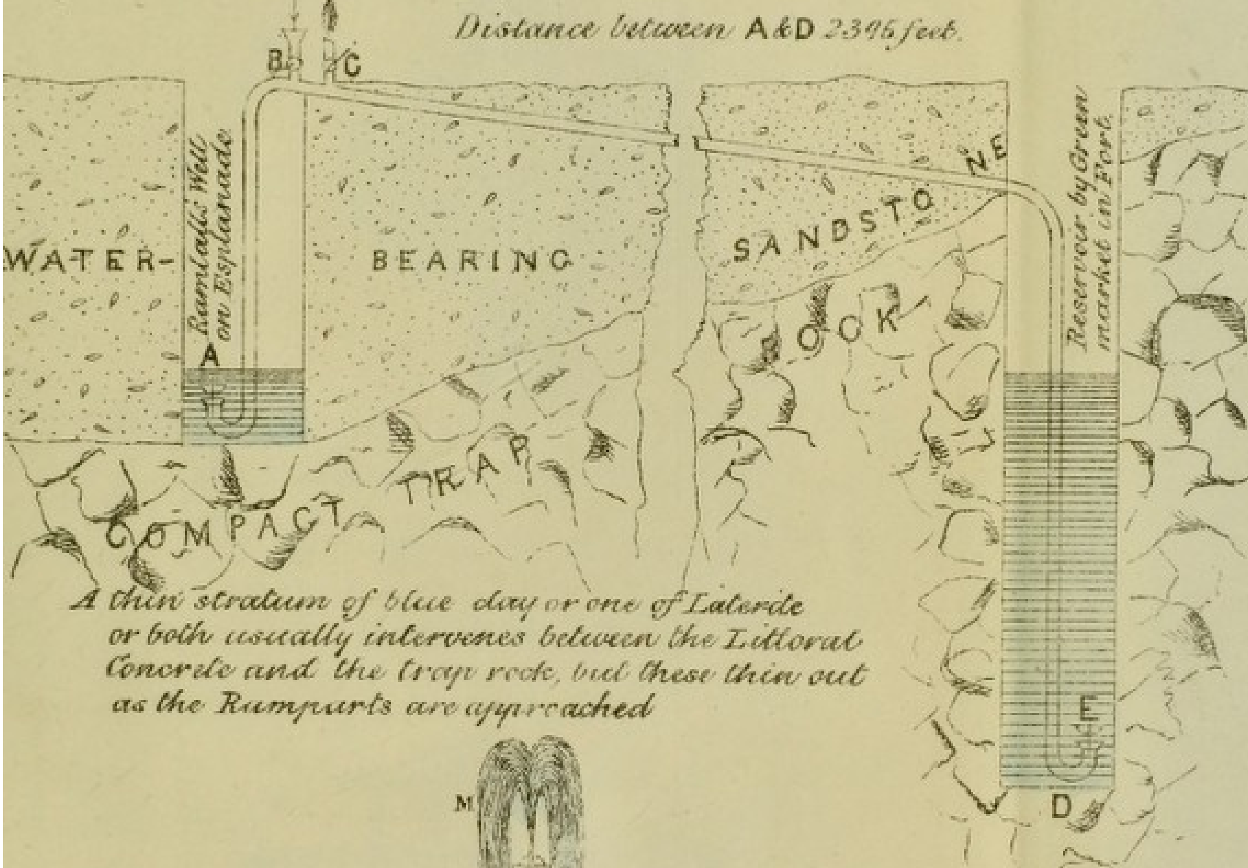


IR.

DRAWING IV.

Fig. 1

diagram of arrangement by which the water of the Sandstone or Littoral Concrete formation might be transferred to distant and waterless localities without the use of steam or animal power, by means of Siphon pipes (see paras 226, 227, 228, and 229.)



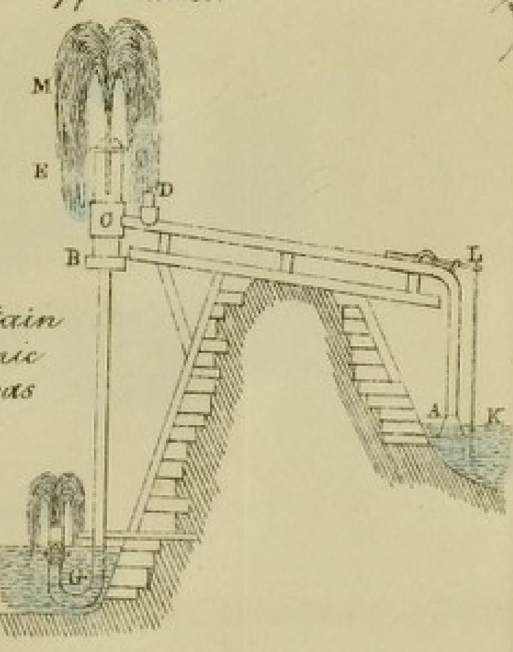


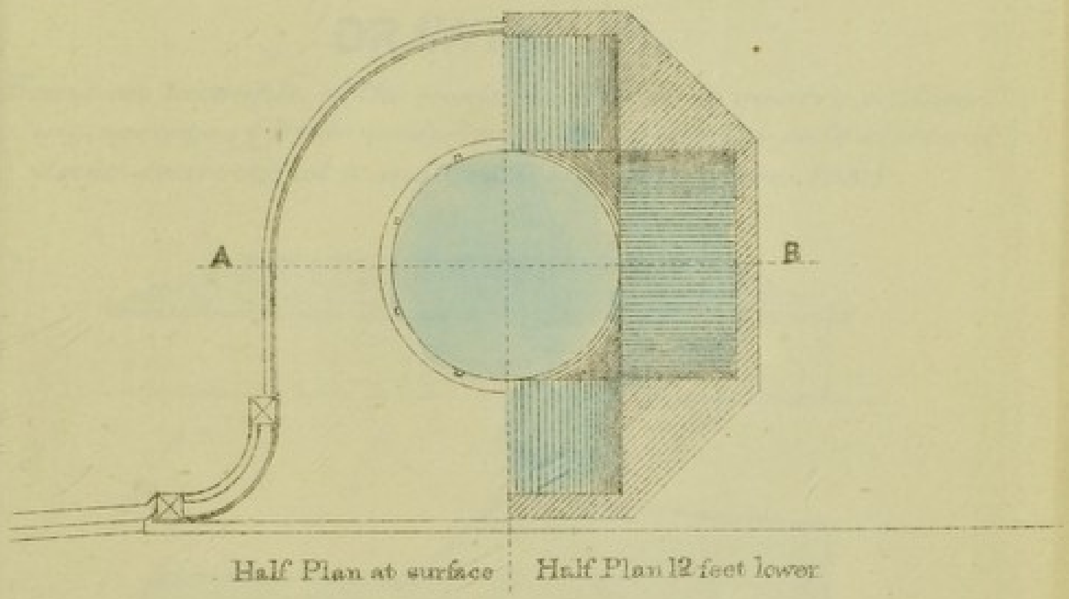
Fig. 2.

Selfacting Siphon Fountain put up at the Polytechnic School at Paris (see paras 230, 231, & 232.)

H. Conybeare

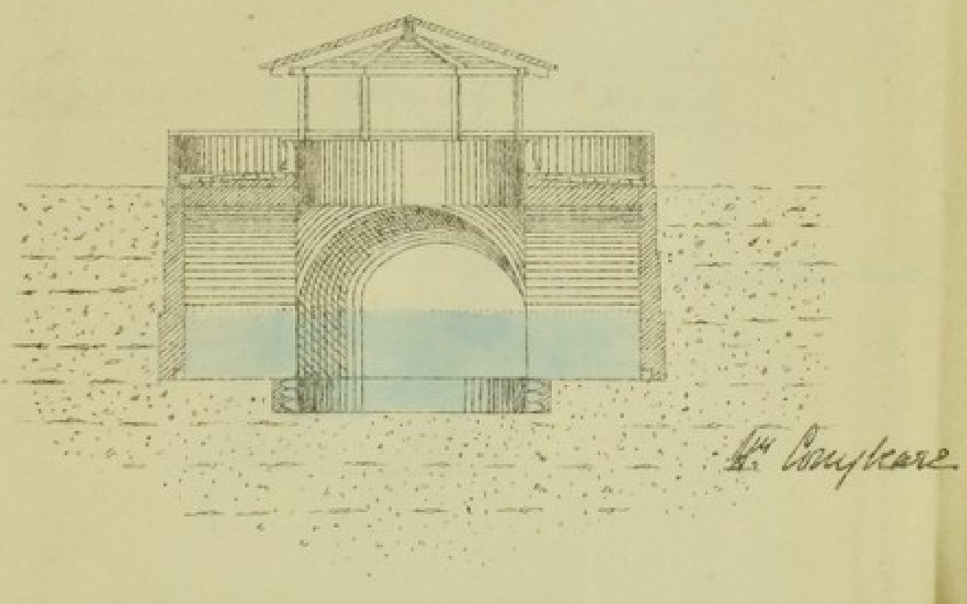
DRAWING V.

Vaulted wells sunk in the water-bearing formation of the Oart Districts in Breach Candy Road, and Girgaum Back Road. (see para 233.)



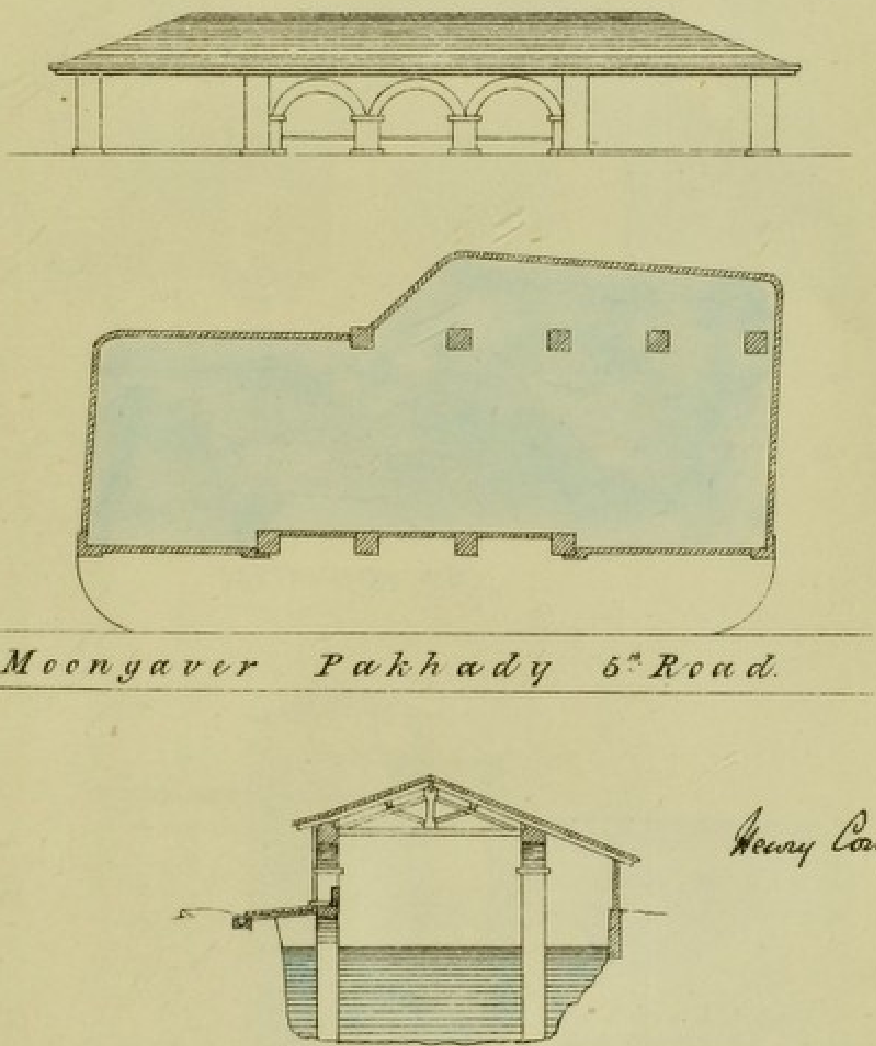
Breach Candy Road

SECTION ON AB



DRAWING VI.

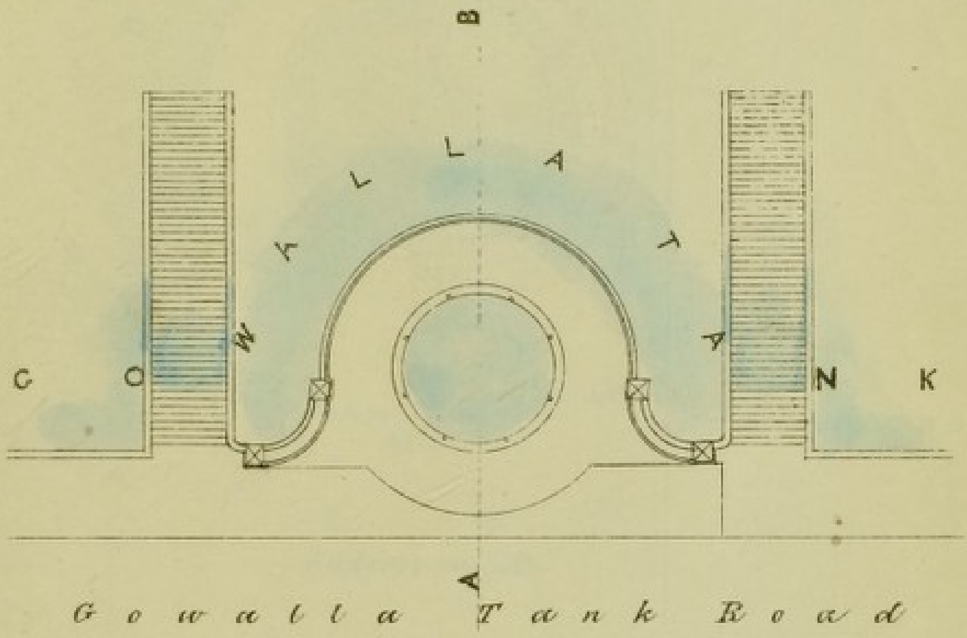
Being an example of the mode in which a quarry containing springs of fresh water may be converted into a covered draw-reservoir, at a moderate cost. (see para 233.)



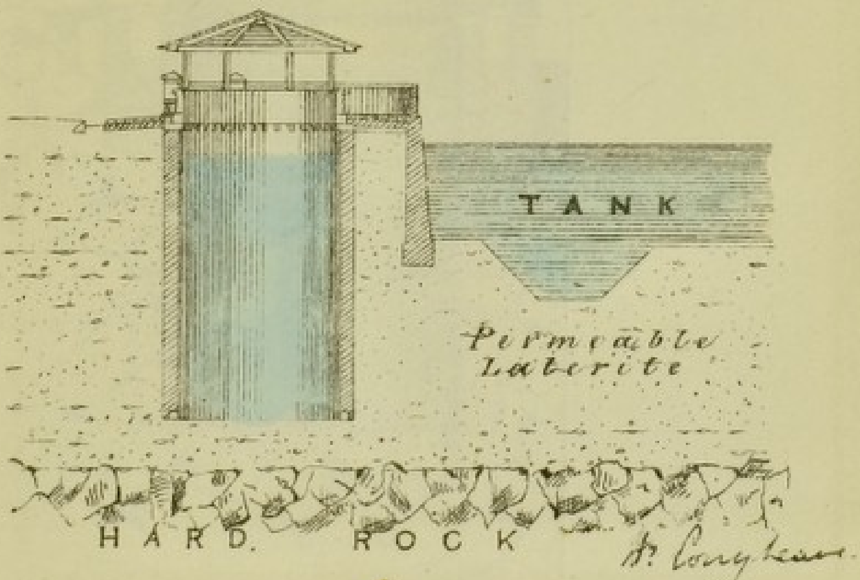
Henry Conybeare

DRAWING VII.

FILTERING WELL IN GOWALLA TANK (*see para 242*)

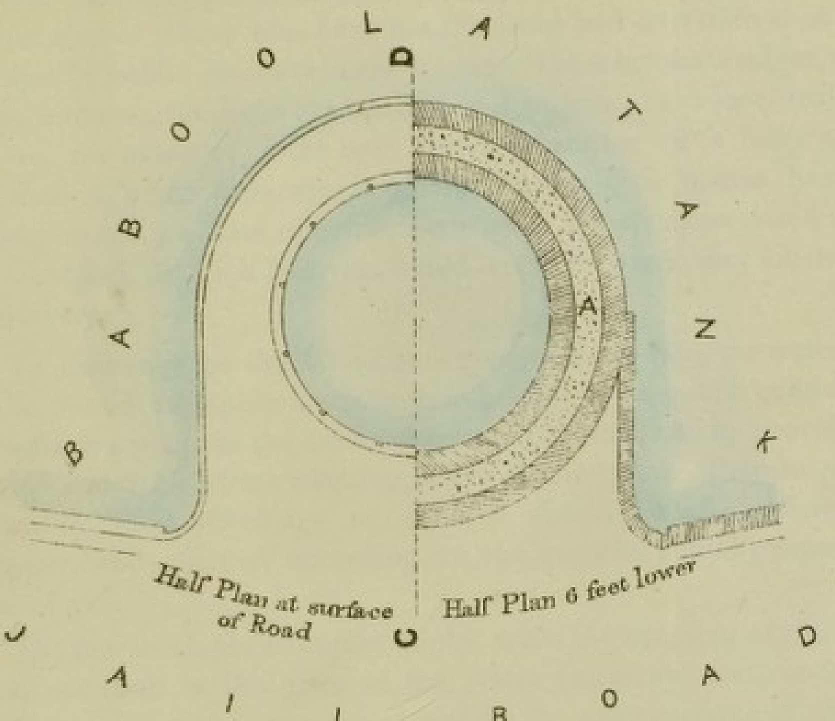


SECTION ON **AB**

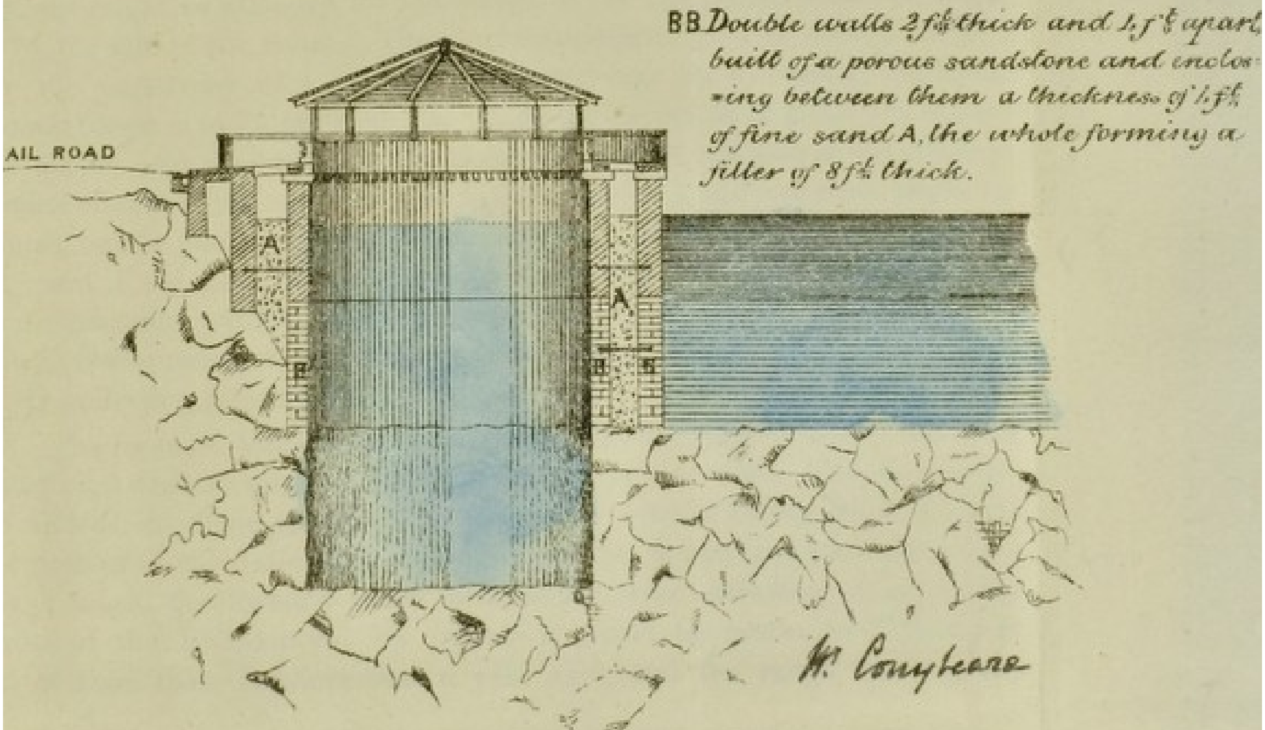


DRAWING VIII.

SED FILTERING WELL IN BABOOLA TANK (*see paras.* 242, 243.)



Section on CD.



Board of Conservancy are prepared on certain conditions to recommend the grant of four lakhs of rupees for such purpose from the Municipal Fund; and this might be very largely increased by subscriptions amongst the richer class of Natives. These might be induced to come forward as follows :—In all towns the poorer classes (those who have not the water laid on within their dwellings) are supplied by public conduits in the streets. These conduits might, at a trifling additional expense, be made ornamental as fountains, each inscribed with, and known by, the name of some one Native subscriber of a large amount. I believe that with the inducement of thus having their names handed down in connection with a class of public benefits so deeply appreciated in India as public fountains, the rich Natives would come forward very liberally, and in large numbers.

28. In exchange for the bonus and general water-rate, the water company should be bound to supply a certain number of these public conduits in each street, to fix fire-plugs in the mains at certain intervals, and to provide a certain amount of water for street watering, sewer flushing, &c. Private parties supplied within their dwellings or gardens should be all furnished with a water-meter, and charged according to the quantity actually consumed, as in the case of gas.

29. Or the local Government might, with the sanction of the Home Authorities, put itself in the place of the water company, and, assisted by the quota of the Board of Conservancy, and by the contributions of rich Natives, might advance the remaining sums required, and undertake the water supply of Bombay in the same manner as works of similar character for purposes of irrigation are undertaken by the Governments of the other Presidencies: reimbursement might be obtained for the outlay, as for the cost of works of irrigation, by the sale of the water. The most convenient mode of doing so would be by the imposition of a general water-rate—say by increasing the house assessment from 5 to 7½ per cent., by which an income of £9,000 per annum might be at once secured; and in this way, and by the sale of the water to the richer classes of the community, a net return of 4½ or 5 per cent. might be reckoned on the portion of the outlay that had been disbursed by Government; and I am sure that the community would think an abundant supply of water cheaply purchased by the imposition of such a rate on so limited a scale. Government would be in a much better position than a private company for collecting rates and enforcing payment.

30. The basin of Vehar is enclosed on all sides by hills, of which those on the north and west are very lofty, precipitous, and well wooded. The neighbourhood affords excellent shooting; and were the interior of the basin and the lower portion of the valley debouching from the Kennery Caves filled by a chain of lakes, the locality would become the most attractive of any in the environs of the Presidency. By railway it would be nearer to Bombay in point of time than Bandora was a year ago; and the range forming the

western boundary of the basin, which must be at least 1,500 feet in height,* would afford sites for a large number of bungalows.

30th March 1854. H. C.

* The theoretical thermometric difference due to a height of 1,500 feet would be only about 4½° (being 1° for every 334 feet), but the actual advantage in temperature is much greater than such a difference would indicate, for at this height we are lifted above the stratum of air heated by contact with the surface, there is always a breeze, and the nights are invariably cool during the seasons in which the nights at Bombay are so unbearably close.

LETTER FROM THE BOARD OF CONSERVANCY, FORWARDING MR. CONYBEARE'S REPORT TO GOVERNMENT.

No. 50 of 1853.

To J. G. Lumsden, Esq.,
Secretary to Government.

Sir,

No. 1679, dated 26th April 1851; No. 2182, dated 10th June 1852; No. 2805, dated 4th August 1852.

In reply to your letter No. 311, dated the 7th February 1852, regarding the supply of water to Bombay, and the several letters from Government noted in the margin, I am directed by the Board of Conservancy to state that your letter No. 1679, with Lieutenant DeLisle's letter annexed, and the plans which accompanied it, was, by a resolution of the Board, dated the 6th May in that year, referred to the Superintendent of Repairs, for his report, as was also, by a resolution of the Board dated the 16th June 1852, your letter No. 2182, with accompaniment, being an extract paragraph 64 of a Despatch from the Honorable the Court of Directors No. 8, dated the 31st March 1852, stating that it was desirable, in considering the question of the supply of water to Bombay generally, Government should give especial attention to the means of providing water for extinguishing fires; and that upon the receipt of your letter No. 2805 above noted, the Superintendent of Repairs was requested by the Board to submit his report without further delay, as communicated to Government in my letter No. 182, dated the 9th of that month.

2. On the 11th of October 1852, pursuant to a resolution of the Board dated that day, the Superintendent of Repairs was desired by the Board to return the papers submitted to him on the subject, either with or without his report, before the 1st of November then next, and on that day the Superintendent of Repairs accordingly returned the same (plans excepted) without any report, stating his reasons for not sending it in in a letter, No. 305 of 1852, a copy of which is annexed.

3. On the day on which this letter was received, Mr. Rivett, then Chairman, having intimated to the Board at their meeting, that the Superintendent of Repairs had informed him that his report on the subject would be ready in three weeks, and Mr. Conybeare having on the 2nd of December 1852 informed the Board that his report would be completed and forwarded to the Board within three weeks from that date, the Board awaited the receipt of it until the 22nd of that month, on which day it was received, and the Board now beg leave to forward the same for the consideration of the Right Honorable the Governor in Council, together with its accompaniments, noted in margin, and to submit the following observations upon the subject:—

Superintendent of Repairs' letter No. 345, dated the 22nd December 1852, and its accompanying Water Report, with Plans.

4. The Board are of opinion that a great additional supply of water is required for the health and comfort of the inhabitants, and that such supply can be best obtained from the valley of Gopur, and in the manner proposed by Captain Crawford and Lieutenant DeLisle.

5. The Board consider that the dam of the proposed reservoir should be so constructed as to admit of its being raised hereafter ; that a filtering bed would be a wise precaution; that the reservoir should be railed in, in order to prevent the access of cattle to it; and that measures should be taken, under the authority of Government, to prevent the occupation of any lands as sites for villages, the drainage from which might find its way into it.

6. The Board have considered Mr. Conybeare's suggestion, that before measures are taken to collect the surface drainage, the spring capabilities of Salsette should be thoroughly investigated; but, independently of the delay that would be occasioned by such investigation, the Board consider that any water which might be derived from springs would be found to be, if not below high-water mark, at so low a level that the water would require to be forced up by machinery, whereas by the proposed lake and filtering bed it would flow on continually, without being raised at a constant annual expense, and supply almost every portion of the Native Town.

7. The Board are of opinion that Mr. Conybeare has greatly overrated the probable consumption, and that 20 gallons per head per diem for the inhabitants, including children, very much exceeds the quantity of additional supply required. The Board also consider that Mr. Conybeare has greatly over-estimated the probable loss by evaporation. The Board find in Part I. Vol. XVII. of the Journal of the Asiatic Society of Bengal, that the rate of evaporation in Calcutta, according to the statement therein contained, and as stated by Mr. Conybeare, is 15 feet per annum. The Board, however, cannot conceive that so large an amount of evaporation takes place in the moist climate of Bombay and Salsette. In Vol. I. page 25 of the Madras Engineers' Professional Papers, one-third of an inch per diem is mentioned as the allowance made for evaporation from reservoirs; and the Board are informed that at the Observatory on Colaba the average daily loss by evaporation from the 1st of January to the end of May is ·26 of an inch only. The Board therefore consider that the daily evaporation from the surface of the proposed lake would not exceed one-third of an inch during those months of the year in which the water flowing into the lake from the sides of the hills surrounding it would fall short of the quantity required for the supply of Bombay, and as the Board consider that the lake would probably be full during seven months in the year, one-third of an inch per diem for five months in each year is all that the Board are of opinion requires to be taken into consideration under this head of objection.

8. The Board are of opinion that none of the water in the public tanks, with the exception, perhaps, of that of Framjee Cowasjee, on the Esplanade, can be considered wholesome. They are all more or less filled by drainage, at the

best of times impure, and subject, moreover, to the taint of a large town. The Salsette lake would be free from the latter pollution, and the water would be collected from an open clear country, to be afterwards filtered and sent into the town as required for use.

9. The Board consider it not unlikely that a sufficient quantity of wholesome water for the supply of the town *might* be found in ordinary seasons on the Esplanade, in the Oart Districts, and in the Mahim Woods; but this is doubtful, and even were it certain, the water would require to be sent into the town at great expense, and from many sources. The Board are informed that for some weeks before the end of each fair season the quantity of water which can be had from the wells on the Esplanade which supply the reservoir at Musjid Bunder is three-fourths less than at the commencement, and that in almost every year it fails entirely before the setting in of the monsoon.

10. Mr Conybeare's report is accompanied by a skeleton map, referred to in paragraph 208 of his report, in which he states that the public wells are therein represented by black dots, and that the tanks and the Fort Ditch are also shown in black. The Board, however, are informed, that many of the wells, and one of the tanks so marked, are private property, that several of the other tanks so marked belong to mosques and temples, and that no distinction is made between those which contain respectively sweet, brackish, and salt water. The Board therefore consider it right to point this out to Government.

11. In paragraph 199, Mr. Conybeare states:—"In Scotland it is found necessary (for keeping the water cool) to lay the pipes at a depth of at least 8 feet below the surface: in India the depth should be greater." The Board, however, are informed that the water at Framjee Cowasjee's Tank and Ramlall's Reservoir at Poydownee, also at the Esplanade well, and the reservoir at Musjid Bunder, have been tested, and that the temperature of the water at each source of supply has been found exactly the same as that at its exit from the pipes at the reservoirs. The Board therefore presume that the great depth at which it is necessary to lay the pipes in Scotland is occasioned by the necessity of providing against the water being frozen.

12. Mr. Spens, the late Chairman, has favoured the Board with a copy of the report made by him to Government on the subject of the water supply, and the Board concur in the opinion expressed by him in his 11th paragraph as regards deepening the Gowalla Tank. The Board, however, do not concur with him as regards the raising of the wall on the eastern side of the tank, inasmuch as the Board observe, from Mr. Conybeare's water return for the month of October last, that subsequent to his having considerably raised the outlet of this tank, the water it contained on the 1st of November last stood at a level of 2 feet 1½ inch lower than on the 15th of the preceding month. The Board therefore conclude that the water escaped through the ground lying below the tank, as there was not much draught upon it at that period, and that it would be inexpedient to raise the level of the water in the tank.

13. It could scarcely be said the town was well supplied with water until each street, according to its length, had one or more reservoirs constantly supplied, and the Board would remark, that such reservoirs in each street would to a certain extent afford water for extinguishing fires, and that when the funds would admit of high service by a reservoir on the top of Nowrojee Hill, the means and appliances mentioned by Mr. Conybeare would meet with this object effectually.

14. With reference to paragraph 2 of your letter, No. 1679, containing the request of Government that the Board will state how far they would be prepared, in the event of a general sanction being given by the Honorable the Court of Directors to the work, to aid Government in completing it, I am directed to state that the Board are disposed to recommend to the Bench of Justices that one-third of the cost should be defrayed by the public, and that this sum should be raised by a special assessment, yielding from Rs. 50,000 to 75,000 per annum, this amount being paid annually to Government from the Municipal Fund, until the contribution of one-third of the cost should be completed.

I have the honour to be, &c.
(Signed) Geo. Hancock,
Clerk to the Board of Conservancy.

Bombay, Town Hall, 15*th March* 1853.

EXTRACTS FROM A MINUTE BY GOVERNMENT.

The following extracts from a minute by Government will be found, it is believed, to furnish a very sufficient *summary* of the information contained in the reports from Lieutenant DeLisle and Mr. Conybeare, and in the communication from the Board of Conservancy :—

" Lieutenant DeLisle proposes a dam 450 feet in length, and of a height of 50·47 feet. The base of the dam to be at an elevation of 69·53 feet above the level of the plinth of the Church Gate of the Fort of Bombay. The datum line of Lieutenant DeLisle's calculation is assumed to be 100 feet below the plinth, the delivery, therefore, 20 feet above the level of the said plinth. The surface thus drained is calculated at 7 square miles.

" The amount of annual fall of rain, taking 76 inches as the average for 34 years, after allowing for a loss by evaporation of 16 feet, is assumed to be 5 feet of water over this space, which is conveyed by the nullah to the sea, (or gallons 6,098,400,000).

" The lake is assumed to be capable of containing 157,100,000 cubic feet of water, or 981,875,000 (say 1,000,000,000) gallons. The supply is therefore six times the above amount.

" There is a proposition to so construct the dam as to be able to double the contents of the lake by raising the dam 10 feet hereafter.

" It is also proposed to have a waste-weir at the same level as the surface of the lake, or 120 feet above the plinth.

" The water is to be brought to a reservoir on the top of Nowrojee Hill, 14½ miles distant from the lake, by an iron pipe of 2 feet in diameter, the calculated discharge of which per hour would be 100,000 gallons (see paragraph 11) while the lake is full.

" The rough estimate framed and furnished by Lieutenant DeLisle provides for—

" 1*st.*—Cost of this iron pipe at £4 per yard, delivered at Bombay, and 14½ miles in length........................	£102,080
" 2*nd.*—The construction of the dam, of the waste-weir, of the delivery reservoirs and conduits, in all..................	15,000
" 3*rd.*—For contingencies	2,920
Total........	£120,000

" Or twelve lakhs of rupees.

" It will be seen that it secures a certain and considerable supply of water by surface drainage, and conveys it direct to a single delivery reservoir, but does not distribute it, or do more.

"Mr. Conybeare's statistics go to establish—

"1*st.*—That until good surface drainage is provided for the Native Town, an over supply of water, by generating damp from wastage, and its concomitant evils, will prove dangerous to the health of the community.

"2*nd.*—That the water provided on the plan proposed will be more or less unwholesome, obtained, as it will be, from a surface drainage.

"3*rd.*—That the more prudent plan at first would be, in Mr. Conybeare's opinion, to extend and to improve the supply and distribution of the present stores of spring water permeating the littoral concrete of this island, as well as that obtained by surface drainage.

"This he tells us is to be effected—

"1*st.*—By pipes and siphons of extraordinary dimensions.

"2*nd.*—By constructing filtering wells.

"3*rd.*—By arching over tanks and wells.

"4*th.*—By altering the side shape of tanks, so as to lessen evaporation.

"5*th.*—By constructing store reservoirs of filtered water, to be opened when the tanks are dried up.

"But he gives us no estimate, however rough, of the outlay to be incurred on works certain to prove extremely costly.

"Further, he contends, from the past experience of English water companies, that the minimum allowance per man of the population should be 20 gallons per diem.

"He thinks, before considering Lieutenant DeLisle's project, it should be ascertained beyond a doubt that sufficient spring water could not be obtained from Salsette, though he believes the supply from springs on that island is local, and that it is not sufficient.

"He brings the following objections to Lieutenant DeLisle's report:—

"In paragraph 261, he points out that Lieutenant DeLisle's estimate does not include the cost of regulating sluices and filtering beds, which he shows to be necessary, and the required number of miles of distribution pipe to the different tanks, streets, and piers. These items, he observes, constitute *the largest portion of the total cost of water-works for the supply of towns.*

"To this it may be added that Mr. Conybeare shows that the iron pipe should be of greater diameter. Captain Crawford says from 24 to 30 inches; Mr. Conybeare contends that it should not be less than 41 inches. This would raise (considerably) the sum of the rough estimate. Another addition would also have to be made to it, from the greatly increased proportions of the dam, if so built as to be hereafter raised to a height of 10 feet additional.

"He also argues that the pipe should be at least 8 feet below the surface, for which no provision is made; but in this the Board of Conservancy do not concur, and with apparent reason.

"In paragraph 263 he shows, that in Lieutenant DeLisle's calculation of loss from evaporation, that officer has overlooked the fact that he only calculates for evaporation till the 1st October. Estimating the mean annual evaporation at 16 feet per annum, he (Mr. Conybeare) goes on to show that Lieutenant DeLisle by this mistake doubles the probable supply of water from the reservoir, the yield of which he makes 1,000,000,000 instead of 500,000,000 gallons, which it ought to be. He further shows, that the average supply of the sixteen water companies, the statistics of which are given in his report, is 24 gallons a head to each man of the population. He argues that 20 gallons a head, *not 10 gallons as proposed* in Captain Crawford's scheme, should be the minimum allowance. This would require for a town with a population of 500,000 inhabitants a storage supply of 4,000,000,000 gallons, while the reservoir would only hold, according to Lieutenant DeLisle's calculation, 1,000,000,000, and according to Mr. Conybeare's 500,000,000 gallons. If, then, the dam were raised to 60 feet, which Mr. Conybeare thinks under the foregoing statement indispensable, the lake might, on a more moderate estimate of loss by evaporation than he has assumed, be supposed to contain storage water for the above population at 20 gallons a man for four and a half months. Another reason for increasing the height of the dam to 60 feet is, that if this be not done, the average depth of the lake or reservoir at Vehar is, according to Lieutenant DeLisle, only 7½ feet, which ensures a luxurious growth of aquatic plants, and thus, by polluting the water, renders a filtering tank indispensable, as he has shown in a previous part of his report.

"He further remarks, in paragraph 269, that Lieutenant DeLisle's calculations assume a jet 20 feet higher than the bottom of the dam. But that the highest head attainable, after allowing for a filtering bed and regulating sluices, is 10 feet *below* the bottom of the dam, or 60 feet above the plinth of the Church Gate, which would yield in the town a jet of only 30 feet above the level of the plinth, "a height," he adds, "not sufficient for real high service." He agrees with both Captain Crawford and Lieutenant DeLisle in believing that the project sketched by the former might be extended by a series of dams and upper tanks at higher elevations further up the valley.

"The letter from the Board of Conservancy may be thus epitomized:—

"*1st.*—They decide on the expediency of obtaining the required supply of water from the valley of Gopur or Vehar.

"*2nd.*—They declare that the dam should be so constructed as to admit of it being raised.

"*3rd.*—They declare that a filtering bed is necessary.

"*4th.*—They advise that the Vehar reservoir be railed in.

" *5th.*—They request Government to take precautions to prevent the selection of sites for villages in the neighbourhood, the drainage of which would otherwise fall into the reservoir.

" *6th.*—In paragraph 13 they contemplate reservoirs and conduits in every street of the *Town* of Bombay, including, probably, the Fort.

" *Finally,* they estimate the evaporation in the climate of Salsette from such a reservoir at about 6 feet per annum only, instead of 16, as estimated by Mr. Conybeare, and they offer to contribute one-third of the expense of the works.

" What this expense may amount to it will be seen from my previous remarks there are no accurate data to enable us to compute even roughly.

" But at paragraph 284 of Mr. Conybeare's report, that gentleman estimates that the cost of supply for 500,000 people would, perhaps, under the most favourable circumstances, come to 10*s.* or Rs. 5 per head, in other words to 25 lakhs of rupees.

" This, however, is intended to cover the entire cost of supplying all Bombay with water at high service, and in the most approved and costly methods for ensuring that the water shall be of the purest quality ; for the estimate is taken from a consideration of the cost of English water-works ; more particularly of the works of the Gorbal's Gravitation Water Company, stated to be the most perfect in Great Britain, the cost of which is given in the previous paragraph of the report."

The average annual expenditure by Government for water for the various establishments in Bombay has been, during the last five years—

	Rs.	*a.*	*p.*
Annual charges passed by the Civil Auditor................	3,197	7	1
Annual charges passed by the Military Board in the Military Department..	4,252	14	3
Annual charges passed by the Military Board in the General Department..	1,373	14	4
Annual charges passed by the Military Board in the Naval Department..	4,975	5	6
Total....	13,799	9	2

Being the interest, at 4 per cent., of nearly three lakhs and a half of rupees. Of the four sums which make up the total here given, a supply of water on high service would save nearly the whole of the first three, and a portion of the fourth, and any considerable increase in the supply would greatly diminish each of the four.

From the Municipal Fund, also, the expenditure during the last five years, chiefly on tanks and wells, has been as follows :—

Statement showing the Average Expenditure incurred Annually by the Municipal Fund during the last Five Years for the Supply of Water in Bombay; including all Extra Establishments entertained during the Hot Season; Compensation for the use of Private Wells, &c. &c.

Description of Works.	1848-49.			1849-50.			1850-51.			1851-52.			1852-53.			Total.		
	Rs.	*a.*	*p.*	*Rs.*	*a.*	*p.*	*Rs.*	*a.*	*p.*	*Rs.*	*a.*	*p.*	*Rs.*	*a.*	*p.*	*Rs.*	*a.*	*p.*
Deepening, cleaning, and removing mud from different tanks and wells on the islands of Bombay and Colaba.........	887	4	7	1,704	4	8	1,567	0	3	30,452	12	5	6,696	0	1	41,307	6	0
Annual repairs to the tanks and wells on the islands of Bombay and Colaba..................................	403	1	0	353	11	0	378	3	0	460	0	0	496	5	8	2,091	4	8
Improving the late quarry or tank belonging to Manockjee Cursetjee, situated at the junction of Duncan and Bellasis Roads..	....			352	4	0	....			....			....			352	4	0
One puckall bheestie employed for supplying water to wash the Beef Market and Slaughter House.....................	17	2	10	20	0	0	30	3	7	12	12	8	27	7	11	107	11	0
Constructing the apparatus, including pipes, for the conveyance of the water of Framjee Cowasjee's Tank to the centre of the Native Town at Poydowney...........................	....			....			11,579	7	7	6,250	13	8	2,169	10	9	20,000	0	0
Sinking and building wells at Gowalla Tank, Girgaum Back Road, Khetwady Road, Wittulwady, Colaba near Gun Carriage compound, Parell, Sewree, Candawady, and near Bazar Gate	....			....			1,530	0	0	10,579	0	4	5,316	8	3	17,425	8	7
Leading into the Baboola Tank the monsoon surface drainage of the high ground in its neighbourhood	....			....			190	13	8	1,144	0	0	....			1,334	13	8
Purchasing and improving a quarry of sweet water situated in Nanabhoy Jamsetjee's ground, at Mazagon	....			....			....			....			2,000	0	0	2,000	0	0
Total....Rupees	1,307	8	5	2,430	3	8	15,275	12	1	48,899	7	1	16,706	0	8	84,618	15	11
Average Expenditure of each year ....Rupees																16,923	12	$9\frac{2}{5}$

C. F. Collier,
Clerk to the Board of Conservancy.

Bombay, Town Hall, 22nd February 1854.