London's Water Infrastructure and the Development of its Technology

By: Jason Strauss

Course Title, Course Number, Term
Introduction to the History of Science, HI 1331-B01, B 2016
GPS: Power the World I, FY 1100-C01, C 2017
Philosophy and the Environment, PY 2717-D01, D 2017
London HUA: Architectural History, HU 2999-E106, E1 2018
London HUA: History of Scientific Museums, HU 2999-EFB1, E1 2018

Presented to: Professor David Spanagel
Department of Humanities & Arts
Term E, 2018
HU 3900-E106

Submitted in Partial Fulfillment of
The Humanities & Arts Requirement
Worcester Polytechnic Institute
Worcester, Massachusetts.

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Introduction

Today over two billion gallons of fresh water are pumped annually into people's homes, but obtaining water it was not always as simple as turning on a faucet.[1] Four hundred years ago in the sixteenth century, there was no running water. All of the water for households had to be collected and carried home in buckets. Citizens that were wealthy could pay people to bring water to their homes, but water still had to be gathered by hand. Over the next two hundred years, the population rose significantly in London scientists and mathematicians developed new technologies for water gathering and distribution to keep up with demand. Most of these developments had origins dealing with other problems in London but were eventually adopted to work for the water gathering process. Engineers, such as Peter Morris, invented waterwheels to drive factories, but in the process, they invented a machine that could consistently carry and lift water out of a river. Engineers, such as James Watt, invented engines and pumps to deal with flooding problems in the mines, but in the process, they invented a machine that could transport water over long distances within a pipe. So many inventions scientists and mathematicians came up with to fuel the Industrial Revolution could also be applied to the water gathering and distribution process.

Scientists and engineers continued to develop the technologies used to gather and distribute water, but a growing concern for sanitation lead these developments down a different path. An increase in demand first drove the initial developments, but soon more and more people became ill from diseases such as cholera. The government demanded that better sanitation drive the developments for water infrastructure instead, and scientists began working on new

[1] Weinreb, B. and Hibbert, C. (eds) *The London Encyclopedia*, London: Macmillan, 1983, 932.

developments such as implementing sand filter beds and ozone tanks to the water gathering process and implementing new, longer lasting pipes to the water distribution process.

Early Water Supply

Before the arrival of London's first major water companies, London's water supply included the same kinds of wells and pumps that existed in European cities well into the nineteenth century, as well as small, low pressure, gravity flow aqueducts that drew water from springs, lakes and rivers. These stone and lead aqueducts typically brought the water to cisterns and public fountains, as well as provided supplies to some privileged buildings, such as palaces or baths. Medieval aqueducts were usually erected and maintained by local institutions such as the town corporation, or in some cases monasteries.[2] Although these preindustrial technologies were diverse, small-scale, and tended to be use-specific, altogether they provided a remarkably sustainable and adequate water supply for urban uses in London through the first couple of centuries of the city's notably rapid growth. These systems only prove to be inadequate to meet demand during the eighteenth century, when a new economic entity would come into play.[3]

There were three main types of pumps that were used in London prior to the arrival of the water companies. These pumps included the chain and rag pump, the bucket pump, and the force pump. The chain and rag pump was a pump used in vertical piping by trapping water between two disks that were originally made from rags and wood. It was only able to lift water and could not supply water under pressure. A crank could then move the chains, to which the disks were attached, upwards moving the water up with it. The bucket pump was primarily used for wells and was originally just a bucket with a valve in the bottom. The valve allowed water to flow into

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[2] Robins, Frederick William. *The Story of Water Supply*. Oxford: Oxford University Press, 1946. In the discussion on medieval aqueducts, 52-68

[3] Robins, Frederick William. *The Story of Water Supply*. Oxford: Oxford University Press, 1946, 52-68. Magnusson, Roberta J. *Water Technology in the Middle Ages: Cities, monasteries, and waterworks after the Roman empire*. Baltimore: Johns Hopkins University Press, 2001, 92-108

the bucket as the bucket was dipped into a reservoir and the valve was then closed upon transport of water. Over time, the bucket became larger and was encased in a shaft creating a huge column of water that can be brought up vertically through a pipe. The force pump worked like a hypodermic syringe. A lever was forced up creating a vacuum, opening a valve, and sucking water in. The first valve then closed, trapping the water. Forcing the lever back down again pushed open a second valve leading to a spout. The use of pressure in the force pump means it could work at very high pressures. The driving force behind all of these pumps was man or animal powered or naturally powered by use of wind and water.[4]

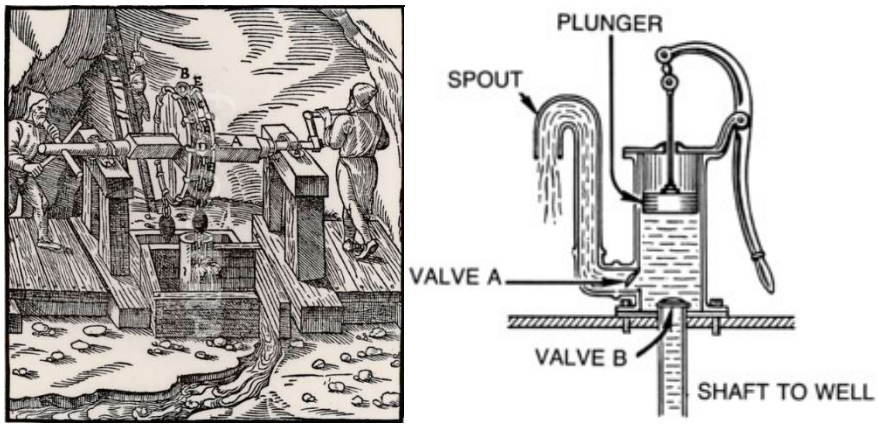

Figure 1: Examples of Early Pumps: Chain and Rag (left) and Force/Piston (right)
Source: De Re Metallica (left) wikiwand (right)

Other forms of providing water to London before the seventeenth century included water wheels. These mechanisms gave access to a quantity of water that surpassed what existing wells and hand-carried buckets could provide. Although waterwheels had been used by the ancient Romans, they were used abundantly during the Middle Ages to drive mills. In the later Middle Ages in particular, waterwheels were being put to an ever-increasing range of uses such as

[4] London Water and Steam Museum, Exhibit on the History of Water Supply
The figure below (left) was originally from De Re Metallica, 1754 based on a chain and rag pump design from the 16th century but can be found from this link http://www.fotolibra.com/gallery/1021429/rag-and-chain-pump-being-used-to-raise-water-from-a-mine/
The figure below (right) can be found from this link http://www.wikiwand.com/en/Piston_pump

slitting mills and fulling mills. In terms of water supply, the wealthy Hanseatic city of Lübeck in northern Germany had a bucket wheel providing drinking water in 1294. The wheel supplied almost 200 houses through wooden pipes made from hollowed-out logs. A number of other German cities also introduced bucket pumps with waterwheels to supply drinking water, such as Hannover (1352), Breslau (1386), Bremen (1396), Bautzen in Saxony (1496).[5] During the sixteenth century, city developers would replace many of these bucket waterwheels, such as the ones in Lübeck and Hannover with new types of pumps called piston pumps providing greater quantities of water. Although it is not clear when piston pumps were invented in Europe, they first appear in manuscripts in Italy in the fifteenth century. Besides use in urban water supply, miners in eastern Europe would often use these piston pumps. In mining as well, the earliest mechanisms from the late fourteenth century were the chain and rag pumps, but by the early sixteenth century, people began using piston pumps. These waterwheel-driven piston pumping mechanisms, with their greater capacity, spread from Germany and arrived in England at the end of the sixteenth century.[6]

By the late sixteenth century, London had a growing interest in hydraulic engineering with, for example, the reconstruction of some of Rome's ancient aqueducts. Many city developers built new pumps in London, such as the force and piston pumps. This was mostly a result of a Dutch or German land drainage engineer by the name of Peter Morris. Morris also proposed building a waterwheel driven mechanism to pump water from the Thames. The City Corporation gave Morris a lease on the first two arches of London Bridge for 10 shillings per

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[5] Magnusson, Roberta J. *Water Technology in the Middle Ages: Cities, monasteries, and waterworks after the Roman empire*. Baltimore: Johns Hopkins University Press, 2001, 92-108

[6] Hansen, Roger D. "Water-Related Infrastructure in Medieval London." 2007 http://www.waterhistory.org/histories/london/.

year. London Bridge, dating from the thirteenth century, was at the time the only one crossing the Thames. The establishment of the London Bridge Waterworks also gave an impulse to the model of direct domestic connections, an important feature of modern networks. Originally, Morris supplied public fountains, as the medieval and Roman conduits did, but he also began to supply individual buildings. Before Morris's arrival, individuals petitioned the City of London to be allowed direct connections to their houses, but with relatively few supporters politicians cleared away these petitions. With the arrival of water companies, the dynamic shifted, and they sought to distribute water more widely, slowly driving the extension of London's water network over the coming decades.[7]

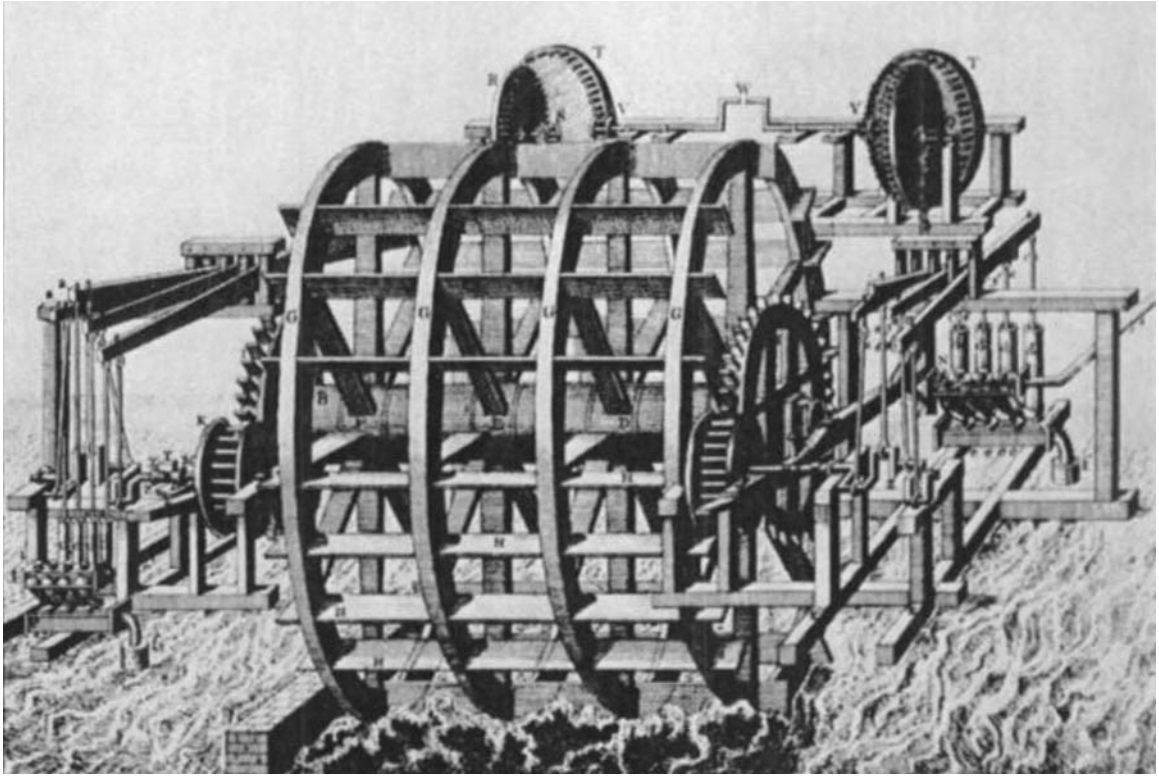

Figure 2: London Bridge Waterworks
Source: National Maritime Museum

[7] Magnusson, Roberta J. *Water Technology in the Middle Ages: Cities, monasteries, and waterworks after the Roman empire*. Baltimore: Johns Hopkins University Press, 2001, 92-108
The picture below can be found at the link: http://collections.rmg.co.uk/collections/objects/151965.html

The Water Companies Arrive

The first major water company to arrive in London was the New River Company. Sir John Backhouse, an English landowner and politician, founded the company after London had obtained Acts of Parliament in 1606 and 1607 to build a channel bringing fresh water from Hertfordshire into reservoirs just north of London and then pipe it to citizens for a price. The first promoter who funded the project left after the company refused to subsidize the project. The second promoter for funding was Hugh Myddelton, a wealthy goldsmith and member of the Parliamentary Committees considering water supply. He underestimated the cost involved with the project and was forced to ask for half of the funding from King James I. Once the project was complete and the system was turned on, it was a success. The New River was an open aqueduct around 42 miles in length, bringing water to reservoirs at Islington, originally outside the city itself. From there, the water entered a number of mains under city streets. The water was distributed directly into houses, or into private courts where a number of dwellings could draw from a common reservoir. The water was low pressure, and supply was intermittent. Typically, water flowed into a basement reservoir two or three times a week for a couple of hours at a time. Servants would then draw water from this reservoir and distribute throughout the house as needed. The significance of this company is that houses for the first time would have a direct intermittent source of water and the New River Company was highly profitable. The piping system was very inefficient though with the use of clay and wooden pipes, and a quarter of the water was lost from leakages in the New River Company's pipes that ran through the city in 1613.[8]

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[8] Ward, Robert. *London's New River*. London: Historical Publications, 2003, 13-34
Hansen, Roger D. "Water-Related Infrastructure in Medieval London." 2007
http://www.waterhistory.org/histories/london/. under the section of Sir Hugh Myddelton

The next water companies to arrive made extensive use of water pumped from the Thames, but still had the expense of reservoirs, pumping, and pipe-laying. The Chelsea water company for example, founded a century after the New River Company in 1723, had operations for extracting and storing water from the Thames. These operations had spread across 89 acres of present day Pimlico and Victoria by the end of the eighteenth century. The company required extensive land in order to raise water out of the Thames using a tidal pumping system that had minimal running costs.[9]

Population Growth and Engines

As early as the year 1500, London had been three to four times the size of the largest provincial town, Norwich. By the end of the seventeenth century, it was fifteen times larger. London was the seventh or eighth biggest city in Europe in 1550, third biggest in 1600 with Paris and Naples in front, and second in 1650 surpassing Naples. By the end of the century, London was the largest city in Europe.[10] London's population in 1580 was approximately 200,000 people and by 1700, London's population had more than tripled to about 700,000 people.[11]

London's demand for water increased naturally as the number of its thirsty citizens began to skyrocket. The water companies at the time were doing their best to keep up with demand. Meanwhile in the mines, scientists began to draw up new patents for designs to pump water. In the seventeenth century, coal replaced wood as the main fuel source but it could only be mined close to the surface and supplies were beginning to run out. It was impossible to mine deep underground due to flooding. Thomas Savery, a military engineer, proposed a solution to make it easier to drain water from mines, and on July 2, 1698 Savery patented an early steam engine. He

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[9] Ball, Michael, and David Sunderland. *An Economic History of London: 1800-1914.* London: Routledge, 2001, 266
Weinreb, B. and Hibbert, C. (eds) *The London Encyclopedia*, London: Macmillan, 1983, 542
[10] Porter, Roy. *London: A Social History*. Cambridge, Mass.: Harvard University Press, 1994, 66
[11] London Museum of Water and Steam Water Exhibit timeline comparing major events of water infrastructure development and population growth

called it "A new invention for raising of water and occasioning motion to all sorts of mill work by the impellent force of fire, which will be of great use and advantage for draining mines, serving towns with water, and for the working of all sorts of mills where they have not the benefit of water nor constant winds." Savery demonstrated his invention to the Royal Society on June 14, 1699. The patent had no illustrations or even description, but in 1702 Savery described the machine in his book, *The Miner's Friend; or an Engine to Raise Water by Fire, Described*.[12]

Savery's pump was the first useful steam pump intended to pump water from mines but it was not a success. Much of the heat was wasted in warming up the water that was being pumped. The engine was also barely capable of withstanding the high-pressured steam needed to force the water up and needed frequent repair. Finally, water was pushed up into the engine only by atmospheric pressure (working against a condensed steam vacuum), so the engine had to be no more than about 30 feet (9.1 m) above the water level—requiring it to be installed, operated, and maintained far down in the dark mines. Savery's pump did however find use for pumping water for fountains and cascades in the gardens of wealthy people's homes. Most importantly, Savery's pump patent covered any method of raising water by fire, including the engine of Sir Thomas Newcomen.[13]

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[12] Savery, Thomas. *The Miners Friend, Or, An Engine to Raise Water by Fire Described: And of the Manner of Fixing It in Mines: With an Account of the Several Other Uses It Is Applicable Unto, and an Answer to the Objections Made against It.* London: Printed for S. Crouch, 1702.
Supplemental information from Lira, Carl. "*Savery Pump*." MSU College of Engineering. 2001. https://www.egr.msu.edu/~lira/supp/steam/savery.htm.

[13] Kitsikopoulos, Harry. *Proceedings of the American Philosophical Society.* In *From Hero to Newcomen: The Critical Scientific and Technological Developments That Led to the Invention of the Steam Engine*. 3rd ed. Vol. 157. American Philosophical Society, 2013, 304-344 "Savery's engine had no piston, and no moving parts except for the taps. It was operated by first raising steam in the boiler; the steam was then admitted to one of the first working vessels, allowing it to blow out through a downpipe into the water that was to be raised. When the system was hot and therefore full of steam, the tap between the boiler and the working vessel was shut, and if necessary the outside of the vessel was cooled. The closing of the tap made the steam inside it condense, creating a partial vacuum, and atmospheric pressure pushed water up the downpipe until the vessel was full. At this point, the tap below the vessel was closed, and the tap between it and the up-pipe opened, and more steam was admitted from the boiler. As the steam pressure built up, it forced the water from the vessel up the up-pipe to the top of the mine" (327)
Additional information from The London Science Museum Steam Engine Exhibit

Thomas Newcomen, an ironmonger, erected the world's first successful steam engine near Dudly Castle, Staffordshire, in 1712. As an ironmonger, Newcomen had significant practical knowledge of what materials would be suitable for such an engine and brought him into contact with people having even more detailed knowledge. The engine pumped water from a mine at the rate of 10 gallons per stroke from a depth of 150 feet (45.7 m)—an unprecedented feat in 1712. Newcomen had essentially built the first widely used engine by which man obtained mechanical power other than from wind, water, or muscular effort. Newcomen's engine worked using contact with the atmosphere to condense water and was therefore called an atmospheric engine. His design was rugged and reliable and changed very little for more than 60 years. By 1775, there were more than 100 atmospheric engines at work in the northeast of England alone. Newcomen's engine was a significant improvement over Savery's pump, but it was still very inefficient.[14]

James Watt was a great steam pioneer and a hero of the industrial age. His knowledge in engineering combined with his partner Matthew Boulton's knowledge in business led to the establishment of the Soho Manufactory in Birmingham in 1777. This Manufactory was an industrial wonder of its time, attracting the interests of competitors, heads of state, and the aristocracy. The Soho Manufactory was powered by a steam engine that Watt and Boulton developed called Old Bess. The Soho Manufactory was intended to be water powered, but the river was inadequate. Summer droughts threatened to halt work. Old Bess allowed for pumping water from the bottom of a water wheel to the top so that the water was constantly recycled.

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[14] Kitsikopoulos, Harry. *Proceedings of the American Philosophical Society.* In *From Hero to Newcomen: The Critical Scientific and Technological Developments That Led to the Invention of the Steam Engine*. 3rd ed. Vol. 157. American Philosophical Society, 2013, 304-344 "Newcomen's engine only had an efficiency of about one percent" (332)
Additional information from The London Science Museum Steam Engine Exhibit

Old Bess was an engine built by Watt and Boulton and used a separate condenser for the steam unlike Newcomen's engine. This cut fuel consumption by 75% compared to Newcomen's engine. Newcomen's engines primarily produced an up and down motion while Watt's engine produced a rotary motion allowing these engines to be adopted for use in factories such as the Soho Manufactory. Watt continued to improve his design for the steam engine but greater precision was needed to build these improvements. Factory owners, who bought the engines, also had little experience in steam power. Watt realized that production methods needed to be improved. In 1796, Watt opened the Soho Foundry in Birmingham in order to build engines. It was the world's first factory specially designed to build machines of any kind. Watt's engines were examples of the most advanced engineering in the eighteenth century. The engines' construction depended on a growing workforce of highly trained engineers and new standards of precision. As more and more accurately made machines of all types were demanded by Britain's thriving industries, this combination of people and precision gave Britain a world-beating advantage.[15]

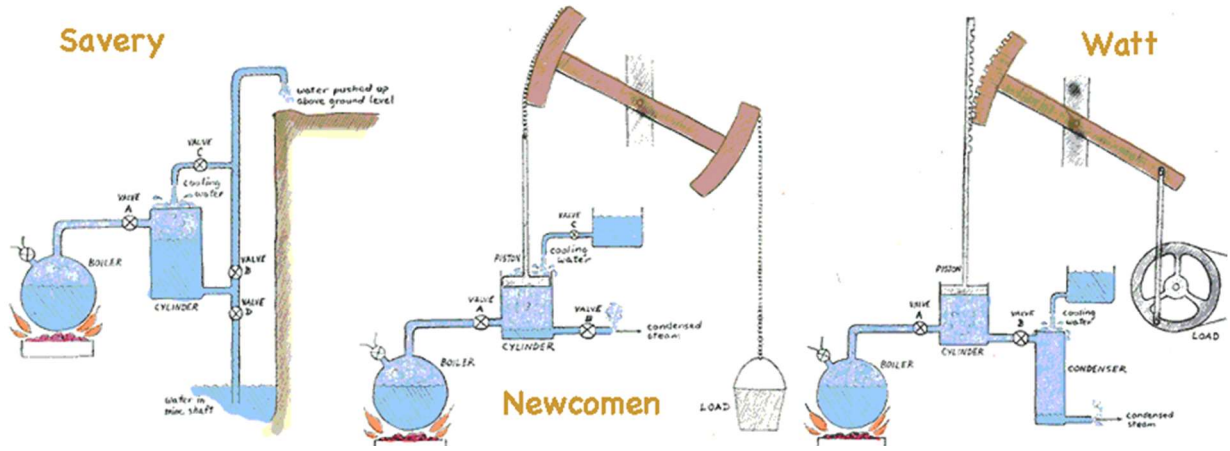

Figure 3: Comparison of the Early Steam Engines
Source: The Triumph of Mechanics, Holt, Rinehart, Winston, 1970

[15] Earl, Bryan. *Cornish Mining: The Techniques of Metal Mining in the West of England, past and Present*. St. Austell: Cornish Hillside Publications, 1994, 62-64
Additional information from The London Science Museum Steam Engine Exhibit
The image below was taken from the link http://d1068036.site.myhosting.com/ePhysics.f/labIII_7.html and was sourced in the link from *The Triumph of Mechanics*

Developments in the Water Companies

The London water industry in the 18th century is notable for the scale it acquired, and this large scale helped finance the industries' expansion. In terms of size, the New River Company represented about 75% of the industry in the city from the point of view of customers served. Although there was a period of fairly intense competition among the companies between 1670 and 1710 when many new companies formed during a joint-stock boom, the New River became increasingly significant from 1700. New River generated consistently healthy profits for its shareholders. The company grew especially after the Great Fire of London in 1666 when much of the city was rebuilt, presenting an opportunity for the company to take on many new customers. The success of the New River's growth became evident in its dividends. From around £33 per share in 1640, they reached £64 in 1665, the year before the fire. By 1670 the Company's dividends were at £70, £145 in 1680, and £222 in 1690. The rapid growth, however, became too fast for the company's own good and the growth proved unable to keep up with the demand for water from all the new customers the company was taking on. In 1682, John Aubrey recorded that "London is grown so populous and big that the new river of Middleton can serve the pipes to private houses but twice a week." Competition from new companies also slowed its profit growth until after 1710, when it expanded it reservoir capacity and began to adopt the use of a wind driven pump. The company stabilized its situation by 1730, providing more regular supply. From that point, dividends increased regularly over the rest of the century, and especially after 1770 when the company began using Watt's engine, greatly increasing its production rate.

The New River achieved its dominance in large part because it did not have to depend entirely on unreliable and intermittent pumping. The Thames tides directly influenced the waterwheel pumps used by the London Bridge, and the pumps stopped working altogether twice per day at the lowest points in the tidal cycle. While the steam engines were greatly superior to

any other driving force behind the pumps at the time, steam engines were also difficult and expensive to run, requiring constant care from worker and a ready supply of coal. They caused aggressive complaints from neighbors' resentment of the black smoke released. Horse engines, which water companies occasionally used, proved to be simply too expensive to function on a large scale, and most water companies abandoned these horse engines or used them as secondary pumps.[16]

By the late eighteenth century, the New River Company's network of pipes and mains had grown to approximately 400 miles (640 km). Although the period of its most rapid growth occurred earlier in the eighteenth century, it continued to lay pipes and take on new customers over time. Maintaining this massive network required a variety of operations. These operations included several crews of pipe borers. The company would buy thousands of loads of elm trees a year and bored out the interiors of trunks to serve as pipes. Most of the pipes were three to five inches in diameter, with the mains being constructed of six to eight-inch diameter pieces. The sections of pipes were narrowed at one end, with the other made larger, so that they could fit together snugly. Later in the eighteenth century, the company began using metal hoops to bind the nose of the pipe to the butt of its neighbor. The wood would rot over time, and finding and fixing leaking pipes became a constant job for the company. By 1751, the company was employing 20 borers at its pipe yard. The pipes they produced added up to over 20,000 yards (11 miles or 17.6 km) per year in the last few decades of the eighteenth century, meaning that the entire 400 miles of pipes would need to be replaced every 20 to 40 years. The company

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[16] Ward, Robert. *London's New River*. London: Historical Publications, 2003, 32-86
Tynan, Nicola. "*London's Private Water Supply, 1582–1902." In Reinventing Water and Wastewater Systems: Global lessons for improving water management*, edited by Paul Seidenstat, David Haarmeyer and Simon Hakim. New York: John Wiley and sons, 2002. 341-360

employed 12 teams of laborers constantly laying pipes. Given the relatively slower growth of the network in the late eighteenth century, most of this work was in repairing smaller sections of existing pipe. At times blowouts occurred and caused water to flood into basements, leading to severe water damage, for which the company paid compensation. At other times, however, there were drops in pressure without the location of the leak being evident. These would be particularly difficult to find if the water ran out of the pipes into sewers since no subterranean flooding would be evident from the surface. When pipes ran besides sewers, the company's laborers would descend into them, searching for the leaks. This job was so squalid and distasteful that the company paid extra compensation to laborers who went more than 100 yards in sewers in search of leaks.[17]

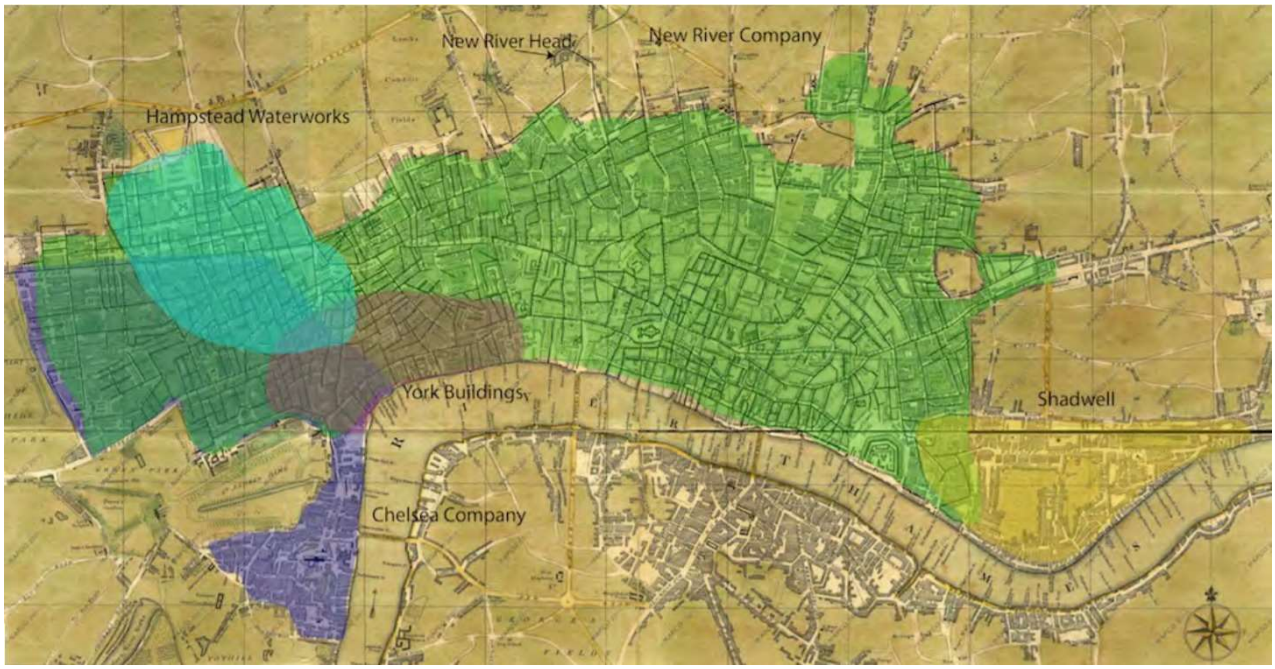

Figure 4: London's Water Company Coverage Area by the End of the Eighteenth Century
Source: Overall, 1878

[17] Ward, Robert. *London's New River*. London: Historical Publications, 2003, 32-86
Jenner, Mark S. R. "*From Conduit Community to Commercial Network? Water in London 1500-1725*." In *Londinopolis: Essays in the social and cultural history of early modern london*, edited by P. Griffths and Mark Jenner. Manchester: Manchester University Press, 2000.
The image below is from Overall, H. C., ed. *Analytical index, to the series of records known as the remembrancia. Preserved among the archives of the city of London A.D. 1579-1664.* London,: E.J. Francis & Co., 1878.

A New Century of Water Distribution

By the turn of the nineteenth century, the success of the New River Company and their monopoly on the water industry fueled a lot more competition. The New River Company was using the Watt engine and with the engines being a success, other water companies realized they could adapt these engines to greatly increase efficiency in their gathering rate of water. By the early nineteenth century, five more companies entered London including the West Middlesex (1806), the East London (1807), and the Grand Junction (1811) to the north of the Thames and Vauxhall (1805) and the Kent (1809) to the south of the Thames.[18]

By the nineteenth century, water companies began to renovate, investing in new facilities and pipe-layering. The New River Company, for example, began to replace its wooden pipes with cast-iron ones in 1811, and the Chelsea company expanded its reservoir in Green Park in the 1820s. Companies had little incentive though at this time to invest significantly on improvements. They also had little incentive to increase water supply to low income households who had difficulties in paying for water charges. Many poor areas even by the nineteenth century remained unconnected to the mains. In Southwark in 1843, 30,000 residents were forced to depend on wells and rainwater butts. As late as 1862, courtyards of poor housing in Whitechapel were served by stand-taps switched on for a quarter to half an hour a day. Those living in the working-class districts supplied by communal standpipes and without water tanks had to store water in any receptacle available. Supply through the standpipes was also completely intermittent. Companies ran water through their pipes for only a few hours or less a day and for three to six days per week. The reason water ran through the pipes intermittently was to reduce the water usage and to minimize leakages from inadequate pipes. If away from the home when

[18] Ball, Michael, and David Sunderland. *An Economic History of London: 1800-1914.* London: Routledge, 2001, 267

supply was turned on, some families went entirely without water or had to borrow from neighbors. By 1876, only 53% of London had constant water supply.[19]

The nineteenth century, like the seventeenth century, included another great population increase in London. According to Sydney Web in 1891, "its suburbs exceeds all Ireland in population: if it were emptied tomorrow, the whole of the inhabitants of Scotland and Wales together could do no more than refill it: the three next largest cities in the world could almost be combined without outnumbering its millions."[20] The population of London was about 1 million in 1800, doubled by 1850, and further grew to about 6.5 million by the end of the century.[21] With such a population growth, there were also many brief periods of population shrinkage. Intermittent water supply and that lack of water treatment was extremely deleterious to people's health allowing disease and infections to spread rapidly throughout the population. Amongst other water-borne illnesses, cholera struck London in 1831. John Snow's efforts made a persuasive case for the connection between some infectious diseases and the water supply by the late 1840s, but cholera infected Londoners for decades to come. [22]

Apart from the East London and New River companies, water was primarily drawn from the stretch of the Themes where the city's sewage and industrial wastes discharged. Even the New and Lee Rivers contained heavily pollution, and the rivers provided little natural filtration. Attempts for filtration began in 1829 when a successful sand filter bed was brought into use in

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[19] Dickinson, H. W. *Water Supply of Greater London*. Leamington Spa: Newcomen Society at the Courier Press, 1954, 52-75
Hillier, Joseph. "The Rise of Constant Water in Nineteenth-Century London." *The London Journal* 36 (2011): 37-53.
[20] Porter, Roy. *London: A Social History*. Cambridge, Mass.: Harvard University Press, 1994, 205-207
[21] London Museum of Water and Steam Water Exhibit timeline comparing major events of water infrastructure development and population growth
[22] Cicak, Tessa, and Nicola Tynan. "Mapping London's Water Companies and Cholera Deaths." *The London Journal* 40 (2015): 21-32

1829 by the Chelsea, and even though in 1834, Parliament required that all water companies incorporate sand filter beds, quality remained poor. Finally, legislation was passed in 1852 when the Metropolitan Water Act prohibited the extraction of Thames water from below the Teddington Lock, obliged all companies to filter river-derived water, and cover all service reservoirs within a radius of five miles of St. Pauls. A London water examiner was also appointed as a regulatory agent. The Lambeth Company moved its intake upstream in 1853 and the death rate in its area fell to 37 deaths per 10,000 residents, which is less than a quarter of the Southwark and Vauxhall's 130 deaths per 10,000 residents. Parliament also set the maximum constraints on the water rate charges. Unfortunately, the legislation controlled only the charge per pound of water used so water charges still rose substantially as the assessed values of London's properties and populations grew. As parliament revaluated properties every five years from the 1870s, parliament granted additional revenue to water companies for supplying the same services to each property. The New River Company, which held the largest districts and

whose property values rose the fastest, was able to boost its dividend from 7.3 percent to 11.5 percent between 1871 and 1881.[23]

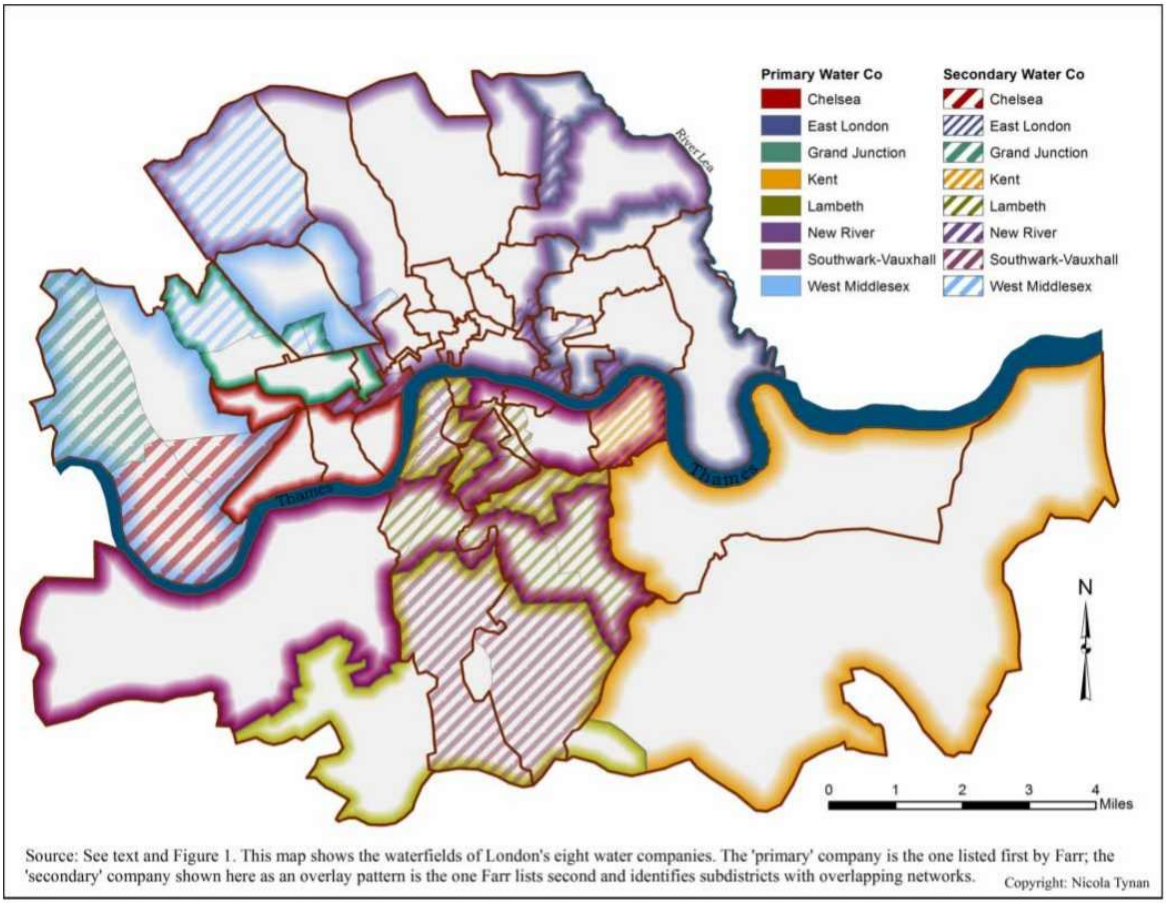

Figure 5: London's Water Coverage Area in the Nineteenth Century
Source: Cicak, Tessa and Tynan, Nicola, 28.

The Metropolitan Water Act of 1852 was the first major piece of legislation set on these water companies, but a few years after the 1852 Act, parliament further required the companies to provide constant water supply, though only if it was requested by 80 percent of the households in the company's district. Parliament also set a 10 percent cap on the companies' profits. In 1871, Parliament passed a new act called the Metropolitan Water Act of 1871. This act forced

[23] Hassan, J. A. *The Growth and Impact of the British Water Industry in the Nineteenth Century.* In *The Economic History Review*, 531-47. 4th ed. Vol. 38. 1985. 531-547
Weinreb, B. and Hibbert, C. (eds) *The London Encyclopedia*, London: Macmillan, 1983, 932
Picture Below from Cicak, Tessa, and Tynan, Nicola. "Mapping London's Water Companies and Cholera Deaths." *The London Journal* 40 (2015): 28.

companies to submit their annual accounts for inspection by the government auditor, provide for the appointment of an impartial water inspector to submit monthly and annual reports on water qualities to the Local Government Board, and to make periodic inspection of the company works.[24]

The government intervention in the water companies resulted in a gradual improvement in both the quality of the water supply and the quality of the water being circulated in London, but the confusion over which water company represented a given district still alarmed citizens. Multiple water suppliers in a given district also meant higher costs associated. Despite the merger of Southwark and Vauxhall Companies in 1845 and the absorption of the Hampstead River by the New Water Company in 1856, water provision was still split between eight different companies. In 1850, the General Board of Health produced a report of London's water supply. They recommended a single metropolitan supply of water that also dealt with sewage. Attempts to bring water under the control of one organization began in 1851, when the government attempted to unite all of the water companies.[25] Pressure to reform continued for the rest of the century. In 1878, the Metropolitan Board of Works (MBW) introduced a bill for the control of the water supply but after lobbying by the water companies and gaining Parliamentary mistrust, the MBW failed to obtain sufficient support and failed to control the water supply. The London County Council also attempted to purchase the companies in the 1895, 1897, 1899, and 1900 Parliamentary sessions but failed repeatedly. The government in 1896 set up the Llandaff Commission to investigate the whole question of control. The inquiry's 1899 report recommended the creation of a public authority outside of the local government despite the

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[24] Ball, Michael, and David Sunderland. *An Economic History of London: 1800-1914.* London: Routledge, 2001, 268-270

[25] Hall, P. *Cities in Civilization: Culture, innovation, and Urban Order,* London: Orion Books, 1999, 690

London County Council's repeated attempts, and in 1902, the London Water Bill created the Metropolitan Water Board, which took over the companies' 8,000 miles of 2-inch to 60-inch pipes and set up home on the site of the New River Company's headquarters. The Board released £40 million in compensation to the companies for the merger.[26]

The Metropolitan Water Board, unlike the individual water companies, did not require revenue. The Board was its own organization, but the Board was also backed by the government. Consequently, the Board simply had to break even. The Board also had to achieve an array of physical measures of performance such as coverage and quality of water. To achieve the financial means to be able to maximize performance, the Board was allowed to set a mandatory rate charge. The Board and the central government also negotiated on Resource allocation. While the Board proved an effective way to control water supply, weaknesses in financial incentives, cost accountability, and constraints on investment caused by periodic public expenditure crisis would eventually cause London water supply to privatize again by the 1980s.[27]

Conclusion

For over a thousand years, citizens of London had to retrieve their water by hand at a local well, or if they were rich, they could pay someone to do it for them. This change to the modern system of companies gathering and distributing water was inevitable but it was not necessary until specific conditions were meant. To someone living in nineteenth century London, drinking well water would lead to an unfortunate, untimely death the very next day. These specific conditions included the population growth as well poor sanitation. Population growth in London skyrocketed in the seventeenth and nineteenth centuries. Population growth in London

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[26] Davis, J. *Reforming London: The London Government Problem 1855-1900*, Oxford: Clarendon Press, 1988, 46
[27] Metropolitan Water Board. *London's Water Supply 1903-1953*, London: Metropolitan Water Board, 1953, 82

meant expansion, and so if new residents of London wanted to receive well water, they had to walk further and further to retrieve it. Population growth also caused the demand for water to skyrocket. A well could no longer meet the demands of so many more people. Consequently, change was needed. Meeting the demands for water became easy by the end of the eighteenth century. Water wheels could now supply water from the rivers, new steam engines could now run twenty-four hours a day without the need of a river nearby, and new developments in pumps and piping materials lead to a prevention of leaks upon the supply of water. Drinking water could now be supplied to all citizens of London without concern for rising demand. Unfortunately, the death rate of 25.2% per thousand individuals within London in 1832 meant that water distribution in London needed to change again.[28] This change was very resistant at first. Disease was not linked to poor water quality and there was nothing visually wrong with the water. Once scientists such as John Snow began making connections between water quality and the deaths, change to water distribution was bound to occur. Unfortunately, there was still one more obstacle in the way. Water companies held great profits in the nineteenth century. These water companies did not want to change anything and risk losing profits. The government had to eventually intervene, and by the end of the nineteenth century, new sanitation technologies such as the sand filter beds and the requirement for constant water supply were forced upon the companies. Water companies in London could now meet the demands and provide constant safe, clean water to all citizens of London.

[28] Cicak, Tessa, and Nicola Tynan. "Mapping London's Water Companies and Cholera Deaths." *The London Journal* 40 (2015), 21-32.

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