Sir Joseph William Bazalgette (1819–1891) Engineer to the Metropolitan Board of Works

by

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> Londoners who can remember the state of London and of the Thames about thirty-five years ago, before those vast undertakings of the Metropolitan Board of Works, the system of main drainage and the magnificent Thames Embankment, which have contributed so much to sanitary improvement and to the convenience and stateliness of this immense city, will regret the death of the able official chief engineer, Sir Joseph Bazalgette.
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> *Illustrated London News*, March 1891

Although the family name is well-known, Bazalgette remains a somewhat shadowy figure in Victorian engineering. He was an eminent engineer, respected by his contemporaries and responsible for public works on an unprecedented scale in the largest city the world had ever known, yet there is no published biography. This may be explained by the absence of personal letters or a diary which would illuminate his family life or reveal relationships with his circle of friends and professional colleagues. This paper draws on contact with the family, on his published reports, on printed Minutes and on the technical press to assess both the man and his work in developing the virtually new field of municipal engineering.

The Bazalgette family is of French origin and Sir Joseph's Grandfather, Jean Louis Bazalgette (1750–1830), was born at Ispagnac in southern France. Jean Louis arrived in England in 1784, via the West Indies, a wealthy man. He acquired British citizenship in October 1792 when living in Grosvenor Street, London.[1] Jean Louis married three times and from his first marriage Sir Joseph's father, also Joseph William, was born. (see Fig. 1). Jean Louis died on 6 February 1830 at Eastwick Park, Bookham, Surrey, which he had purchased in 1809. Joseph William Bazalgette (1783–1849), Sir Joseph's father, entered the Royal Navy in October 1796, was engaged in the Napoleonic Wars, and was severely wounded in action in 1809 whilst boarding a French vessel. After a distinguished career he retired in July 1814 with the rank of Commander[2] and became the first Secretary of the Army and Navy Bible Society. Joseph married Theresa Philo Pilton by whom he had nine children; she died in June 1850.[3] In 1819 he was living in Enfield, Middlesex, and in 1831 moved to Hamilton Terrace, Regent's Park,[4] where he died in 1849. He is buried in Brading Churchyard, Isle of Wight.

Joseph William Bazalgette (1819–1891), the fourth child and only son of Joseph and Theresa, was born in Enfield on 28 March 1819. Little is known of Joseph's childhood although we are told that he was educated privately.[5] By the age of nineteen he was 'pursuing a course of study to qualify him for the profession of a civil engineer'.[6] On 20 February 1845 Joseph married Maria Keogh at St. Margaret's Westminster. Maria was also born in 1819, at New Cross, County Wexford. Her father, Edward, was a magistrate of Kilkenny but, at the time of the marriage, was described as a 'Gentleman of Ham, Surrey'. In October 1845 Joseph and Maria moved to a newly-built house at 12 Westbourne Park Road (now No. 28). By 1851 they had moved to Morden in Surrey where they and their young

family occupied a house in Morden Lane (now Central Road). The 1851 Census lists Joseph as 'civil engineer, born Enfield, aged 32', together with Maria his wife, their sons Joseph William (aged 5), Charles Norman (aged 4) and Edward (aged 2) all born in London, and a daughter Theresa Philo (aged 7 months) born in Morden.[7] Joseph and Maria were eventually to have ten children. The eldest, Joseph William, went into the Army, Edward became a civil engineer and other descendants followed in the profession. Charles Norman became a lawyer and embraced his father's interests to the extent that he wrote on the legal aspects of municipal engineering.[8] In 1873 Joseph built a house, called 'St. Mary's', in Arthur Road, Wimbledon, opposite the parish church. He had been Rector's Churchwarden at St. Lawrence, Morden and he was also Churchwarden at St. Mary's, Wimbledon. Sir Joseph died in the Wimbledon house on Sunday 15 March 1891 after a brief retirement and is buried in the family vault in St. Mary's churchyard.

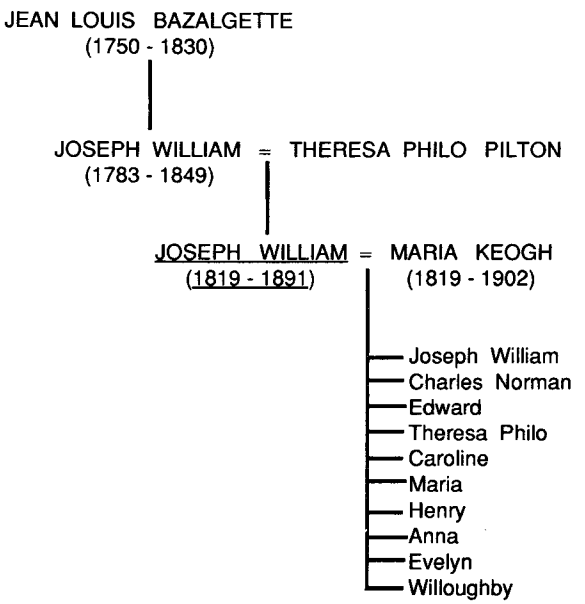


Fig. 1. Part of the Family Tree.

BAZALGETTE'S ENGINEERING CAREER

Before considering Bazalgette's works with the Metropolitan Board, it is important to consider his early career and set it against the background of sanitary reform which characterised the middle years of the nineteenth century. The resulting legislation provided the appropriate administrative structure and sufficient funds for massive civil engineering schemes in public health works.

Bazalgette began his engineering career in 1836 when he became an Articled Pupil of John McNeill, the eminent Irish civil engineer. Bazalgette was Resident Engineer for him on land drainage works at Loughs Foyle and Swilley in Londonderry. This work was the subject of the young Bazalgette's first paper to the Institution of Civil Engineers,[9] of which he was elected a Graduate on 13 March 1838.[10] In 1842, aged only 23, he set up in private practice as a consulting engineer with an office in Great George Street, Westminster. He was elected a Member of the Institution on 17 February 1846 when he had:[11]

> served a regular period of pupilage under Sir J. McNeill, was for 2 years Resident Engineer on works in Ireland, 1 year laying out lines for the Railway Commissioners & has been upwards of 2 years in business for himself as a civil engineer.

During 1847–8 the pressure of work took its toll and he had a severe breakdown in health and left London to recuperate. Later he said 'I began my work when the great railway mania broke out, and nearly killed myself before I joined the old Commission of Sewers'.[12]

THE COMMISSIONERS OF SEWERS

The consequences of inadequate drainage became serious as London expanded during the early Victorian period and small, local attempts to deal with the problems 'produced results as multifarious as they were discordant'[13] and central government intervention became inescapable by the 1840s. In 1847 a Royal Commission was established to 'Inquire whether any, and what special means might be requisite for the improvement of the health of the Metropolis, with regard more especially . . . to better house, street, and land drainage'.[14] They proposed amalgamating the seven existing drainage districts and brought into being the first Metropolitan Commission of Sewers under an Act of 1848.[15] The recognition of the need for a body with a broader view of London's sanitary problems marked the beginning of a new era. It made possible the full-time employment of salaried professional civil engineers on urban drainage issues with the consequent accumulation of expertise, design data and site experience.

Under the 1848 Act the Commissioners were responsible for all matters relating to drainage and flood prevention within an area including:[16]

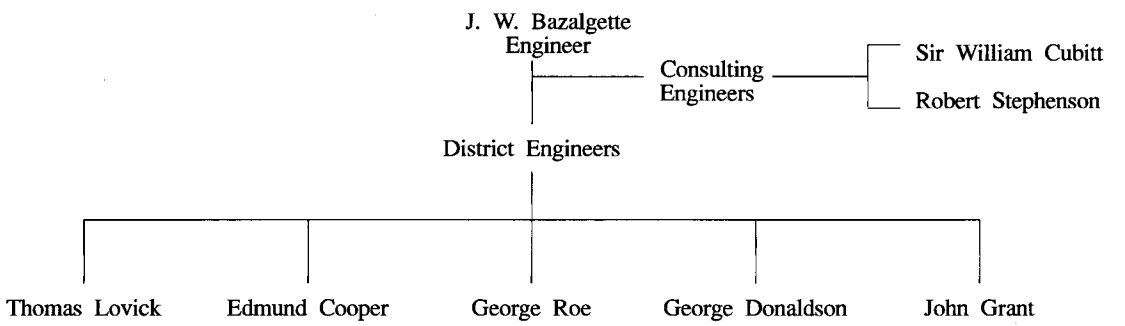
> all such places or parts in the counties of Middlesex, Surrey, Essex, and Kent, or any of them, not more than twelve miles distant in a straight line from St. Paul's Cathedral in the City of London, but not being within the City of London or the liberties thereof.

The exclusion of the City reflects the disproportionate influence of the "square mile" in metropolitan matters, and an 1851 guide book to London wondered:[17]

> why the effete corporation of the city should be allowed to retain its privilege of exemption from the effect of every general measure for the public benefit; it is as though it were desired to form an Egypt of darkness in the midst of the enlightened progress of the rest of London.

The duration of each twelve-man Commission was limited to two years and there were six such Commissions between 1848 and 1855.

Having recovered from his illness, Bazalgette returned to London in 1849 and on 16 August was appointed 'Assistant Surveyor' to the second Commission at a salary of £250 a year. Thus began his engineering career in local government. The technical staff of the Metropolitan Commissions were based at No. 1 Greek Street, Soho, and the main drainage scheme, as implemented, was planned there. The City Corporation had their own Commissioners of Sewers and the two bodies obviously had to be in communication. The Surveyor (later Engineer) to the City was Colonel William Haywood (1821–1894),[18] who was appointed in 1846 and served until he retired in March 1894. Bazalgette and Haywood were to have a long professional relationship and a few disagreements. Apart from their salaried staff, both the City and the Metropolitan Commissioners occasionally employed consulting engineers including Robert Stephenson, I. K. Brunel, Sir William Cubitt, Thomas Hawksley and George Parker Bidder. By 1851, the Metropolitan Commission, under their Engineer, Frank Forster (1800–1852),[19] had clearly established the broad outline of London's proposed main drainage scheme, with its essential components of separate systems north and south of the Thames, and west-east intercepting sewers with remote outfalls to the east of London. However, Forster died, the victim of 'harassing fatigues and anxieties of official duties',[20] in 1852 when Bazalgette was appointed Engineer and remained so to the last two Commissions. The engineering team of the last Metropolitan Commission in 1855 comprised:



One of the issues which drew Bazalgette and Haywood into close collaboration, and in fact, united them against a common enemy, was the proposed *Great London Drainage Company* to bring private capital into the funding of the drainage works. The promoters hoped to exploit a profitable agricultural fertilizer market. During 1853 these proposals occupied much of Bazalgette's and Haywood's time. The Company had Thomas Wicksteed (1806–1872) as their engineer and Haywood's diary for 29 March 1853 records; 'With Bazalgette to Leicester',[21] where they met Wicksteed and stayed three days. The working relationship between Bazalgette and Haywood, or of the Metropolis and the City, immediately before the formation of the Metropolitan Board of Works is revealed in letters written during 1853. On 18 March Bazalgette writes:[22]

Principal Office: 1 Greek Street
Soho Square

Dear Haywood,

I am to meet Mr. Stephenson and Sir Wm. Cubitt on Tuesday at 12 o'clock. Could you manage to meet me here say at 10 that morning & go down there with me. It will be an advantage our all meeting together, and though you would not attend officially but at my invitation it can do no harm and it will afford you an introduction which will help your transfer at the Instn.

That Bazalgette intended to keep Haywood abreast of Metropolitan developments is clear from his letter of 10 October:[23]

My Dear Haywood,

I have been driven on in the preparation of plans for works upon which we are to borrow money under our Consulting Engineers, step by step till the Southern drainage is designed, and the Hackney Brook on the North Side, without the opportunity of consulting you in the matter. I regret this has been so, but I have had no choice in the matter, for I have been acting directly under the instructions of Sir William Cubitt who has taken up the subject himself and has devoted a great deal of his time to it; and I have been so fully engaged that I have scarcely had breathing time till now.

By November 1853 the effect of the proposed underground railway on the drainage plans had to be considered, and on 3 November Bazalgette writes to Haywood:[24]

My Dear Sir,

I have just written to Mr. Fowler to request him to lay his views upon the diversion of the sewerage by the North Metropolitan Railway before me as soon as possible. This we must have I think before we can progress with the main drainage.

The foregoing serves to illustrate Bazalgette's considerable involvement with the London Main Drainage from 1849 up to the formation of the Metropolitan Board of Works in 1855.

THE METROPOLITAN BOARD OF WORKS

The Metropolitan Board of Works was created by the Metropolis Management Act of 1855.[25] The Board acquired powers on 1 January 1856 and were responsible for the built environment within the capital's area of 117 square miles. The technical journal *The Engineer* was launched in the same week as the Board and said 'we confess that we take a great interest in the proceedings of this Board'[26] and its Editorials provide an interesting critical commentary on the progress of the works. In March 1856 it described the Board's function:[27]

> the public works of the metropolis are in its charge, metropolitan improvements are its special function; under the earth and above the earth its authority is now established . . . metaphorically speaking, the Board is appointed physician to the metropolitan organism, and has accepted the duty of restoring it to health and promoting its future growth, of giving strength to its muscular, and vitality to its arterial system, roundness to its limbs, and beauty to its face.

The Board, comprising some 45 members, had no offices in which to meet and for the first three meetings hired rooms in Burlington House. Neither did the Board have any technical staff and, in January 1856, decided that:[28]

> In order to prevent the injurious consequences to the public which might result from any interruption in the supervision of sewers, Mr. Bazalgette be requested to take charge of all the main sewers and other works . . . with power to obtain such temporary assistance as may be necessary to discharge such duty until the Board otherwise direct.

So Bazalgette continued to act in this temporary capacity from his old office in Greek Street.

The press took a keen interest in the appointment of an Engineer to the Board emphasising the rivalry between the City and the new Metropolitan body. *The Observer* thought the City aimed to gain maximum power 'so that it might be spared any innovation' and that 'Their great object is to get the engineer to the late Commission of Sewers re-appointed. Hence their anxiety to have him nominated for a month. In this they have succeeded, and have certainly stolen a march upon the metropolitan party'.[29] The extent of public interest in the selection of an Engineer can be gauged from their concluding remarks:[30]

> Upon the appointment of this officer hundreds of thousands of the ratepayers' money depend; and they, therefore, look to their deputies to weigh carefully all the pros and cons of the case, and to select only the very best possible man that can be procured, and pay him most liberally and ungrudgingly. The proceedings of the next fortnight are pregnant with the fate of the great measure now in operation.

A week later the Board formally decided to appoint an Engineer, that 'advertisements as to such election be inserted in all the daily papers,'[31] and that the election should take place on Friday 25 January at 12 o'clock. On the Sunday before the election *The Observer* remarked:[32]

> The number of candidates will doubtless be considerable but the contest, most probably, will virtually lie between Mr. Bazalgette and Mr. Robert Rawlinson . . . Of Mr. Bazalgette it is unnecessary to say anything, as his saying and doings have but too frequently been discussed in the public press . . . Between the two candidates the Metropolitan Board of Works must now judge. It is to be hoped that they will select the right one.

In the event nine candidates applied for the post.[33] On the day, the Board proceeded, by a show of hands, to reduce the list to four. The letters of application and testimonials were then read. At this point the Secretary announced that he had that morning received a letter claiming that Bazalgette's statements in his application relating to his work on the Tame Valley Canal, Portsmouth Dockyard, and other works were 'at variance with the facts'.[34] Bazalgette was called in to address the Board, and must have been convincing since at the next vote he was elected Engineer outright. He was appointed at a salary (including travelling expenses) of £1000 a year, and he quickly had three Assistant Engineers appointed. They were John Grant, Thomas Lovick, and Edmund Cooper, who had each worked with Bazalgette at the Metropolitan Commission of Sewers. The salary of each Assistant Engineer was £350 a year plus £50 for travelling expenses. Grant was put in charge of the area south of the Thames and Lovick and Cooper shared the northern area.

THE ENGINEERING WORKS OF THE BOARD

In addition to main drainage the Board was also responsible for a range of other works concerning the built environment of London. These included street improvements, street lighting, new roads, river bridges, ferries and tunnels, flood prevention, and the Metropolitan Fire Brigade. There was also much Parliamentary business in connection with the Board's own Bills and with those of others. The Parliamentary deadline for submission of proposals for consideration in the ensuing session was 30 November and Bazalgette said 'We were working generally night work in November to get the plans and book of reference ready for deposit on the 30th.'[35] When living in Morden, Bazalgette said 'I often used to drive down there from my office in a cab at twelve or one o'clock in the morning'.[36] Even then the pressure of Parliamentary work did not ease as Bazalgette added:[37]

> It is my duty every year after November, as soon as possible after the bills are deposited, to report as to the effect upon the public interests of all private enterprises contemplated in the coming session; then to appear before Parliament and give evidence if necessary on behalf of the public.

He was thus involved with Railway and Tramway Acts, the Gas and Petroleum Acts, Hydraulic Power, Waterworks and Docks Acts, among many others.[38]

The Board met every Friday and Bazalgette made an engineering progress report on the first Friday of each month. He had to collect data, produce design proposals and submit them to the Board. The proposals having been agreed, the Engineer would produce the contract drawings and specification and advertise for public tenders. The documents were printed and issued for a fee of five pounds, 'to secure that none but *bona fide* tenderers shall send in their tenders'.[39] Bazalgette added:[40]

> I have always adopted the plan of having a lithographed circular sent out to every person who is supplied with plans in order that every contractor may have the same information before him before he tenders.

When tenders were received a meticulous procedure was always followed:[41]

> The tenders are deposited in a box on the Thursday afternoon before a Board meeting. They are opened at the Board meeting, or they are opened by the clerk before the Board meeting and handed to the Chairman, who announces them at the public board.

The Board did not always accept the lowest tender and, when questioned, Bazalgette replied:[42]

> it stands to reason that if there is a contractor whom they well know, and whose tender is not materially above the lower one, they will naturally prefer it. It is a very great mistake to employ a contractor who has not the means of carrying out his contract thoroughly. It always leads to constant wrangling, difficulty, stoppage, and very often eventual failure.

Having let the contract, the Engineer's team supervised and measured the work for certified interim monthly payments. A list of the principal constructional contracts is given in Appendix A. In estimating, Bazalgette allowed 10% for contingencies and on completion the contractor sent in an account. When there were disagreements, Bazalgette said:[43]

> I then have the assistant engineer and the clerks of works with the contract drawings and specifications before me, and the contractor and his agents, and I hear what each has to say, and look to the specifications and drawings and determine those points. After that is done the account is sent to the accountant, certified as to quantities, and the accountant compares the prices with the schedule of extra works . . . and eventually signs it as correct. Then I sign the certificate for the Board.

Being in the service of local government and responsible for spending exceptionally large sums of public money, Bazalgette spent a great deal of his time explaining his schemes and procedures to lay members of Boards and Commissions. Nevertheless, a prodigious amount of construction was successfully completed during the thirty-three years of the Board's existence. It is not possible here to describe in detail the extensive engineering works which were to shape the London we now know and the following account of the principal works uses, as far as possible, Bazalgette's own words.

THE MAIN DRAINAGE

Concern for public health was the primary motive in setting up the Board and, in January 1856, Bazalgette dramatically described the nature of the problem which it had inherited:[44]

> the whole of the sewage passed down sewers from the high ground at right angles to the Thames into the low grounds adjoining the Thames, where at high water it was pent up in the sewers, forming great elongated cesspools of stagnant sewage, and then when the tide went down and opened the outlets that sewage was poured into the river at low water at a time when there was very little water in the river.

Furthermore, this sewage 'kept oscillating up and down the river, while more filth was continually adding to it, until the Thames became absolutely pestilential'.[45] On 8 February 1856 the Board, 'impressed with the necessity of at once proceeding with the works necessary for the complete interception of the sewerage'[46] asked Bazalgette to report as soon as possible. His report, of 3 April, was for an interception system which was fundamentally that of the last Metropolitan Commission. Then began an enormously protracted public discussion of this and other schemes involving central government, referees, and the press. Eventually, in November 1857 the Board asked for a final report by Bazalgette in conjunction with G. P. Bidder and T. Hawksley as consultants and this was published in April 1858.[47] Bidder and Hawksley were paid £2754 16s. 4d. for 'professional services and disbursements'.[48]

In August 1858 the Board obtained its enabling Act[49] and site work began on the northern mid-level sewer on 31 January 1859.[50] The difficulties of constructing sewers in dense urban areas made cost-control a problem and as early as May 1859 Bazalgette was taken to task by a member of the Board about cost variations and he replied:[51]

> I have learned, after estimating and constructing some hundreds of miles of sewer in London, that it is not possible to frame standard estimates which shall be generally applicable to other cases, and any attempt to do this must prove delusive and lead to great and serious errors.

Bazalgette received a vote of confidence from the Board and in July received his first salary increase.[52]

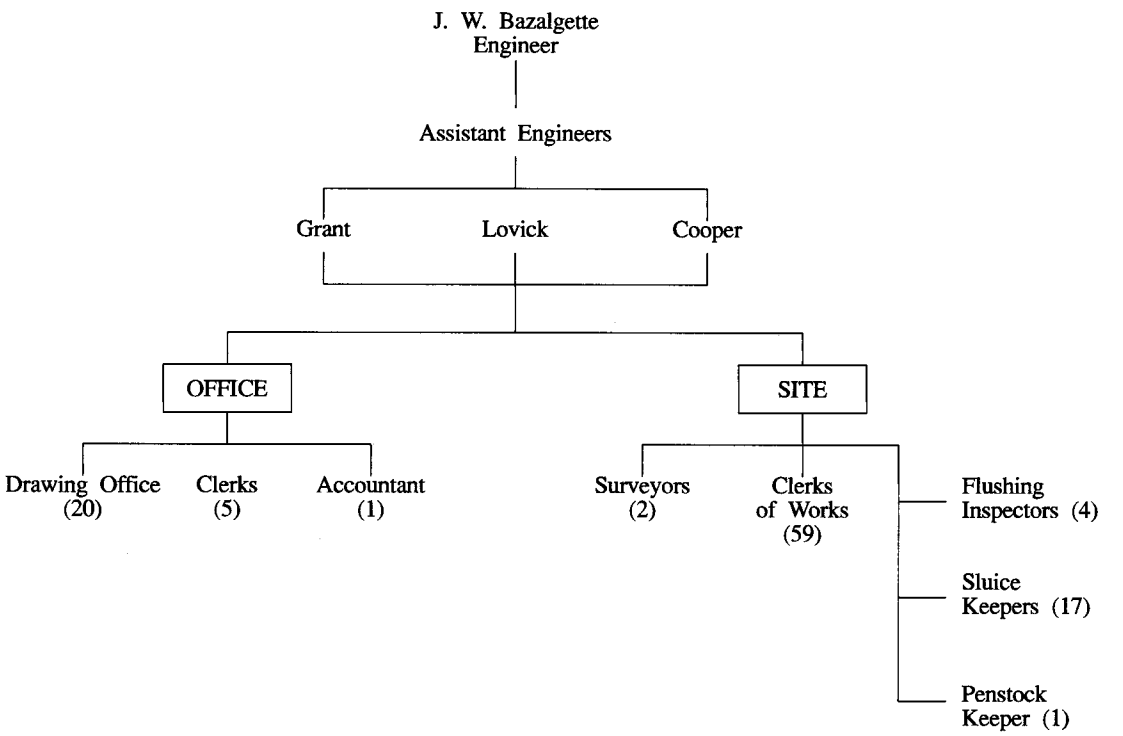
The brick-built intercepting sewers were laid to a fall of 2 feet per mile from west to east and it was, therefore, necessary to lift the sewage into the outfall sewers with pumping stations sited in east London. Progress was the more rapid south of the river and in February 1859 it became necessary to advertise for tenders for the engines, boilers, and other plant for Deptford pumping station. Bazalgette

had only limited experience of this type of work and it was decided to invite a committee of engineers to examine and comment on the designs sent in. This eminent ad hoc committee comprised Bazalgette, Robert Stephenson, Joshua Field, John Penn, Thomas Hawksley and George Parker Bidder,[53] and in July the Board thanked those who 'with a degree of liberality and public spirit . . . gratuitously undertook this important and laborious duty'.[54]

The work progressed towards completion, at least on the south side, during the summer of 1864 and Bazalgette's eighth annual report of 4 July captures something of the scale and character of the task:[55]

> It is with satisfaction that I am enabled to state that fair progress has been made in the construction of the Main Drainage Lines of Sewers, and with numerous and extensive works in course of execution therewith at the several Pumping Stations, Reservoirs, Outlets, &c. during the past year, the weather having, as in the preceding year, been favourable to their progression, without any material interruption from long continued frosts or heavy rains. It is also satisfactory to me to be able to state that, whilst a large amount of tunneling has been completed on the South Side of the River, under canals, railways, houses, and through treacherous soils, filled with water, from the precautions taken by the several Contractors for the safety of their respective works, and from the skill and judgement evinced in their execution, no one section of these works has failed, whilst the damage to property, allowing for the nature and magnitude of the work, and the extent of the Metropolis traversed by it, has been unimportant, and the casualties to the workmen not numerous, and with but few of a fatal character.

In 1865, at the peak of the drainage works, the Engineering Department comprised:



To cater for the interest of those concerned, annual visits to the drainage works with groups comprising Board members, the City, Parliament, and District Vestries were arranged. Such a visit was made on Monday 25 July 1864 when 'The party numbered between 500 and 600 strong, and were conveyed by two steamboats, which started from Hungerford early in the morning'.[56] These visits

foreshadowed the ceremonial opening of the drainage works. This took place on Tuesday 4 April 1865 when amongst others, the Prince of Wales, Members of Parliament, the Archbishops of Canterbury and York, and the Lord Mayors of London and Dublin 'proceeded by steamboat down the river',[57] where:[58]

> the Royal party landed at the Northern Outfall, at Barking, and after a brief inspection of the works at that place resumed their passage to the Southern Outfall at Crossness, where the general company had already assembled . . . they were conducted over the works; after which the Engineer explained the general principles and engineering details . . . the four pumping engines were then succesively set in motion by His Royal Highness the Prince of Wales, which completed the opening of the works . . . the company then partook of luncheon.

After lunch, the Prince proposed 'Success to the great national undertaking' and congratulated 'Mr. Thwaites, the Chairman of the Metropolitan Board of Works, and the eminent and skillful Engineer, Mr. Bazalgette, upon the great success which they have achieved'.[59] The Crossness works were designed to impound sewage in a 6½ acre covered reservoir until it was discharged into the Thames on the ebb tide.

In July 1866, perhaps in recognition that the bulk of the drainage works were complete, the Main Drainage Committee of the Board was re-designated the 'Works and General Purposes Committee'.[60] Work north of the Thames was delayed by the complication of accommodating the low-level sewer in the Victoria Embankment. But Abbey Mills Pumping Station, the Northern Outfall Sewer, and the Beckton Outfall works were completed by 1868. The fourth, and last of the original sewage lift works was the Western Pumping Station in Pimlico, opened in 1875. Technical details of the pumping stations are given in Appendix B.

Once the system was commissioned, Bazalgette's department had a continuing responsibility for staffing, maintenance and replacement, and for renewable contracts for coal and other supplies. The 80 miles of intercepting sewers, and the two outfall sewers, were maintained by the Board's engineers and although the other sewers were managed by the local District Boards and Vestries, Bazalgette explained that:[61]

> in order to make it one complete system, they are bound to send in plans for any sewers they propose to construct to the Metropolitan Board of Works and get its approval of those plans. By this means one complete system is always maintained although the works are constructed by a number of different district boards.

The system worked well and was adequate for about twenty years until the growth of London made the Board explore new means of treating and disposing of the sewage at Crossness and Barking. In 1888 Bazalgette remarked:[62]

> the subject of the treatment of sewage by various chemical agents has occupied the attention of the Board, and their chemical advisers, for a great number of years.

Precipitation works were planned for the outfalls and Bazalgette had experimented with pressing the residual sludge to reduce its bulk, but having failed to find a market for it as fertilizer said, 'We are having hopper vessels constructed for taking the sludge right out to sea'.[63] But this was all too late; it was in the last days of the Metropolitan Board of Works and, with Bazalgette's retirement imminent, the full realisation of these plans fell to the London County Council.

THE THAMES EMBANKMENTS

A long-cherished plan was achieved when the Board built the Victoria, Albert and Chelsea embankments. They succeeded, where others failed, because sufficient funds and powers were made available to them.[64] The issue was discussed at length in the early 1860s when it was suggested that the embankment works would be better managed by special Commissioners rather than by the Board. However, the need to integrate the low-level sewer into the works ensured control by the Board. Bazalgette's department undertook design and supervision of this major project although he later confessed, 'I get most credit for the Thames Embankment, but it wasn't anything like such a job as the drainage'.[65]

The Victoria Embankment is a mile and a quarter in length running between Westminster and Blackfriars bridges. It follows the line laid down by James Walker in 1840 and was the most complex

of the three built. Protracted negotiations were necessary with private property owners, coal wharf operators, the City Gas Company, and the railway authorities before work could begin in 1864.[66] Bazalgette had to reconcile matters he considered to be 'of small importance to a private company, but of great consequence to the public interests'[67] and in April 1864 a barrister at the Temple confided to his diary, 'Never more after this year will any one look down from our walks straight into the tide. Oh Public Good, what private wrongs are committed in thy name.'[68] There were three contractors[69] and difficulties arose with the Thames Conservancers. The contractors were required to take a certain amount of material dredged from the Thames as fill behind the new wall and the Conservancers found them reluctant. Bazalgette was involved in numerous meetings and massive correspondence to keep the works running smoothly. The supply of granite for facing the wall also proved difficult. Bazalgette had specified stone from the Dalbeattie quarries but explained, 'We could not get it in fast enough, and eventually we had to get it from a number of different quarries'.[70] The embankment was opened by the Prince of Wales on 13 July 1870. The massive scale of this work is given by the quantity of material used:

Granite	650,000 cubic feet
Brickwork	80,000 cubic yards
Concrete	140,000 cubic yards
Timber (for cofferdam)	500,000 cubic feet
Iron caissons (for cofferdam)	2000 tons
Earth filling	1,000,000 cubic yards
Excavation	144,000 cubic yards
York paving	125,000 square feet
Broken granite	50,000 superficial yards

The Albert Embankment between Westminster and Vauxhall bridges was constructed under an Act of 1863.[71] Work began in September 1865 and it was opened to the public in May 1868. The contract was let to William Webster and the Resident Engineer was John Grant. The reclaimed land provided a site for the building of St Thomas's Hospital. The Chelsea Embankment, about three-quarters of a mile long, was also constructed by Webster under the Board's Act of 1868.[72] Work began in July 1871 and was completed in May 1874. The engineering of both these works is generally similar to that of the Victoria Embankment. Bazalgette summarised the contribution of the three embankments by saying they 'extended for a distance of 3½ miles along the river, and they had reclaimed about 52 acres of land.'[73]

FLOOD PREVENTION AND THE RIVER

The Thames River, Prevention of Floods Act of 1879 imposed on the Board the duty of implementing its requirements and Bazalgette considered this 'one of the most difficult and intricate things the Board have had to do'.[74] He described the scale of the project as:[75]

> 40 miles of river frontage, and every wharf has had to be dealt with and plans prepared carefully for each particular wharf after conference with the persons in occupation to see the nature of their business and how it was conducted and to devise those works in such a way that the business could be carried on with as little interruption as possible.

His system comprised 'moveable tide boards which have to be inspected and kept in order'.[76]

Another aspect of the régime of the river which involved the Board's Engineer was the claim made by the Thames Conservators that mudbanks in the Thames at Crossness were the result of deposits from the sewer outfalls. The Conservators were responsible for dredging, but demanded that the Board should remove the obstructing mudbanks. The case went to arbitration in the spring of 1880 and both parties were represented by Counsel. The arbitrators were Captain Douglas Galton, appointed by the Conservators, and F. J. Bramwell, appointed by the Board; Sir Charles Hartley was appointed Umpire by the Board of Trade. The inquiry lasted 25 days and in May 1880 the Arbitrators reported in favour of the Board:[77]

> the three banks cannot be said . . . to have arisen from the flow of sewage at the outfalls; and we are, therefore, of opinion that the Metropolitan Board of Works should not be called on to remove, or contribute any portion of the expense of removing, the three banks, or any of them.

The two parties each had to bear their own costs and the press thought it possible that 'Sir Joseph Bazalgette bears a heightened reputation as an engineer in consequence of the decision'.[78]

RIVER CROSSINGS

In 1854 a Select Committee had reported on the bridges over the Thames[79] and the Board inherited a growing traffic problem where 'the greatest obstructions in the way of distributing the traffic are the tolls and the insufficient approaches'.[80] But it was not until 1877 that the Metropolis Toll Bridges Act[81] enabled the Board to purchase the river bridges from their private owners and free them from tolls. Bazalgette observed, 'Ever so small a toll tends very much to restrict the use of a bridge',[82] and:[83]

> The loads going over a bridge when under the control of a toll keeper with gates and so forth are very different to what they are when you throw it open free, and it is crowded as much as possible.

Twelve bridges were to be freed; Hammersmith, Putney, Wandsworth, Battersea, Albert, Vauxhall, Lambeth, Waterloo, Deptford Creek and Chelsea, together with the Charing Cross and Cannon Street railway footbridges. They were all owned by bridge companies with the exception of Chelsea, built by the Commissioners of H.M. Works, and the footbridges owned by the South Eastern Railway Company. Bazalgette described his task:[84]

> Before the bridges were purchased it was my duty to see what the condition of the bridges was, and what in my judgement would have to be done to them, and present that to the arbitrator to show him if the Board purchased the bridge in its then condition what expenditure would have to be laid out on it in all probability to make it fit for public use.

Bazalgette published his very thorough report in May 1888.[85] Having agreed the value, the Board acquired the bridges for just under £1,500,00.

Work was done on nearly all the bridges, beginning with the underpinning of Rennie's Waterloo Bridge. The acquisition led to three major bridge works to Bazalgette's designs, namely the replacement of Putney, Hammersmith and Battersea bridges.[86] The bridge at Putney was of timber and was built in 1729; Bazalgette replaced it with the present five-arched granite structure, opened on 29 May 1886. In February 1882 the Fulham District Board complained that William Tierney Clark's suspension bridge at Hammersmith was 'dangerous and unfit for general traffic'.[87] Bazalgette examined the old structure and decided to retain the abutments but to rebuild the masonry towers in metal and replace the wrought iron chains with steel links of a new design; together with a new deck, the whole was estimated to cost £80,000. The new bridge was opened on 18 June 1887. At the same time, Battersea Bridge was 'an old wooden structure, unsightly in appearance, inconvenient to passengers over it, and still more to steamboats under it'.[88] To replace it, Bazalgette designed the present five-span arch structure with iron ribs. It was still under construction when the Board was replaced by the London County Council and Bazalgette lived just long enough to see it opened in 1890.

After the up-river bridges had been freed from tolls using Metropolitan funds, demands arose from east-Londoners for river crossings and Bazalgette pointed out that whilst three-fifths of Londoners had access to twelve bridges above London Bridge, the two-fifths below that bridge had none. Various proposals were discussed, resulting in Bazalgette designs for a bridge at the Tower, a ferry at Woolwich and a tunnel at Blackwall—his last major project before retirement.

Bazalgette produced three designs for Tower Bridge in 1878[89] but his preferred scheme was for a 'braced arch bridge, crossing the river by one span of 850 feet'.[90] Moreover, he proposed using steel and justified this by saying:[91]

> Steel is a new material to use in a bridge of such a span, and in point of fact is the only material which would render the construction of such a bridge practicable, taking the whole thing in one span.

However, the City Corporation effectively excluded Bazalgette and the Board by proposing to pay the whole cost of the bridge from their wealthy Bridge House Estates Trust.

The Board obtained an Act for constructing Blackwall Tunnel in 1887[92] and Bazalgette said of the possible cost: 'the parliamentary estimate was one million and a quarter . . . I can only give the works. I cannot state what the property will come to'.[93] His design comprised 'three subways, two 25 feet in diameter, and one 15 feet' and he feared:[94]

> there is very considerable difficulty to be encountered in constructing that tunnel. It goes through treacherous ground and water. We shall do it by pneumatic pressure.

Although the Board's demise was imminent, it pressed on and was about to advertise for tenders when wound up in the Spring of 1889. The tunnel was eventually constructed, to a different design, by the London County Council. However, the Metropolitan Board did initiate the other east London river crossing and in July 1888 Bazalgette could say 'our steam ferry at Woolwich we are constructing will cost £113,000'.[95]

STREET IMPROVEMENTS

When the Board took control in 1856, connections between the main-line London railway termini entailed journeys in horse-drawn road vehicles across the Capital. New traffic routes were urgently required. Bazalgette took up the challenge and explained his role: 'Each street improvement being determined upon, it is my duty to lay out the line of street, and consider the width of street, and report upon it and prepare it'.[96] He worked in conjunction with the Architect's and Solicitor's departments to acquire the necessary property. This all had to be done before work could begin: 'the contractor must have room to put his men into the work; we must have the ground cleared to lay out the street in fact'.[97] Garrick Street was the first new street constructed by the Board and Bazalgette seized the opportunity of making provision for underground services:[98]

> we have introduced the system of subways in the main thoroughfares in order that the gas and water pipes may be laid in the subways under those thoroughfares and the streets may not be pulled up from time to time afterwards. It will only do in important main streets because it is costly, but it is a great improvement.

Many new streets were built from the 1860's until the end of the Board's period in 1889. The principal examples and opening dates include; Southwark Street (January 1864), Queen Victoria Street (November 1871), Northumberland Avenue (March 1876), Shaftesbury Avenue (June 1886) and Charing Cross Road (February 1887). The Board did not take on subsequent responsibility for new roads and 'All new streets are laid out by the Board, paved and completed, and then handed over to the district boards'.[99] Bazalgette explained that 'Only the Thames Embankment and the approaches'[100] were maintained by the Board. Street lighting by gas and, later, electricity also came within the power of the Board. Bazalgette was involved with the first significant step taken by a public authority in connection with electric lighting. In October 1878, he got his Committee to accept an offer from a firm in Paris to instal an experimental system on the Victoria Embankment. As a result:[101]

> The Victoria Embankment was illuminated by electricity for the first time on 13 December 1878. The lights, which were along the river wall . . . consisted of 20 Jablochkoff lamps spaced about 45 yards apart. . . . just west of Charing Cross Bridge, was a wooden shed containing a semi-portable steam engine . . . capable of developing about 60 I.H.P. at 160 R.P.M. . . . It was belted to a countershaft from which were driven a direct current Gramme dynamo at 650 R.P.M. and its separate exciting dynamo at 700 R.P.M.

The arrangement was terminated in 1884 and the Embankment reverted to gas lighting.

Bazalgette's department had reported on the plans for about 3000 new streets and the total cost of street improvement works was about £14,000,000 and, as he correctly observed, 'Had we not kept pace with the increased want of communication we should have been in a state of block in our streets.'[102]

BAZALGETTE AS CONSULTING ENGINEER

An interesting aspect of Victorian civil engineering in local government was the freedom enjoyed by the salaried professional engineer to engage in private, fee-earning, consulting work and even to take private Articled Pupils at a premium. In August 1859 Bazalgette reported to the Board that he had been asked to:[103]

> receive a pupil who might gain experience upon the Main Drainage Works now being executed, and whose services would shortly become available upon those works, and would thus effect a saving to the Board.

He was granted permission to take the pupil and receive the premium. Through one such pupil, who joined Bazalgette on 1 January 1865 and stayed four years, we learn something of his Articles and of life and work in the Engineer's office at Spring Gardens.[104] He was H. P. Boulnois, who went on to a successful career in municipal engineering.[105] His mother paid Bazalgette a premium of £420, and his Articles describe Boulnois as 'an infant of the age of 19 years', and as Bazalgette's 'pupil and apprentice

in the profession, business, or employment of a civil engineer'[106] At that time there were five other pupils in Bazalgette's office all working on the Main Drainage and the Thames Embankments. Portland cement was extensively used in these works and Boulnois reminds us of research undertaken by the Board which was to make the material more widely adopted by engineers:[107]

> I remember that at one period of my pupilage I assisted in carrying out some experiments, at Messrs. Eastwood's works, into the strength of concrete beams of various descriptions, by subjecting them to certain strains and pressures, carefully noting the results, which were handed to Mr. Grant.

The pupil also recalled that 'The head of the drawing office was a Mr. Gunyon, an extraordinarily clever man, and at the same time of a most kindly and considerate disposition'.[108] He also remembered that the surveyors' chainmen:[109]

> were not on the permanent staff, but were merely "odd" men who sat in a corridor until wanted, and were then paid a shilling an hour whilst the job lasted. Some of them would thus be out of work for days, and as they often looked half starved they were the recipients of many small tips from some of us.

The term of his pupilage with Bazalgette expired in 1869 but:[110]

> he kept me on for a year longer as an assistant on various private jobs that he had in hand. Amongst others I surveyed and levelled the Cray Valley for a joint sewerage scheme, and also Oxford and Weston-super-Mare, but whether these schemes were carried out or not I do not remember.

Throughout his career as Engineer to the Board Bazalgette was consulted and reported on the drainage of towns at home and abroad as well as on many other matters. The drainage schemes were mostly prepared by the local authority's engineer and Bazalgette was asked for his comments. Occasionally, the Local Authority would hold a competition for a design for a drainage system and Bazalgette was asked to judge the entries. The Minutes of the Board are punctuated with Bazalgette's requests for permission to engage in such activities. Appendix C gives an idea of the scope of his work. One or two examples will serve to illustrate the range of his clients. In July 1862 he was asked to serve as Juror for the prizes awarded at the International Exhibition in London.[111] In September 1864, in connection with the Metropolitan District Railway, he reported that as:[112]

> the superintending so much of the Railway as shall be constructed through the Thames Embankment . . . was cast upon the Engineer to the Board . . . Mr. Fowler, the Engineer to the company, had agreed, subject to the approval of the Board, that the Engineering Fee to be paid by the Company for this portion of the work should be divided between them, in equal moieties.

The Board agreed. In July 1867 he arbitrated a disputed account between Brighton Corporation and a contractor.[113] In November 1868 he was consulted by the Crown Agents for the Colonies and asked to report on the drainage of Port Louis, Mauritius[114] and, early in 1869, Bazalgette sent his son Edward out there to make surveys.[115] On another occasion, in January 1869 the Board resolved:[116]

> That the sum of £210 forwarded by the London and South Western Railway Company to the Board, in respect of the Engineer's professional fee for examining, revising, and reporting upon their plans of proposed sewers and bridges in connexion with their Kensington and Richmond line, be received by the Board, and handed to the Engineer, in pursuance of the resolution of the Board of the 19th. February last, allowing him to charge a fee for the works in question.

MAIDSTONE BRIDGE

The replacement of the old bridge over the Medway provides further evidence of Bazalgette's external consultancy work. He was introduced to the proposal in September 1875 when 'requested by the Charity Commissioners to advise them respecting a proposed expenditure of their surplus funds in forming an improved communication across the river Medway'.[117] The Board again agreed to Bazalgette's involvement. The Town Council promoted the work and, in January 1877, resolved to apply for an Act. Bazalgette was retained as Engineer and he joined in the public debate as to whether the bridge should be of iron or masonry. However, in July Bazalgette sent in his Report saying:[118]

> the bridge should be constructed of stone, the abutments, piers, and arch stones, cornice and coping being of granite; and the spandrils, wing walls and parapets of Kentish rag . . . Its interior and foundations would be of concrete. In form it would consist of three flat segmental arches . . . The span of the centre arch is 54 feet, and that of each of the side arches 47 feet 6 inches.

Bazalgette estimated the cost at £32,000 of which the Wardens of Rochester Bridge would contribute

half. The Maidstone Bridge Act[119] was passed in August 1877 and the Local Board advertised for Tenders for the:[120]

> ERECTION and COMPLETION of the proposed STONE BRIDGE . . . and the maintenance thereof for twelve month after the completion of the works. The Plans, Sections, Specification, Bill of Quantities, and Form of Tender . . . can be had on payment of £3 3s., at the office of HENRY LAW, Esq C.E., 18 Adam Street, Adelphi, and from whom, or from Sir Joseph Bazalgette, Spring Gardens, London further particulars may be obtained.

Even at this late stage the iron versus stone argument continued and the Mayor published a letter explaining the bridge committee's dilemma and pointing out that if they:[121]

> were now to throw over SIR JOSEPH BAZALGETTE; why, they would have to pay him his commission for the work, in full probably, as if it had all been executed, and so sacrifice £2000 or £3000 . . . You would lose the services of an eminent Engineer, and instead begin afresh with an engineer of a lower order.

However, four tenders were received on 3 October 1877 and that of William Webster for £22,300 was accepted, 'as advised by Sir J. Bazalgette'.[122] The first pile was driven on 24 October 1877 and the bridge was opened with due ceremony on Wednesday 6 August 1879.[123] Bazalgette and William Webster received the balance of money due to them in June 1881 when the Bridge-building Account was closed.[124]

THE ODESSA CONTRACT

Bazalgette's relationship with a contractor currently working for the Board and with another engineer was called into question in 1863. Sir John Rennie had negotiated a concession with the Russian government for the drainage and paving of the city of Odessa. In February 1862 Rennie consulted Bazalgette about a suitable contractor for the work, suggesting George Furness, and offering Bazalgette a share in the profits of the concession for his advice. Bazalgette introduced Rennie to Furness, who was subsequently awarded the Odessa contract. A tripartite agreement was made between Rennie, Bazalgette, and Furness. Furness was to pay Rennie 5% of the gross contract price and Rennie agreed to share 3½% equally with Bazalgette and the remaining 1½% with others. The Vestries were angry and the Board unhappy about this and the Board set up a Committee of Inquiry comprising the Chairman and 24 Board members. They reported, unanimously, in November 1863 in the following terms:[125]

> the Committee disapprove of their Engineer having been concerned in any transaction with any contractor without the consent of the Board, and in contravention of the terms of his appointment, although in respect of works to be performed in a foreign country.
>
> That they find that Mr. Bazalgette, from the first, expressed his readiness to relinquish all his interests in the Odessa Contract, which course he has adopted.
>
> That, after a most anxious inquiry into the whole facts of the case, they are satisfied that there has been nothing reflecting in any way on Mr. Bazalgette's professional or personal honor, and that he has throughout discharged his duty, both to the Board and their Contractors, with ability, impartiality, and integrity.

At the beginning of this affair, Furness was constructing the Northern Outfall Sewer and, during the Inquiry, was awarded contracts for the Northern Outfall reservoirs and the Victoria Embankment. Bazalgette's reputation did not suffer as a result of this episode. He was made a Companion of the Bath in 1871, was Knighted by Queen Victoria at Windsor in 1874 and elected President of the Institution of Civil Engineers in 1884.[126]

THE LAST DAYS

As the end of the Metropolitan Board drew nearer, Sir Joseph decided to retire and, on 8 February 1889, he wrote to the Board:[127]

> My Lord and Gentlemen,—After forty years of arduous and responsible work in the public service, I feel that the time has arrived when I may request to be allowed to retire from the office I hold under your Board, and, in doing so, I would ask you to award me such pension as my services appear to you to deserve.

A week later the Board resolved to pay him a 'retiring allowance' of £1333 6s. 8d. per annum (two-thirds of his salary), 'on condition that he should resign his said office on the 25th. March next'.[128] His retirement was regarded as 'something more than an ordinary event . . . in the management of the

Metropolis'.[129] Thomas Lovick and several other principal assistants in the Engineer's Department also resigned at this time. In July 1889 the newly-formed London County Council appointed Joseph Gordon, previously Engineer and Surveyor to the Borough of Leicester, Chief Engineer to the Council at a salary of £1500 a year.[130]

Sir Joseph continued to live in his house in Wimbledon and retained some consultancy and Parliamentary business. In August 1890 he was interviewed at home and the resulting publication gives a rare and fascinating glimpse of Sir Joseph's home life in retirement. His house was 'a large square-built, roomy-looking dwelling, with lawn and shrubberies in front of it, and twenty acres, or so, of land behind it'.[131] He was described as doing 'a little bit of farming—keeps one or two cows, and makes a little hay in summer'.[132] Sir Joseph said, 'I ride a good deal—usually two or three hours a day. I find it splendid exercise for counteracting the effects of a sedentary life'.[133] Of Sir Joseph, the reporter said:[134]

> Among his colleagues at Spring Gardens, the veteren engineer was, I believe, generally regarded as a quiet man of a somewhat cold and phlegmatic temperament, but there is something very pleasant and genial in the smile that he turns upon his visitor . . . and though he was born in 1819, he gives you the impression of a man with very many years of life and activity yet before him.

However, Sir Joseph died, aged 72 years, at home, on Sunday 15 March 1891, just two years after the Board ceased to exist. At the Institution of Civil Engineers on the following Tuesday evening the President, Sir John Coode, spoke of 'our old and esteemed colleague' whose works 'lie, as it were, at our very doors; and perhaps there is no member of our profession who has had his great works brought so much under the eye of the whole world as Sir Joseph Bazalgette'.[135] The official resolution of sympathy and condolence with Lady Bazalgette and the family, said:[136]

> his life had been given, to considerations affecting public health and welfare in all the large cities of the world, and his works, as the engineer for many years of the Metropolitan Board of Works, will ever remain as monuments of his skill and professional ability.

Sir Joseph's death was widely reported in both the national and technical press. *The Engineer* said, 'the late chief engineer had a very quiet way of discharging his functions' and 'Sir Joseph Bazalgette never appeared to be an ambitious man, and yet he became identified with undertakings which the most ambitious might have been proud to accomplish'.[137] *The Times* commented on another sphere of his life's work:[138]

> In the Parliamentary committee rooms there were few witnesses better known or more influential than Sir Joseph Bazalgette . . . there are few witnesses, it may be added, who will be so much missed as the late engineer of the Metropolitan Board of Works.

An engineering career in Local Government, with responsibility for huge sums of public money, provides daily opportunities for alienating politicians, committee members and ratepayers. Sir Joseph's career with the Metropolitan Board, spanning thirty-three years, shows him to have been an administrator of great ability and tact. He also had the gift of selecting able engineering colleagues without prejudice.[139] Bazalgette was also very supportive to members of his staff, however lowly, and the Board Minutes contain many examples of his persuasive pleading on their behalf. Although the Board ended its days somewhat under a cloud,[140] Bazalgette and his department retained their unimpeached integrity.

Sir Joseph was described as 'very slight and spare, and considerably under the average height; but his face, with its prominent acquiline nose, its keen grey eyes, and its grey whiskers and black eyebrows, gives you the impression of a man of exceptional power'.[141] This impression is captured in his bronze memorial, unveiled in 1901,[142] on the Victoria Embankment. Bazalgette certainly left his mark on London and, like Sir Christopher Wren, it could surely be said of Sir Joseph: 'If you seek his memorial, look around you'.

ACKNOWLEDGEMENTS

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APPENDIX A

PRINCIPAL M.B.W. CONTRACTS

JOB	CONTRACTOR	DATE	AMOUNT
Southern Outfall Sewer	Webster	1860	310,000
Northern Outfall Sewer	Furness	1860	669,000
Northern Mid-level Sewer	Brassey	1861	358,000
Crossness Works	Webster	1862	395,000
Southern Low-level Sewer	Webster	1863	237,000
Northern Outfall Reservoir	Furness	1863	172,000
Thames Embankment North (1)	Furness	1863	500,000
Thames Embankment North (2)	Ritson	1864	247,000
Northern Low-level Sewer	Webster	1864	253,000
Thames Embankment South	Webster	1865	293,000
Isle of Dogs Branch Sewer	Webster	1866	120,000
Thames Embankment North (3)	Webster	1867	127,000
Chelsea Embankment	Webster	1871	132,000
Western Pumping Station	Webster	1872	188,000*
Putney Bridge	Waddell	1882	222,000
Sewers	Waddell	1882	140,000
Battersea Bridge	Williams, Son & Willington	1886	143,000
Northern Outfall: Precipitation Works	Mowlem	1887	406,000

*Includes Engines, boilers, etc.

APPENDIX B

MAIN DRAINAGE PUMPING STATIONS (M.B.W.)

PUMPING STATION	DATE OPEN	CONTRACTORS		ORIGINAL PLANT	TOTAL STAFF
		BUILDING	ENGINE		
Deptford	1865	Aird & Son	Slaughter, Gruning & Co.	4 Beam Engings Total HP = 500 10 Cornish boilers	23
Crossness	1865	Webster	James Watt & Co.	4 Beam Engines Total HP = 500 12 Cornish boilers	51
Abbey Mills	1868	Webster	Rothwell & Co.	8 Beam Engines Total HP = 1136 16 Lancashire boilers	26
Western	1875	Webster	James Watt & Co.	4 Beam Engines Total HP = 360 8 boilers	19
Effra Creek	1879			1 Steam engine Vertical spindle pump (68 in. dia.)	
Falcon Creek	1879			1 Steam Engine Vertical spindle pump (72 in. dia.)	
Isle of Dogs	1888	Perry & Co.	James Watt & Co.	2 Horizontal engines.	

APPENDIX C

BAZALGETTE'S DRAINAGE REPORTS 1858–1875

	SUBJECT
5 Aug 1858	EPSOM: Drainage of the Royal Medical Benevolent College.
1858	LUTON: Drainage.
13 Jan 1859	NETLEY: Royal Victoria Hospital—best means of disposing of its sewage.
10 Oct 1862	FELTHAM: Drainage of Middlesex Industrial School.
Jun 1862	SHREWSBURY: Sewage, Pipe sizes, Estimate.
8 Jun 1863	BRISTOL: Drainage.
14 Oct 1863	CHELTENHAM: Sewage Deodourization.
20 Jun 1865	WESTON SUPER MARE: Drainage.
Nov 1865	OXFORD: Drainage.
10 Jan 1866	HASTINGS & ST. LEONARD'S: Drainage.
Mar 1866	FOLKESTONE: Drainage.
1 May 1866	OXFORD: Drainage.

15. *11 & 12 Vict*, c. 112, "An Act to Consolidate, and continue in force for Two Years . . . the Metropolitan Commission of Sewers" (4 September 1848).
16. Ibid.
17. Op. cit. (13).
18. *The Engineer*, 20 April 1894, p. 335.
19. Obituary of Mr. Frank Forster, *Min. Proc. I.C.E.*, **Vol. XII** (1852–53), p. 157.
20. *Civil Engineer and Architect's Journal*, Vol. **15** (1852), p. 160.
21. Haywood's overtime schedule, Engineer's Main Drainage Papers, 2.2, City Corporation Record Office.
22. Engineer's Main Drainage Papers, 1.16, City Corporation Record Office.
23. Op. cit. (21).
24. Ibid.
25. *18 & 19 Vict.*, "An Act for the Better Management of the Metropolis" (14 August 1855).
26. *The Engineer*, 28 March 1856, p. 169.
27. Ibid.
28. Minute of 1 January, M.B.W. Minutes, 1856, p. 7.
29. *The Observer*, 6 January 1856.
30. Ibid.
31. Minute of 14 January, M.B.W. Minutes, 1856, p. 15.
32. *The Observer*, 20 January 1856.
33. Minute of 25 January, M.B.W. Minutes, 1856, pp. 19–20. The candidates were:

J. W. Bazalgette	1, Greek Street, Soho.
R. Rawlinson	34, Parliament Street.
Thomas Cox	Croydon.
D. Henry	Borough Engineer's Office, Wolverhampton.
W. Y. Freebody	9, Duke Street, Westminster.
Richard Dixon	Rotherham, Yorkshire.
John Alfred Ikin	14, Chatham Place, Blackfriars.
Wm. Trego	1, Chelsea Villas, West Brompton.
G. R. Booth	9, Portland Place, Wandsworth Road.

34. Ibid., p. 20. The voting was as follows:

Candidate	Show of Hands		
	1	2	3
Mr. Bazalgette	31	32	32
Mr. Henry	15	12	0
Mr. Rawlinson	12	10	0
Mr. Booth	1	0	0

35. Parliamentary Papers (London, 1889), XXIX, *Final Report of the Royal Commission appointed to Inquire into Certain Matters connected with the working of the Metropolitan Board of Works* (8 April 1889), p. 327, Bazalgette's evidence of 13 July 1888.
36. *Cassell's Saturday Journal*, 30 August 1890, p. 1161.
37. Op. cit. (35), p. 327.
38. To help with this extensive parliamentary business, Bazalgette was assisted by the consulting engineering firm of Law & Chatterton. See Obituary of Mr. Henry Law, *Min. Proc. I.C.E.*, Vol. **CXLII** (1899–1900 Part IV), p. 362.
39. Op. cit. (35), p. 341, evidence of 13 July 1888.
40. Ibid., p. 474, evidence of 14 August 1888.
41. Ibid., p. 321, evidence of 10 July 1888.
42. Ibid., p. 363, evidence of 17 July 1888.

43. Ibid., p. 322, evidence of 10 July 1888.
44. Ibid., p. 335, evidence of 13 July 1888.
45. *Cassell's Saturday Journal*, 30 August 1890, p. 1161.
46. M.B.W. Minutes, 1856, p. 35.
47. Report to M.B.W. (6 April 1858), "The Main Drainage of the Metropolis, presented by Messrs. Bidder, Hawksley, and Bazalgette, in accordance with a resolution of the Board, dated 23 November 1857".
48. Minute of 15 October, M.B.W. Minutes, 1858, p. 666.
49. *21 & 22 Vict.*, c. 104, "An Act . . . to extend the powers of the Metropolitan Board of Works for the Purification of the Thames and the Main Drainage of the Metropolis" (2 August 1850).
50. This sewer, 12 miles long, runs from Kensal Green, under Bayswater Road and Oxford Street and then through Clerkenwell, to the River Lea. The contractor was Thomas Brassey, who used steam cranes to lift the excavated material.
51. Minute of 12 May, M.B.W. Minutes, 1859, p. 310.
52. Bazalgette's salary and travelling allowances progressed as follows:

Date	Salary £	Expenses £	Total £
14 January 1856	1000	—	1000
15 June 1859	1000	200	1200
19 July 1861	1200	200	1400
21 November 1862	1500	200	1700
13 October 1865	2000	200	2200*

*Remained so until Bazalgette retired in 1889.

The Assistant Engineers' salaries progressed as follows:

Date	Salary (£)	Expenses (£)	Total (£)
February 1856	350	50	400
July 1859	350	150	500
November 1861	500	200	700
October 1865	800	200	1000

53. Minute of 25 February, M.B.W. Minutes, 1859, p. 115. Twenty-five designs were sent in and considered by the Committee.
54. Minute of 30 July, M.B.W. Minutes, 1857, p. 16. The Committee members requested, and were supplied (in June) with photographs of the competition drawings.
55. Engineer's Eighth Annual Report (to the M.B.W.), 4 July 1864.
56. *The Engineer*, 29 July 1864, p. 71.
57. Minute of 7 April, M.B.W. Minutes, 1865, p. 434.
58. Ibid.
59. Ibid. 269 guests sat down to lunch in the covered reservoir. The guests included the Dean of St. Paul's, Edwin Chadwick, Professor Airey, William Haywood and J. R. M. McClean (President of the Institution of Civil Engineers).
60. Minute of 6 July, M.B.W. Minutes, 1866, p. 891.
61. Op. cit. (35), p. 235.

62. Ibid., p. 363.
63. Ibid., p. 330. The first sludge-vessel was built at Barrow, at a cost of £16,353, arrived in the Thames in June 1887 and was named the *Bazalgette*.
64. The idea of embanking the Thames goes back certainly to the fourteenth century. Sir Christopher Wren conceived a plan to embark the Thames from Temple Gardens to the Tower after the Great Fire of 1666. In the 1860s, Parliamentary Committees and Commissions discussed plans submitted by the following engineers: Fowler, McClean, Hemans, Page, Shields, Gisborne and Bazalgette. Parliament had allocated the Coal Duty revenue to pay for the works.
65. *Cassell's Saturday Journal*, 30 August 1890, p. 1160.
66. The north bank between Westminster and Blackfriars was indented with coal wharves and river access to the City Gas Works was also a problem. The Duke of Northumberland owned extensive property in the area, which he eventually conveyed to the M.B.W.
67. Report of the Select Committee on the Thames Embankment Bill, 23 June 1862, Bazalgette in evidence on 28 May 1862.
68. Derek Hudson, *Munby: Man of Two Worlds*, (London, Abacus, 1974), p. 188, "Friday 15 April 1864".
69. The contractors were:
    Contract No. 1, Westminster to Waterloo Bridge: Mr. Furness.
    Contract No. 2, Waterloo Bridge to Temple: Mr. Ritson.
    Contract No. 3, Temple to Blackfriars, plus the whole roadway: Mr. Webster.
70. Op. cit. (35), p. 329.
71. *26 & 27 Vict.*, c. 75, "An Act for the Embankment of part of the River Thames, on the South Side thereof . . ." (29 July 1863).
72. *31 & 32 Vict.*, c. 135, "An Act to enable the Metropolitan Board of Works to Embank the River Thames between the Royal Hospital at Chelsea and Battersea Bridge", (13 July 1868).
73. Edward Bazalgette, "The Victoria, Albert, and Chelsea Embankments of the River Thames", *Min. Proc. I.C.E.*, Vol. **LIV** (1877–78 Part IV), pp. 1–24 and ibid., p. 30, J. W. Bazalgette in discussion on 9 April 1878.
74. Op. cit. (35), p. 337.
75. Ibid.
76. Ibid., p. 321.
77. *The Engineer*, 21 May 1880, p. 373.
78. Ibid.
79. Parliamentary Papers (London, 1854), XIV, *Report from the Select Committee on Metropolitan Bridges*. The Committee considered that, although it may become necessary to build additional bridges, it would be better, first, to ascertain the effect of freeing the bridges from tolls.
80. *The Artizan*, Vol. **XII**, No. CXLIII, 1 December 1854, p. 34.
81. *40 & 41 Vict.*, c. 99, "An Act to provide for throwing open for the free use of the public certain Toll Bridges within the Metropolis" (12 July 1877).
82. *Cassell's Saturday Journal*, 30 August 1890, p. 1161.
83. Op. cit. (35), p. 337.
84. Ibid.
85. Report to M.B.W. (26 May 1880): "Metropolitan Bridges, Report by Sir J. W. Bazalgette, CB, as to repairs urgently Necessary".
86. Bazalgette's bridge designs were done in conjunction with his son Edward, who was by then "Assistant Engineer (Metropolitan Bridges)".
87. Minute of 17 February, M.B.W. Minutes, 1882, p. 266.
88. *Collins' Illustrated Guide to London* (1877), p. 104.
89. These were all high-level, fixed bridges and the designs included a parallel lattice girder, a braced cantilever and a lattice arch design.
90. Bazalgette's report to the M.B.W. (15 March 1877): "Proposed Bridge over the Thames below London Bridge", p. 14.
91. Parliamentary Papers (London, 1879), *Select Committee on the "Tower High Level Bridge (Metropolis) Bill"*, p. 127. Bazalgette in evidence on 20 May 1879.

92. *50 & 51 Vict.*, c. CLXXII, "An Act for Enabling the Metropolitan Board of Works to make a new means of Communication across the River Thames by means of a Tunnel at Blackwall" (8 August 1887).
93. Op. cit. (35), p. 331.
94. Ibid.
95. Ibid.
96. Ibid., p. 336.
97. Ibid., p. 339.
98. Ibid., p. 336.
99. Ibid., p. 334.
100. Ibid., p. 323.
101. R. H. Parsons, *Early Days of the Power Station Industry*, (Cambridge, C.U.P., 1939), pp. 4–5.
102. Op. cit. (35), p. 336.
103. Minute of 12 August, M.B.W. Minutes, 1859, p. 593.
104. The premises in Greek Street soon became inadequate and were sold, by auction, for £6400 in August 1861 (M.B.W. Minutes, 1861, p. 630). The M.B.W. acquired a new site in Spring Gardens on which it built a new office building.
105. H. P. Boulnois (1846–1927) became Engineer to Exeter (1874), Poetsmouth (1883) and Liverpool (1890) Corporations and Inspector with the Local Government Board in 1897.
106. H. Percy Boulnois, *Reminiscences of a Municipal Engineer*, (St. Bride's Press, London, 1920), p. 29.
107. Ibid., p. 30. (See also A. W. Skempton, "Portland Cements, 1843–1887", *Transactions of the Newcomen Society*, Vol. **35** (1962–63), p. 117).
108. Ibid.
109. Ibid., p. 31.
110. Ibid., p. 34.
111. Minute of 4 July, M.B.W. Minutes, 1862, p. 521.
112. Minute of 23 September, M.B.W. Minutes, 1864, p. 941.
113. Minute of 12 July, M.B.W. Minutes, 1867, p. 882.
114. Minute of 6 November, M.B.W. Minutes, 1868, p. 1224.
115. Edward Bazalgette's Membership certificate, 8 April 1879, Muniment Room, I.C.E.
116. Minute of 21 January, M.B.W. Minutes, 1869, p. 46.
117. Minute of 24 September, M.B.W. Minutes, 1875, p. 281.
118. Printed report "To the Corporation of Maidstone" dated "Spring Gardens, London, S.W., July 1877", Maidstone Corporation Minute Book, Maidstone Council Offices.
119. *40 & 41 Vict.*, c. 138, "An Act for Authorizing the construction of a Bridge over the River Medway at Maidstone; and for other purposes" (2 August 1877).
120. Letter, J. W. Bazalgette to Maidstone Corporation, 7 August 1879, suggesting his form of advertisement for tenders (which was adopted), Maidstone Corporation Minute Book, p. 179, Maidstone Council Offices.
121. Para. 3 of printed letter "The Mayor to Mr Ellis", 10 September 1877, Maidstone Corporation Minute Book, p. 195, Maidstone Council Offices.
122. Bridge Committee Report, 30 October 1877, Maidstone Corporation Minute Book, p. 179, Maidstone Council Offices. The four tenders were: William Webster, £22,300; Henry Lee and Sons, £24,500; Ball and Gammon, £28,800 an Mr. Hill, £29,875.
123. See *South Eastern Gazette*, 9 August 1879, p. 4, for full description, speeches, etc.
124. Minute of 8 June 1881, Maidstone Corporation Minute Book, p. 407, Maidstone Council Offices.
125. Enclosure of 27 November, Report dated "Spring Gardens, 25 November 1863", M.B.W. Minutes, 1863, p. 1069. Copies of London and to each of the Vestries and District Boards of the Metropolis. At the next meeting of the Board on 4 December, The Vestry of Shoreditch requested a copy for each member of the committee and the Chelsea Vestry requested 60 copies.
126. Sir Joseph's Presidential Address was given on 8 January 1884 and dealt with "engineering works which promote the health and comfort of the inhabitants of large cities". He took a global view and produced statistics of population and death-rate per 1000 for 45 large cities. (*Min. Proc. I.C.E.*, Vol. **LXXVI** (1883–84), Part II), pp. 1–69).
127. Minute of 8 February, M.B.W. Minutes, 1889, p. 326.

128. Minute of 15 February, M.B.W. Minutes, 1889, p. 423.
129. *The Engineer*, 15 February 1889, p. 141.
130. Minute of 9 July, London County Council Minutes, 1889, p. 540. The L.C.C. could not match Bazalgette's continuity of service. Joseph Gordon died on 9 November 1889 and was replaced by C. Dunscombe who, in turn, was replaced by A. R. Binnie (later Sir Alexander) in 1890—three engineers in little over a year.
131. *Cassell's Saturday Journal*, 30 August 1890, pp. 1160–61: "Representative Men at Home—Sir Joseph Bazalgette, C.B., at Wimbledon".
132. Ibid.
133. Ibid.
134. Ibid.
135. Sir John Coode on the death of Sir J. W. Bazalgette, *Min. Proc. I.C.E.*, Vol. **CV** (1890-91 Part III), p. 106.
136. Ibid.
137. *The Engineer*, 20 March 1891, p. 231.
138. *The Times*, 16 March 1891.
139. During 1855, the last year of the Metropolitan Commission on Sewers, Bazalgette was drawn into conflict with John Grant, one of his District Engineers. The issue concerned the relative merits of glazed pipe sewers and brick sewers. Bazalgette preferred brick sewers and Grant preferred pipes. Grant published a report on 30 March 1855, Bazalgette replied with a report on 30 April and then, on 8 May, there appeared the "Rejoinder of Mr. J. Grant to Mr. Bazalgette's remarks". Bazalgette was annoyed and, on 10 May, wrote to the Commissioners thus:

> "Though quite prepared on any fitting occasion when required to meet Mr. Grant's observations . . . the tone of that document is such that I feel I should best consult what is due to me personally and officially, and to the position I occupy, by at present refraining from any counter observations whatever.

Nevertheless, Bazalgette selected Grant as one of his Assistant Engineers at the M.B.W. and, on Grant's death in 1888, he described Grant as:

> "A man on whose word I could depend thoroughly an a most careful painstaking officer with reference to his work. He has introduced into the Metropolis some of the best work that has ever been constructed in public works, and he has been the means of improving the manufacture of cement for which the country is greatly indebted to him". (Op. cit. (35), p. 338).

140. Charges of corrupt practice were made against the Board in 1886 with regard to the allocation of building sites in Shaftesbury Avenue. A Royal Commission was appointed, in 1888, to "Inquire into Certain Matters connected with the working of the Metropolitan Board of Works". They questioned many Officers and Members of the Board, including Bazalgette, who was asked 661 questions between 10 July and 14 August 1888. They made their report without exposing any misconduct of those interviewed. They had, however, received a letter from the Architect's Assistant for Valuation stating that he "had failed in his duty to the Board" but was too ill to be interviewed. The Metropolitan Board of Works was wound up under the powers of the Local Government Act (*51 & 52 Vict*, c. 41 (13 August 1888)). The London County Council came into office on 21 March 1889.
141. *Cassell's Saturday Journal*, 30 August 1890.
142. The memorial, with bronze bust, is by George Simmonds and was unveiled in 1901.

DISCUSSION

Mr. Peter Skilton asked whether Bazalgette had investigated the possible damage to the Thames embankment service ducts which might arise from the roots of the trees lining the embankments? **Dr. Smith** replied that Bazalgette seemed to have foreseen the problem; the tree roots were contained in special pockets within the Portland cement concrete, which were provided as part of the design.

Mr. Geoffrey Binnie said that within a year of Bazalgette's retirement his place had been taken by Alexander Binnie (the speaker's grandfather), who was responsible for completing Bazalgette's unfinished schemes as well as for building the Blackwall Tunnel. In relation to the paper, Mr. Binnie wondered whether George Roe, who had been one of Bazalgette's Assistant Engineers, was any relation of John Roe, who had developed the egg-shaped sewer? Dr. Smith said he thought the two Roes were related, but could not confirm that without further checking.

A visitor asked whether Bazalgette was known to have introduced hot-air central heating in any public building? Such heating had been used in 1890 in a Wimbledon house built by Bazalgette for his daughter which, unusually for its day—had no fireplaces. Dr. Smith said such matters would have been the responsibility of the Architect's Department of the Board and not of Bazalgette.

Mr. John Butler asked which firm had been responsible for making the 8½ feet diameter metal pipes used to carry the Northern Outfall Sewer across railway lines? Dr. Smith said that Rothwell's of Bolton were responsible for the metal pipes used on the Northern Outfall contract.

Mr. E. F. Clark said that, as mentioned in the paper, Bazalgette had not originated the concept of intercepting sewers but that the idea went back to before Frank Forster's time having, apparently, been suggested by one John Martin, an artist, in 1834. Mr. Clark went on to say that the political moves which preceded the final enabling Act of August 1858 were even more complex than Dr. Smith had indicated. No fewer than 5 pairs of sites for the outfalls were considered, those furthest down the river being below Tilbury and Gravesend respectively. When the Chairman of the Metropolitan Board of Works, in the words of a later official report '. . . enquired whether Her Majesty's Government would be prepared to contribute to the additional cost . . .', the First Commissioner stated that '. . . in his opinion, Parliament would refuse to make any contribution to the works in question'. The resulting deadlock was only resolved by a change of Government to one in which Disraeli became Chancellor of the Exchequer. He enunciated the principle that 'He who pays the fiddler has a right to call the tune'. As a result, the Metropolitan Board of Works, emboldened by the report submitted on 6 April 1858 by Bazalgette, Hawksley and Bidder, went ahead with the scheme which forms the basis of the present arrangements. Dr. Smith replied that it was probable that the concept of intercepting sewers could be traced back even earlier than 1834 but, by 1851, it was firmly established as a realistic engineering project with proper design drawings and so on.

Rear-Admiral Derek Bazalgette said that his great-grandfather would have been delighted with Dr. Smith's paper about him. The family had few details about Sir Joseph but it was known that he was small, very asthmatic and probably rather irascible. He was obviously a 'workaholic' who had time only to work on London—and produce children. He was not infallible; papers in the family's possession recorded controversies he had encountered over a scheme for draining Windsor Castle. Although Queen Victoria had made him a Companion of the Bath, he had incurred the hostility of the Commissioner of Lands and Revenues, and of the citizens of Windsor. This seemed to suggest that Sir Joseph's scheme was, on that occasion, less than perfect.

Mr. Robert Cargill asked how well Bazalgette's works were surviving. Would the intercepting sewers need replacing soon? Dr. Smith said that the basic system was a palimpsest which had been worked on by successive generations of engineers. It was difficult to say which portions of it were the original work of the 1860s and which were more recent. The Thames Water Authority had a rolling programme of maintenance, upgrading and renewals going on all the time, but the original works had certainly stood up remarkably well to the passage of time.

Mr. David Perret asked whether Bazalgette's road-building activities had been, in a sense, part of a more general scheme of urban improvement? All the large London schemes seemed to be aimed at large slum concentrations but, under the legislation of the 1870s, the M.W.B. had no obligation to rehouse those who were displaced. Dr. Smith replied that artisans' housing was, indeed, one of Bazalgette's responsibilities, discharged jointly with the Architect's Department, but space had not permitted the development of that theme in the current paper.

A visitor asked why the outfall positions had been chosen at Crossness and Beckton? Recent observations suggested that, on the Beckton side at least, the Thames current flowed upstream whatever the state of the tide; perhaps the flow testing had not been done so thoroughly on the northern side? Dr. Smith replied that he supposed the most important consideration had been that the sewage should not back up as far as the Houses of Parliament!

Mr. J. S. Allen (President) proposed a vote of thanks to Dr. Smith, which was carried with acclaim.