Input to deliverable 6.1.5-6 Comparative Analysis of Enabling Factors for Sustainable Urban Water Management

Case study brief – Sustainable urban water management in London

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Introduction

There are a few cities, notably those in Germany, which have made substantial process towards delivering sustainable urban water management in practice. There are the majority of the cities in the world which have yet to begin to make the change; and a growing third group which have made the policy decision to change, where some form of practical change has started to take place, but the change is in practice still largely aspirational. London is in the third group; compared to Germany, it has a long way to go (household water consumption is about 160 l/p/d compared to 122 l/p/d for example) but because the politic change is relatively recent, the reasons why the change was made and how the change is being made are more apparent. Equally, the barriers it faces in making the practical change are current rather than matters of history and thus more obvious. Thus, the lessons that may be learnt by other cities are more visible. Moreover, compared to most of the cities that are making the change, the change is towards the principle of a sustainable approach rather than centred upon adoption of a single technology. A pragmatic advantage is that it is possible to undertake a more detailed analysis of the process in a country where there is a large amount of material in English.

The lessons that may be transferable to other cities are both positive but also negative and often negative lessons offer more insights than catalogues of successes. Notably, successes are often preceded by a period of failed attempts; whilst the successes are recorded, the failures often are not. It is therefore as important to know what does not work (and why), and to avoid those approaches, as to know what does work (and in what context). This is the difference between learning and being lucky.

Finally, a reason for analysing London is to seek to determine what changes will need to be made if sustainable water management is to be delivered in London and so to feed back into the policy process.

The two questions at the centre of this paper are:

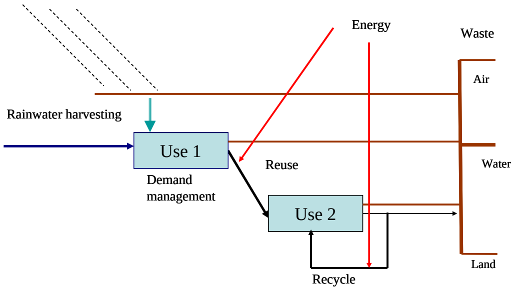
- Why did London begin the change to sustainable urban water management? and
- How is that policy being implemented?

The focus is upon finding lessons that can be transferred or adopted by other cities.

Sustainable urban water management

As part of the water cycle, urban areas import some treated water, use it for various purposes, and then export the wastewater (**Figure 1**). Most urban water usage is non-consumptive: the water is used and then exported. What is consumed is energy; the problem with the water exported is what is added in its urban use such as pathogens and solids.

Figure 1



Sustainable water management

The system that was progressively adopted from the nineteenth century was characterised both a tendency to decouple the surface water management system from the potable water–wastewater system, and adopting simple linear systems which generally maximised the use of potential energy, gravity. A downside to the shift to sustainable urban water management is that it will involve somewhat higher energy costs both by the greater use of kinetic energy and because of the loss of economies of scale.

Description: socio-economics and demographics

A key characteristic of London is that it is an old settlement, having been important at least since the Roman period, developing at the lowest bridging point on the river and as a port. In turn, that long period of settlement has markedly influenced the current position in terms of the pattern of settlement, centred on the original river crossing point as well as creating the extensive archaeological and industrial inheritance, which includes soil contamination left by the nineteenth century industry, as well as an infrastructure which was put in place in the nineteenth and early twentieth centuries. Physically, it lies in the old river channel when, during the Ice Age, the Thames was a tributary of the river Rhine. It developed at the lowest bridging point of the river Thames and the highest point on the river which was accessible to ships.

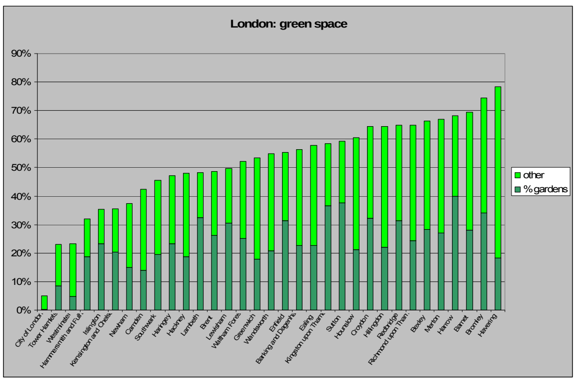
It has long been the dominant city in the UK; it has a population of 7.6 million, with a further 8 million in the regions dominated by London, out of a total population of England of 51 million. The South-East region, centred on London is roughly the same size as the Netherlands, with approximately the same population density. The next largest city, Birmingham, has a population of some one million. Attempts were made after the Second World War to move people and firms out of London and to curtail the growth of London. Growth has now restarted, and this is projected to continue: with a growth in population of 16% over the next two decades (Mayor of London 2009).

Whilst the population of Europe as a whole is expected to stabilise and fall in some areas (Giannakouris 2008), the population of the UK is expected to grow but as a result of migration. In addition, the number of people in the average household is falling so the number of households is projected to grow faster than the total population. At the same time, population growth will be accompanied by an ageing population.

This pattern of migration, which replicates the historical development of London, means that London is now the most culturally diverse city in the world (Benedictus 2005). Thirty per cent of Londoners were born outside of England, and 42% of the population is non-white (National Statistics 2007). An enormous number of languages are spoken in London and, more importantly, there are now a very wide range of cuisines.

London has a slightly higher population density than is usual for European cities: 4800 people per square kilometre, with some areas having a significantly higher density. The highest density is in Kensington and Chelsea where it reaches 16,200 people/km2. Thus, it is low in density as compared with the high density cities that characterise Asian, Africa and South America. However, it has a high proportion of green space (**Figure 2**). There is enormous difference in the proportions of the different London boroughs which are green, with boroughs like Enfield and Barnet over 60% green compared to 5% in the City of London, 29% in Westminster, 33% in Kensington and Chelsea, and 44% in Camden. A detailed study of the London Borough of Ealing (www.ealingfrontgardens.org.uk) found that there are some 74,300 front gardens in the area, with a total area of 3.052 km2; 5.5% of entire area of the Borough. Of these, 68% were hard surfaced.

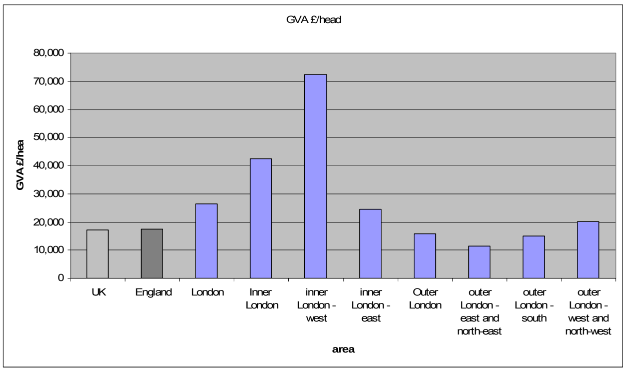
Figure 2



London is the capital city but it is, as its size relative other cities in the country implies, dominant in most other areas as well. The London and the South-East region produces 1/3 of the GDP of the UK as a whole. It was and remains the main entrepot for the country: originally through the docks and now by air. It always has been and continues to be the financial centre for the country and has a major international role in banking, investment and insurance, as well as hosting a series of major exchanges. Whilst it was always an industrial centre as well, this has declined, as it has across the UK as a whole. The proportion of the workforce (4.6 million of which 3.8 million live in London) engaged in the industrial sector has been falling fast, from around 24% in 1982 to about 11% now, and is projected to fall further (GLA 2010). At the same time, the proportion employed in offices has increased from 24% to 37%.

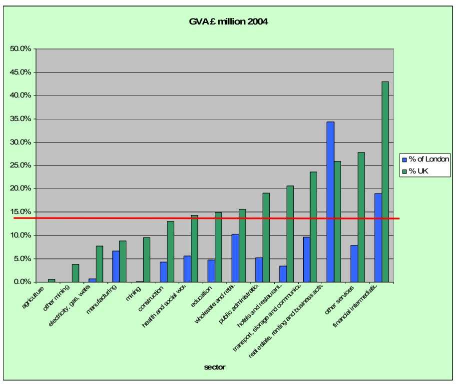
The Gross Value Added per capita is higher in London than in other parts of the country but shows even more marked differences between parts of the city (**Figure 3**), the lower than UK average figures for the outer east and north-east areas reflective of their poor economic condition.

Figure 3



The pattern of the Gross Valued Added for London is also somewhat different from the rest of the UK. In **Figure 4**, the sectors are ordered from left to right according to the proportion of the UK total GVA. Along with the obvious sectors, such as agriculture, where London as a lower than proportionate share, there are others, notable financial intermediaries, where London has a well above average share. London differs in another way from the rest of the country in that the largest proportionate share is taken up by ‘real estate, renting and business activities.

Figure 4



Because it is an historic city, it also a centre for tourism and recreation; currently, there are some 25 million overnight stays in the city. This is significant because after domestic use, leisure services are now the biggest consumer of water and per capita visitor usage in hotels is particularly high. The foreshore in front of the Tower of London was a beach from 1934 until 1971 when the health risks of bathing in the Thames were recognised.

Compared to the UK average, in London, large and ultra-large firms are more important both in employment and turnover terms. An estimated 42% of all large firms in the country have employment in London, and 75% of all large firms in the financial services sector. The largest 110 firms provide 49% of all private sector employment in the capital (BERR 2008). In turn, the proportion of employment in the SMEs is necessarily low as compared to the national average: 49% versus 58.8%. Average income levels are higher than those elsewhere in the country although this conceals some areas of socio-economic deprivation.

The Thames, running through the centre of the city, has always played an important symbolic and cultural role in the city as well as having a functional role as a transport artery.

Climate and water availability

There is a very marked rainfall gradient across the UK; the South-East, including London, has a low annual rainfall (c 600mm/year) but there is little variation over the year. Because the climate is temperate, Potential Evapo-transpiration is also low and hence this rainfall level is entirely adequate to support rain fed agriculture. Although comparisons are often drawn as to water availability in the South-East of England and such places as Somalia, these comparisons are misleading because of the significant difference in evapo-transpiration in the two areas.

The low variability in rainfall across the years, and the similar low variability between years, means that storage requirements are low: London has approximately 90 days water supply in storage (Green 2003) whilst in arid climates, such as Australia, 3 years storage capacity is required to provide a reasonable buffer against variability. Unfortunately, climate change is predicted to decrease summer rainfall whilst increasing winter rainfall (Jenkins et al 2009); an effect will be to increase the required storage capacity for water.

As a temperate climate, rainfall intensities are also low; as everywhere, the peak short term intensities are in the hottest periods, the summer, and usually associated with thunderstorms along frontal systems. However, compared to many other countries, peak rainfall intensities are low; total annual rainfall in London is less than the recorded world record three hour rainfall (Hydrometeorological Design Studies Center nd).

London lies at the bottom of Thames and its sub-catchments, the Thames in London being a tidal river. As a small and flat country, the rivers in England are in global terms short and in flow terms, little more than streams. The ratio of flood flow to base flow is also low compared to countries in the hurricane/ typhoon/cyclone belts (Rivers Bureau 2000).

Within those catchments, there is a considerable degree of water recycling; it was always claimed that the water drunk in London had already been through seven sets of kidneys, having been previously been abstracted to supply and then discharged from the upper stream urban areas such as Reading, Oxford and Swindon. Unfortunately, it is not possible substantiate this claim. But hypothetically if the population were to be uniformly distributed, which it is not, amongst 8 service units with London as the lowest, and assuming a recovery rate of 70%, it would be possible to achieve a use to raw water abstraction ratio of 2.35. Still assuming that the return rate is 70%, if the consumers are arranged in 3 blocks of 1, 1 and 6 respectively, then ratio of use to abstraction is 1.3; shifting to three blocks in the ratio 1:2:5 would increase the use to abstraction ratio to 1.7 (**Figure 5**). In practice, Merrett (1997) reports an estimate that the ratio is approximately 1.2.

Figure 5

As an old river valley, London is characterised by river terrace deposits of sand and gravel overlaying a layer up to 80 metres of London Clay with a chalk aquifer further below.

Both the water supply and wastewater systems betray their nineteenth century origins in terms of the structure of the systems. The figures always quoted is of over 80% of the area's water supply is based upon abstraction from the river Thames to the west; the remaining 20% coming from two tributaries to the river Thames; the River Lea (or Lee) in the north-east, and the river Colne in the north-west, plus some groundwater usage from the chalk aquifer. There is a conjunctive use scheme in the Enfield-Haringey area. In winter, water is pumped from the New River into the aquifer and in summer it is pumped from the aquifer back to the New River along which it flows before being treated and put into supply.

These are the locations for abstraction and treatment established after intakes were required in 1856 to be above the tidal limits. The direct river abstractions feed raw water storage reservoirs. Similarly, Bazalgette's interceptor sewer system still forms the backbone of the sewage system and the treatment works developed at the original outfalls for the north and south trunk sewers.

Problems

The central root of the physical problems are those being of the first industrialised and urbanised country in Europe, and its location. Thus, the infrastructure was largely designed and installed in the nineteenth and early twentieth centuries; both the structure of the potable water system and the wastewater system is largely unchanged from the relocation of abstraction works following the 1852 Act and Bazalgette's construction of trunk sewers and outfalls after 1856 (Halliday 1999). Again, the early leakage problem of water supply was solved when the wooden pipes were replaced in the late nineteenth century by wrought iron pipes (Graham-Leigh 2000); in turn, these have now come to the end of their life, much of the network being over a hundred years ago, a problem compounded by the aggressive soils, the heave of London clay, and heavy traffic loads. Adaptations for modern requirements are bolt on extras, end of pipe solutions, starting with the wastewater treatment works which were constructed at Bazalgette's outfalls. The latest of these end of pipe solutions is the Thames Tideway (Thames Water 2006): a 32 kilometre long 7.2 meter diameter tunnel to be constructed under the Thames to store surface water in heavy rainstorms. This £2 billion project is required under the Urban Wastewater Directive to reduce the frequency with which Combined Sewer Overflows discharge to the river Thames.

The inheritance plays in another way as well; given that each person in the country is connected to approximately £3,500 of sewers alone in terms of replacement cost, the sunk investment cost of the current system militiates against radical change. Only in Greenfield sites does it seem conceptually possible to think from the beginning rather than to seek to make marginal changes to the existing system.

Thirdly, legislation has often been written in terms of assumptions about the technology adopted. Thus, a claimed problem with the adoption of SUDS has been the definition in legislation of a sewer effectively as a conduit which eventually discharges. Similarly, there has been a presumption in that legislation that all properties should connect to both the reticulated potable water system and discharge to a public sewer.

In central London, the wastewater system is a combined sewer system. Whilst when the surburbs were constructed in the 1920s and 1930s, separate foul and surface water systems were used, these are now not seen has having been a particularly successful innovation. The problems of misconnections of household drains to sewers and those of infiltration to or exfiltration from sewers (Ellis et al 2004) were not foreseen. Overall, some 300,000 homes in the UK are believed to have at least one drain misconnected to the wrong sewer, with Thames Water estimating up to 1 in 10 properties in London being misconnected. Given that misconnections can only occur when there are separate sewer systems, it is not clear what is the misconnection rate for separate sewer systems.

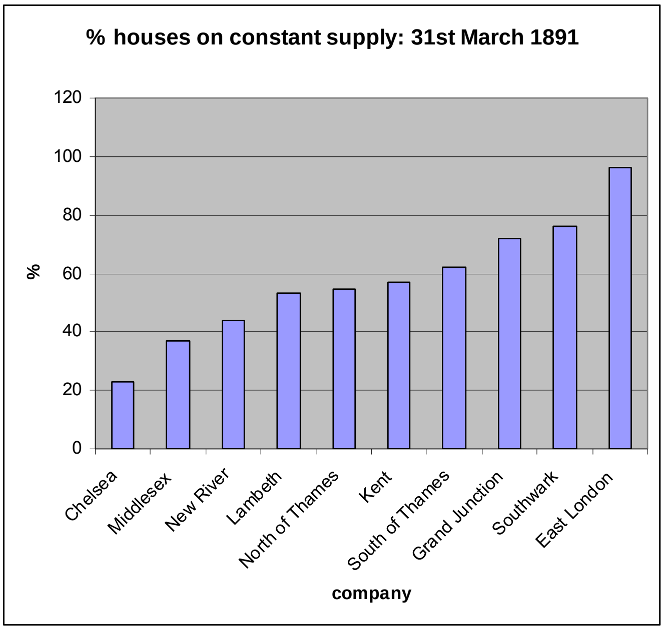
Given the absence of comprehensive historical statistical data, it is not clear when London (or other developed cities) or the UK reached the Millennium Development Goals for water services (United Nations 2009) but it is probably not earlier than the late nineteenth century and probably considerably later. For example, in 1848, in the Bethnal Green area of London, there were 50 WCs for 82,000 people with privies, generally in a dangerous condition, at a ratio of one to several households serving the rest (Eveleigh 2008). In 1900, an estimated 75% of the population did not have a bath in their home (Eveleigh 2002). The Royal Commission on the Health in Towns, reporting in 1845, found that in only six of the fifty towns it investigated were the water supplies adequate; in 31, they were bad (Falkus 1977). In Bristol, of a population of 130,000, only 5,000 had piped water supplies and in Newcastle piped water reached only 1 in 12 of the population (Falkus 1977).

In New Lanark, a famous model mill town in Scotland, workers' dwellings were not provided with interior cold water taps and inside toilets until 1933 (Knox nd). Similarly, the great housing reformer Octavia Hill provided only a cold water supply to a communal tap on each floor of her tenements (Hardy 1984). In Beverley, in Yorkshire, in 1934, only about half the dwellings in the town had water closets; a piped water supply having reached 50% of the homes by 1913 (Allison 1989). Similarly, in 1861, there were 2 WCs in Dundee (and three more in hotels) for 91,664 inhabitants and all water was drawn from wells. In 1913, there were 7,106 one room homes in Edinburgh; of these, 95% shared a common WC and 43% a common sink. In Glasgow at that time, a population of 104,000 lived in one room homes and 93% shared a WC (Knox nd).

Water supply was intermittent (**Figure 6**) and until 1870, water was never supplied on a Sunday but only 2 or 3 times a week to a communal tap (Hardy 1984). Part of the limitation was the consequence of the very limited storage capacity of the different companies; the Chelsea Company had 14.1 days demand in storage; the West Middlesex, 7.4 days; and Southwark and Vauxhall, 2.7 days. Obviously, pollution pulses and droughts caused interruptions to supply, notably in 1894-95, 1896, and 1898. Only in 1899 was the supply constant to all houses in the London area, largely as a result of pressure from the Fire Brigade Committee (Hardy 1984). The companies then started the great necklaces of storage reservoirs along the Thames and Lea valleys which were greatly extended by the Metropolitan Water Board after 1903.

The 1871 Metropolis Water Act gave power to the metropolitan authority (after 1889 the London County Council) the power to require the provision of constant supply in districts where this was thought to be necessary but this power was rarely applied. Only in 1891 did local authorities have the power to compel house owners to supply water to their tenants for domestic purposes unless supplying wells were found unfit for use (Hardy 1984). Hardy goes on to stress that it was governance issues that limited to the provision of water supplies to rented accommodation, a problem which is seen in developing cities today.

Figure 6



To-day, the demand-supply balance in the South-East is seen as critical (London Assembly 2003) and Thames Water has constructed a small (140,000 tonnes/day) desalination plant, using renewable energy, in London as an emergency reserve. The supposition is that this plant is being constructed against the risk of a drought occurring during the London Olympics. So far, given the low variability of rainfall, it has sufficed to have only 90 days storage in the reservoirs serving London. Longer term there is a proposal to build a major new reservoir at the head of the Thames

Because London is part of the water supply area for four different companies, there is no breakdown by sector (e.g. leisure, office) of water consumption for the city. But from the national breakdown, and the data on the employment breakdown, it can be inferred that whilst household consumption forms the largest component, leisure services, including hotels and restaurants, are the second largest consumers. In addition, from **Table 1** it can be seen that assuming per capita household consumption is the same across the four company areas, the ratio of non-household consumption to household consumption is higher in the Thames Water served region of London, the central area, than in the outer areas. Nationally, household consumption is approximately 60% of total potable consumption so the central London ratio for non-domestic to domestic is also higher than the national average.

Table 1

		Thames	Three Valleys	Essex & Suffolk	Sutton & East Surrey	total
1000	**population**	5693	1022	491	277	7483
mill l/day	**total supply**	2115	280	139	69	2603
mill l/day	**loss**	561	30	12	6	609
	loss as % supply	27%	11%	9%	9%	23%
l/p	**loss per population**	99	29	24	22	81
l/p	**supply per person**	372	274	283	249	348

Household water consumption in London at 160 l/p/d is higher than some other parts of the country (OFWAT 2007) and at the middle of the range for Europe. In turn, per capita consumption figures are considerably lower than in some other countries (Environment Agency 2009).

Household water demand is determined by three groups of factors (Green 2003):

- Demographical
- Technological
- Cultural

For example, two important determinants are household size, per capita demand being less in larger households, and the age of those forming a household.

The second group of factors is the water using technology adopted in the household e.g. toilet cistern capacities, washing machine type. The simplest example is a frequent recommendation is to turn off the shower whilst soaping. However, this requires that it be possible to control the shower volume without simultaneously affecting the water temperature. Such control is not possible in older showers in Britain. The most dramatic difference is, of course, between the water consumption of the front loading washing machines normally used in Europe and the much higher water consumption of the top-loading washing machines (Pugh and Tomlinson 1999) which are more commonly used in the USA and Australia.

Finally, there are cultural factors. Ashenberg (2008) demonstrates the cultural nature of the concept of cleanliness and the way in which bathing has been performed. Similarly, Ball (2000) neatly summarises the cultural conception of water itself.

Climate change has the potential to significantly increase water consumption in that showering is more frequent in hot climates than in more temperate climates. For example, whilst Singapore has an exemplary demand management approach, household water consumption is still relatively high at around 156 l/p/d (Lee 2005), partly I am told because people often take several showers a day.

In terms of pathogens, London's water supply is excellent in so far as can be judged (Chief Inspector of Drinking Water 2010): that is, in terms of bacteria and viruses. Outside of London, there are private water supply systems, serving anything from a single property to a small community; the water quality standards of those systems are markedly less satisfactory (Kay et al

2007; Rutter et al 2000). The caveats are in regard to helminths and protozoa. There is very limited data on the prevalence of helminths with the UK population or indeed with regard to the populations of other developed countries. The incidence of giardia and cryptosporidium in the UK population is possibly under-reported but low (Ellam et al 2008; Foundation for Water Research 2002), and there have been isolated incidents of both occurring the water supply (Drinking Water Inspectorate 2006). What appears to have happened is that removing an extreme health hazard (e.g. cholera) has exposed a less serious or chronic health hazard.

Since parts of the water distribution system are very old, there is a preference for a chlorine disinfection system in order to maintain a residual level of chlorine in the water.

In England, those cities sitting over an aquifer are suffering from groundwater rebound. In the nineteenth and early twentieth century, industries such as breweries abstracted groundwater, abstraction reaching a peak in the 1960s at which time the groundwater levels in the chalk aquifer underlying central London had fallen to 88m below sea level from a level in 1900 of 48m. With the relocation of those industries out of the urban areas and the reduction in the size of the industrial sector, abstraction fell and instead of depression cone sitting under the centre of the city, groundwater levels are returning to their original levels, with a rebound of up to 3 metres a year, reaching 35m below sea level now (Galloway 2001). Unfortunately, much of the underground infrastructure, such as the underground railway system, was built in the time when groundwater levels were artificially low. The groundwater rebound has consequently created a variety of problems, including the need to pump water out of the underground infrastructure. Much of that water is not suitable for putting into potable supply, because it is very old water, without very extensive treatment, but can be used for toilet flushing (Galloway 2001) although a competing use is heat exchangers. Abstraction is being increased to 70 Ml/d to hold the depression cone at -35m.

London is exposed primarily to tidal flooding but like England as a whole, flooding is not a dramatic problem as compared to other countries. In the assessment of the relative risks of natural, technological and terrorist hazards, coastal flooding had the highest ranking of the natural hazards (Cabinet Office 2010). But as we have recently seen and was argued previously, financial hazards pose the greatest risk (Green 2007). Thus, for example, the national floods of the summer of 2008 resulted in an economic loss equivalent to around 0.25% of GDP and so were in risk terms a relatively minor affair. Those floods brought to fore the lessons that had been forgotten, notably the risk to infrastructure such as water supply and power systems. In the larger floods of 1947, the Coppermills water treatment works serving the whole of east London were flooded and the water supplies to a million or so people were disrupted. It is estimated that in London some 100,000 are exposed to a risk of worse than 1 in 200 from river flooding and 1 in 7 properties have a greater than 1 in 50 risk of surface water flooding (Mayor of London 2009). As elsewhere, systems designed to cope with pluvial flooding allow a higher risk of overloading than do systems designed to cope with river or tidal flooding. The design standard for sewers is that a 1 in 30 year return period event should not lead to surface water flooding (WRc 2006). The Pitt review (2008) focused particularly upon the problem of pluvial flooding and probably promised more than can be delivered in the short to medium future in terms of remediation.

For pluvial flooding, the risks of flooding and of diffuse pollution are intertwined; Bazalgette's combined sewer system being designed that when overloaded it would discharge to the river rather than flooding occurring on the surface. Bazalgette designed his system on the basis that discharges to the Thames would occur during rainstorm events which occurred on average 12 times a year (Halliday 1999). This frequency is now substantially exceeded (Thames Water 2006).

Water management is very closely coupled with solid waste management; solid waste collection removing materials which would otherwise be disposed of to part of the water management system. The nineteenth century public health acts required local authorities to ensure the provision of garbage collection and street cleaning as well as water and sewers. Whilst 'fly-tipping'[1] continues to be a problem, including in or around water courses, the remaining problem is what is disposed over via the drains. FOGs (Fats, Oils and Grease) are a significant cause of blockage not just in restaurant and fast food areas but also in residential areas. The use of WCs to dispose of tampons, cotton buds and the like is also not unusual.

Some 120 species of fish have now been recorded in the Thames, although presence is not the same as a return to their prior population density. Equally, most chemical trends for the tidal Thames are now positive, the exception being the decline in oxygen availability (Attrill 2006). In the Thames river basin district, some 23% of surface waters and 35% of groundwater achieves good ecological status (Environment Agency 2009).

As with removing pathogens from water supply, removing one source of pollution often does little more than reveal another form of pollution hidden underneath. There has been incremental improvements over time in wastewater treatments; progressively adding, as the names imply, primary, secondary and tertiary forms of treatment. The effect has in some cases to result in less improvement in the standard of the receiving waters than might be expected. The problem exposed in London, as elsewhere, is that of diffuse pollution. Whilst nationally, agricultural non-point sources are the major problem, in London, as in other urban areas, industrial sites and roads continue pose the major problem; industrial sites are particularly a problem where there is a separate sewer system because external yard areas served by the surface water drainage system are a major source of pollution. Although London has a lower proportion of firms which are SMEs than the national average, there are still over 700,000 and this poses an impossible problem of enforcement. Thus, one perceived advantage of the adoption of SUDs is the physical disconnection of external yard areas from the system of

[1] Dumping of household, garden or commercial refuse illegally.

watercourses. This obviously requires that the SUDS systems can provide pollution abatement.

CSOs (Combined Sewer Overflows) continue to be a problem because central London is served by a combined sewer system; most recently, the problem has been managed by oxygenating the Thames when overflows occur.

A further heritage problem is contaminated land, another legacy of Britain's early industrialisation. An eighteenth or nineteenth century industrial site can be expected to be heavily contaminated and so especially can a nineteenth or twentieth century coal gas works. Any rainwater infiltrating though such sites will inevitably become heavily contaminated, and contaminated sites limit the scope for using infiltration SUDS techniques as a means of managing rainfall. Equally, the industrial past has left contaminated sediments along many watercourses which sediment is remobilised in extreme flow events. Limiting the discharge of suspended solids is in turn often a key problem because of heavy metals and other persistent pollutants often bind to those solids.

As with other countries, attention is also now focusing on PCPs (Personal Care Products) in wastewater and the risk of PCPs entering drinking water (Watts and Crane Associates 2007).

The Water Framework Directive is, of course, a great aspirational document although it is doubtful if anyone ever believed that the objective of 2015 for good ecological quality was ever plausible, let alone realistic. Currently, it is predicted that it will not be possible to achieve good status in 75% of surface waters in the Thames District by 2015 (Environment Agency 2009). Nor, since achieving that standard by the proposed date could only be achieved by yet more end of pipe solutions, can it be seen as a step towards delivering sustainable water management. So far, England has been much more sparing in adopting either of the two forms of derogations available under the Directive than some other countries such as the Netherlands where the majority of the waters have been deemed to be 'heavily modified watercourses' and thus covered by derogations. Thus, the district River Basin Management Plan for London (Environment Agency 2009) discusses only derogations for heavily modified and artificial watercourses.

If the river Thames has always had an important symbolic and cultural role as well as a functional role, the other rivers in the city were treated purely functionally and many have now disappeared. Some, like the Tyburn, were reduced when their sources were diverted to provide water supply to the city; conduits were built in the C13th to divert some of the springs serving the Tyburn to city. Later, some were diverted for other purposes; for example, the Westbourne was impounded to form the Serpentine Lake in Hyde Park and the Tyburn to create the lakes in Regents Park (Barton 1962).

Others, like the Fleet, were used for waste disposal for early industry (e.g. tanneries) and became so obnoxious that they were covered over as waste conveyors. The larger rivers, such as the Lea, became important navigations and were canalised for those purposes. Water power was the main source of power well into the nineteenth century (Crafts and Mills 2004) and historic waves of industrialisation settled along such rivers as the Wandle (Barton 1962). But otherwise, these smaller rivers were seen as a waste of space and culverted. Their flood plains were equally seen as a waste of space and most of the rivers were canalised for flood control purposes although flood plains were also a preferential location for public parks. London is also the centre of the canal network; the canals serving to transfer goods to and from the docks. Those canals now form part of the recreational network and the basins in particular are centres for regeneration.

However, the main problem has been one of governance. The institutional framework has developed both in an ad hoc manner and one of increasing centralisation. The result was one of incoherent fragmentation and ill-considered incentives.

Governance[2]

Governance is essentially people acting in social relationships. Those social relationships have both a functional purpose; from the perspective of sustainable development, they are part of the answer to the problem of doing more with less. But they also have a moral content: what ought to be the relationships between which people? What might be the most efficient is not always morally acceptable; thus, for instance, even could it be shown that slavery was economically efficient, this argument would be trumped by the moral claim that it is entirely unacceptable. The economic efficiency argument might then explain why it is difficult to find a society which at some time in the past did not employ slavery but it would not make it any less appalling.

The social rules governing social relationships may be overt but are often either covert or implicit; that is, they may either not be referred to at all, being taboo subjects, or so widely understood that there is no need to refer to them and they are not consciously employed by those following those rules. These hidden social relationship rules are part of what an anthropologist will define as a culture.

In particular, as discussed in the theoretical frameworks set out earlier in the SWITCH project (Green et al 2007; Green 2009), governance is about who has what forms of power over what things or what people, and the rules which create, delimit and control the use of those powers (Green 2010). In particular, where have the boundaries been created between different zones of power? Secondly, what incentives are there for the different organisations, households and individuals to use their powers to take particular forms of action? However, discussions of power are often taboo and since the most effective form of power is hegemony, where one group has adopted the rules which disadvantage it relative to another group, the most effective form of power is that which is hidden.

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[2] With the election of a new government in May, there are likely to be changes made to parts to the institutional structure, particularly the abolition of some bodies

That England is now a highly centralised country simplifies the picture enormously: power is concentrated at the level of central government. Stating that power is centralised is to some degree a simplification; if decisions are largely taken by central government, there are an enormous number of advisory boards, and quasi-official groups involved in the decision process. As a matter of routine, each new incoming government sets out to eliminate a large proportion of these existing bodies. Nevertheless, as compared to some other countries, England is characterised by a large amount of 'spur of the moment' legislation when a minister decides to do something rather than legislation being the outcome of a formal process of policy analysis.

Similarly, because it is centralised, the Institutional Maps prototyped for Birmingham (Green et al 2007) largely also apply to London. There are a maximum of two levels of government below central government[3], and a pyramid which is not only shallow but also narrow: there being a total of 354 elected units of local government and 89 single purpose boards to which there is no direct election (CLG 2010). In consequence, local governments in England are by far the largest in terms of average population of any in Europe. For a period under the last Conservative government, there was no strategic elected government for the London metropolitan region. The incoming Labour government introduced a system of an elected executive Mayor and a small (25 members) elected Assembly to scrutinise the Mayor's decisions, together forming the Greater London Authority (GLA). The Assembly is seen by its members as a stepping stone to election to Parliament. The GLA covers an area of 1579 km^2. The Mayor has a strategic role in setting policy for transport, policing, fire and rescue services, economic development, planning, culture, environment and health. Four delivery organisations (Transport for London, the London Development Agency, London Fire and Emergency Planning Authority, and the Metropolitan Police Authority are overseen by the Mayor in different ways); together they are classed as the GLA group.

Other responsibilities rest with the 32 London Boroughs and the City of London Corporation. As an organisation, the GLA is small, employing only 600 people. Equally, of the total budget for which the GLA has responsibility, some £3.2 billion in 2009/10, only a small component is for the GLA itself - £135 million.

Thus the Greater London Authority is a strategic authority but the local London boroughs retain the operational functions. In this context, the City of London, the original London, is a London Borough but with more powers (i.e. it currently retains its own police force). This strategic-operational split is not exact: **Table 2** gives the Communities and Local Government Department's outline of how the responsibilities are split between the GLA and the Boroughs. As compared to the budget of £3.2 billion for which the GLA is responsible, most of which is for the Metropolitan Police Authority and Transport for London, the 32 boroughs and the City of London have a total budget of £12 billion.

Table 2

(Source: DLG 2009)

[3] This is to ignore the existence in parts of the country of some 8,700 parish and town councils; they are ignored because both their powers and revenues are so limited (budgets of £100 to £2 million a year).

Function	**City of London**	**London Borough**	**GLA**
Education (essentially to age 18)	●	●	
Highways	●	●	●[4]
Transport planning	●	●	●
Passenger transport			●
Social services	●	●	
Housing	●	●	
Libraries	●	●	
Leisure and recreation	●	●	
Environmental health	●	●	
Waste collection	●	●	
Waste disposal[5]	●	●	
Planning applications	●	●	
Strategic planning	●	●	●
Police	●		●
Fire and rescue			●
Local taxation	●	●	

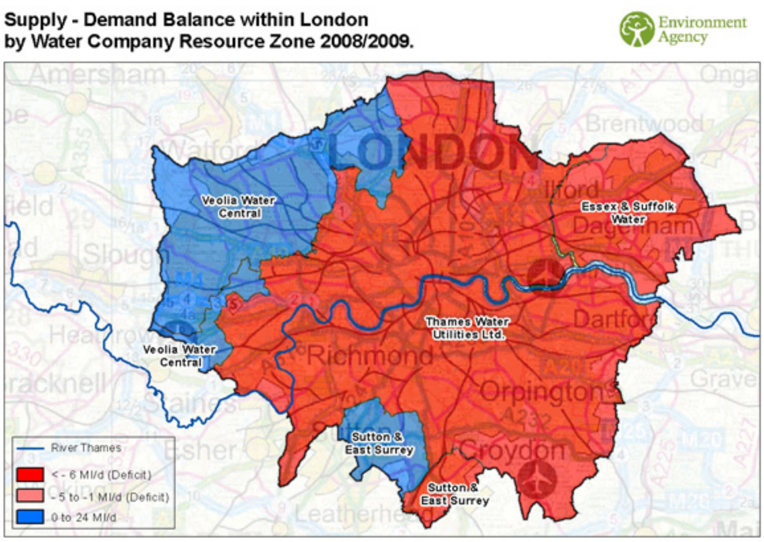
Local governments have less powers and much less autonomy than local governments in other European countries (CEMR nd). Equally, local government expenditure is lower as a proportion of central government expenditure than it is in most European countries (CEMR 2008) and a large proportion of local government funding is from central government rather than locally raised taxes. Indeed, the only local tax is a property tax on dwellings and central government caps the rate which each municipality can levy. Whilst on average, 25% of local government revenue comes from this local property tax and the remainder from central government as either ringfenced grants for specific purposes or as a general support payment (CLG 2009). The proportion of revenue funded by local taxation in London is much less:

[4] The GLA has responsibility for about 5% of the roads in London
[5] for parts of London, waste disposal is the responsibility of separate waste disposal authorities. The GLA has strategic responsibility for municipal waste

about 10% (Greater London Authority 2010) because a large proportion of the costs of police and transport services in London are paid from general taxation. The Mayor of London has stated that the figure has now fallen from 10% to 7% (Mayor of London 2010).

Water supply and wastewater management was privatised in 1989. In order to make the change as quickly as possible, as little change as possible was made to the existing publically owned system. The result was that there was no concern to introduce efficiency into the system through competition or other means such as economies of scale or scope, and there was no attempt to ensure coherence in the system. Thus, the structure now is a mixture of WoCs (Water Only Companies) and WaSCs (Water and Sewerage Companies). Thus there are areas where one company provides the water supply and another company provides the wastewater services, and another area where one company provides both water supply and wastewater services. In London, Thames Water is the WaSC and there are a number of WoCs; their service areas are shown in **Figure 7.**

Figure 7



Thus, whilst Thames Water is the WaSC for the whole London area, it is the water supplier for only the central area, with three WoCs supplying parts of the surburban fringe.

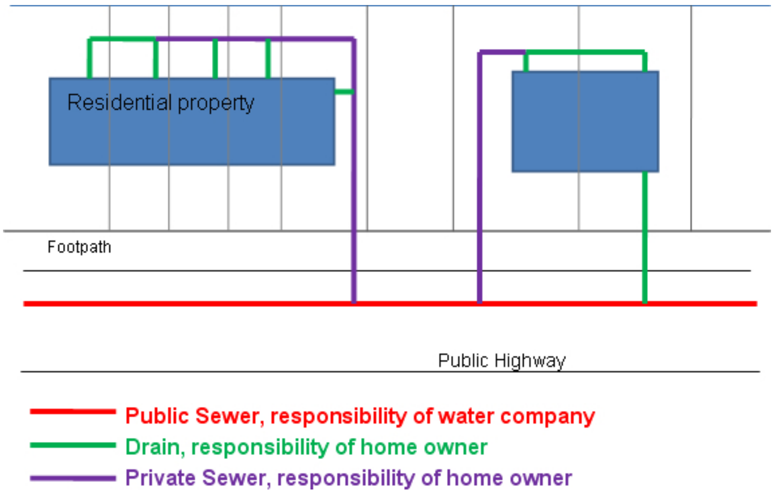
A primary driver of privatisation was the then government's desire to get the investment needed to meet the requirements of different EU water directives out of the public sector borrowing requirement and on to private sector borrowing requirement. That in itself was satisfactorily achieved, some £89 billion having been invested since privatisation. That shift has in itself probably increased the cost of meeting those standards in the difference between the cost of government borrowing and the higher cost of commercial borrowing, and the even higher cost of share capital.

But a more fundamental problem that was created is the fragmented system that was haphazardly created first though the creation of Regional Water Authorities and then by privatisation. Prior to the creation of the Regional Water Authorities, service delivery was essentially integrated at local level by the municipalities who dealt with water supply, wastewater collection and treatment, and surface water management. The weaknesses of the system was that they did so at a local level without integration across the catchment, and some were too small to capture the economies of scale. Under the Regional Water Authorities, it was a reasonable approximation to assume that the Authority did everything except highway drainage, not least because of the strong representation by elected members of the local authorities on their boards of directors.

So, a negative lesson from the experience of England is that when dis-integrating a formally ad hoc integrated system, it is essential to:

- Define responsibilities
- Define responsibilities with regard to physical assets
- Establish incentives for the different agencies, organisations and companies to cooperate

Figure 8 **public and private sewers**



Actually identifying where are the boundaries of responsibilities in what is necessarily physically an integrated system is now difficult. Equally, what were originally unimportant boundaries are now critical boundaries. For example, prior to privatisation, although the 1936 Public Health Act created a distinction between a sewer[6] built prior to that date and one built after that date[7], this distinction was of little concern at the time because both types of

[6] A sewer being essentially defined as a pipe conveying wastewater to some discharge point.

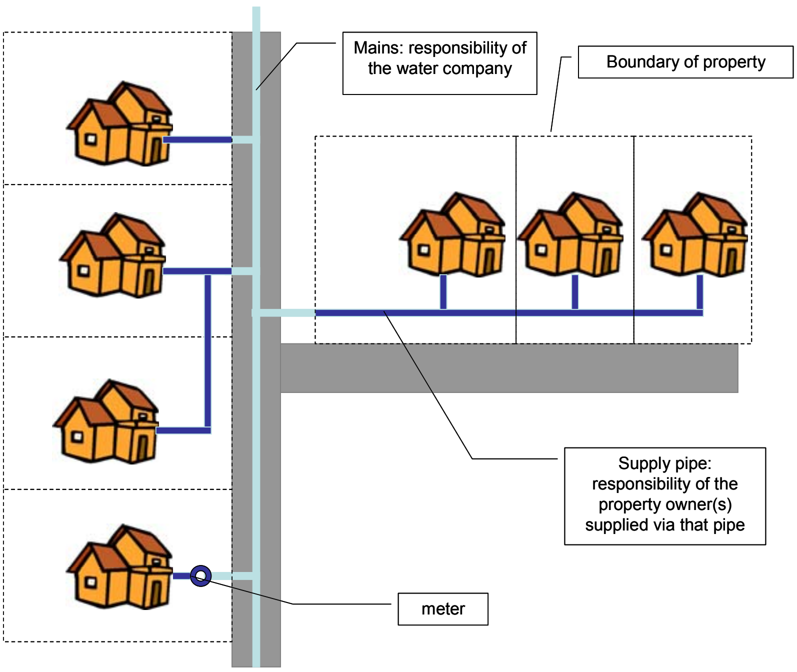
[7] All pipes connecting two or more properties to another pipe connecting two or properties to a discharge point and built before 1936 were adopted as Public Sewers and became thereby the responsibility of first the municipality and ultimately the WaSCs to maintain those sewers. As **Figure 9** shows, a pipe connecting two or more properties to a larger pipe but constructed after 1936 was deemed to be a 'private sewer' and it was the responsibility of the property owners to maintain it and repair it if necessary.

sewer were managed by the local authorities. Now it matters; any pipe connecting two or more properties to a main sewer and built before 1936 is a public sewer and the responsibility now of the WaSC. Conversely, any pipe serving the same purposes but built after 1936 is a private sewer and the joint responsibility of the land owners (**Figure 8**). After quite a lengthy debate, it is now proposed to transfer the responsibility for private sewers to the WaSCs.

Equally, when both public sewers and highway drainage were the responsibility of the local authorities, and the two were highly interconnected, the boundary between the two was irrelevant. With privatisation, the public sewers became the responsibility of the privatised wastewater companies; highway drainage remained the responsibility of the relevant Highway Authority; for all except major roads, the local authority. When the EFRA Select Committee asked a wastewater industry representative when a highway drain became a public sewer, they got the reply "that is a very good question."

Responsibilities for water mains and service pipes are clearer cut (**Figure 9**), and much of the leakage of water occurs in service pipes for which a land owner has responsibility rather than the mains which are the responsibility of the WaSC or WoC. But the picture is necessarily more confusing in multi-occupancy buildings and when properties are held as leasehold, as they are in much of central London.

Figure 9 **water mains and service pipes**



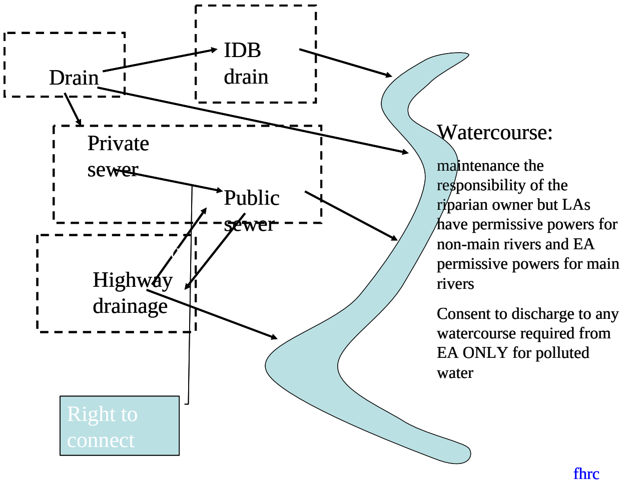
The boundaries are quite clearly established with regard to water abstraction both from groundwater and surface water and also with regard to the discharge of polluted water.

The position with regard to surface water is however confusing and ill-defined. Traditionally, any land owner could discharge surface water to a watercourse in whatever amounts were necessary to drain their land. The same principle applied to the organisations with a responsibility for dealing with surface water drainage. Hence, there was no control over the well known effect where urban areas produce a sharp, rapid rising pulse of floods in the watercourses. In addition, the land owners along the bank of a watercourse, the 'riparian owners' have a duty under Common Law to remove obstructions from the watercourse (under English Common Law, the river bed of non-tidal rivers is owned by the adjoining land owners unless a specific exemption has been created). What constitutes an obstruction and what constitutes a watercourse were then determined by case law (Howarth 1992). Hence, downstream property owners had to accept both the increased flows and the consequences of those flows as a result of the activities of upstream land users. In principle, part of riparian law is that upstream owners should not act in a way which interferes with the enjoyment of downstream land owners but that duty is unenforceable. Since a watercourse could also be designated as a public sewer, there is also some confusion as to what watercourses are public sewers and which are watercourses. For example, if a watercourse was covered over for part of its course and then emerges into the open, the upper part may be a watercourse, the culverted section a public sewer, and the lower part a watercourse again. Alternatively, the culverted section may still be a watercourse in which case the land owners over and beside it have a duty to ensure that obstructions are removed. The result is that in some areas it has proved impossible to establish who has responsibility for particular sections of watercourse.

There remains no requirement to license a discharge of unpolluted water to a watercourse although if after the fact the water proves to be polluted, then the Environment Agency can take action. There is now an indirect control as a result of Planning Guidance issued by the CLG. When a municipality is examining a planning proposal, it can impose conditions on the consent it gives for that development. In addition, the PSS25 guidance document (CLG 2006) sets guide limits for discharges to watercourses and the Environment Agency as a consultee will object to increases in flows to rivers above natural runoff.

More generally, the pattern of responsibilities with regard to surface water runoff is fragmented and unclear. Whilst the 1989 Act privatising the industry at S67 stated that: "It shall be the duty of every sewerage undertaker – (a) to provide, improve and extend such a system of public sewers (whether inside its area or elsewhere) and so to cleanse and maintain those sewers as to ensure that area is and continues to be effectually drained", that duty has been interpreted as being in respect of foul sewage. Nobody consequently has a corresponding duty with respect to surface water drainage but a number of different bodies have responsibilities for different physical assets of which the system as a whole is made up (**Figure 10**).

Figure 10



The concern on privatisation was to avoid adopting the US model of rate of return regulation. The rate of return approach had also been used during the nineteenth century to control the charges levied by the water companies and found to be unsatisfactory (Hardy 1984). Hence, the ‘rpi – x + K’ formula was adopted for price regulation: prices being allowed to increase at the rate of inflation minus some allowance for cost efficiency gains (x), plus an allowance for the agreed capital investment programme (k). The twin flaws in the argument were that a major driver for privatisation was the need for major capital investment and that in a capital intensive industry, everything ultimately comes down to the cost of capital and equivalently the return on capital. To make privatisation a success, the government initially allowed a return on capital that was very generous. Ever since, the twin arguments have been about what is the real cost of capital in the industry (NERA 2009)? And what should constitute capital expenditure, and thus included in the ‘k’ factor, and what is part of operation and maintenance expenditure and thus subject to ‘x’?

Secondly, the form of privatisation adopted was based neither on seeking economies of scale and scope nor on promoting efficiency through competition. Instead, reliance was placed upon ‘comparative competition’: the comparison of the costs of different activities by different companies. That pursuit of comparative competition has been held to restrict the scope for company mergers and thus the possible gains of economies of scale or scope.

Thirdly, we advanced into the future looking firmly into the past: the assumed future was that it would forever be like the past only bigger. The whole system was geared to meeting an inevitable growth in demand. Thus, two of the reasons why the water community is trailing behind the shift to sustainable development are the built-in mind fix; and the suspicion that a shift to sustainable water management will be immensely problematic for the industry.

So, the form of privatisation adopted created an enormously complex and dysfunctional form of organisation for the industry.

Environmental NGOs are a third centre of power in England; in particular, the RSPB (the Royal Society for the Protection of Birds). The RSPB is a long standing body, founded in 1881, with a very large mass membership of over a million, larger than that of any political party (Tunstall and Green 2003). The role of the environmental NGOs has not been wholly positive in water management because their focus is on environmental conservation rather than on sustainable development. In water management, their influence has consequently been towards short-term, end of pipe fixes rather than promoting sustainable water management, which will necessarily take longer to achieve. For example, a very successful public relations campaign was run in support of lobbying for the Thames Tideway project, a classic end of pipe technical fix. Clearly, the monies spent upon that project are not available to be spent upon implementing sustainable urban water management instead.

What this focus on short term improvements to the state of the environment ignores is that climate change is predicted to causes drastic changes to ecosystems and unmitigated climate change would cause devastating change (Alcamo et al 2003). What also has to be recognised is that NGOs are also governed by incentives and that those are as short term as those which drive companies and often politicians.

In consequence, the companies, the environmental NGOs and the Environment Agency have had since privatisation great joy in spending other people's money, the consumers' money, in capital investment. The chair of the Consumer Council for Water described previous price and quality rounds as being like '.. the opening of the sweetie shop' and argued that the process for determining whether investments were justified was much less rigorous than that applied to public investments (EFRA 2009b Ev30 Q119, Q121).

This distortion towards end of pipe solutions because these involve capital investment is part of the explanation for the otherwise apparently irrational call for universal water metering: the cost of installing water metering counts as capital investment and can be added to the companies' Regulatory Capital on which they are allowed a return. Conversely, demand management measures are counted as O & M, which the price formula requires the companies to reduce. A consensus has developed around an ineffective and expensive approach to demand management (the Walker report (Walker 2009) estimated that metering would increase the costs of charging for water by £30/year, about 20% of the average water bill) because it fits within the existing institutional framework. Again, money is being wasted on a short term fix rather than invested in a more effective approach. A reversal in the consensus for metering can be expected when it is realised that a anticipated fall of 40% in water consumption is the worst possible time to introduce metering as it adds a revenue risk which will increase the cost of capital.

Traditionally, all the costs of all water and wastewater charges were recovered on the basis of a property tax. The water and wastewater services were provided by the local authorities and a property tax was the only tax that the local authorities had the power to levy. In turn, charging on the basis of a property tax was a cheap option. In addition, since all properties were required to be connected to both the water supply and a sewer, a property tax basis was logical. Thus, unlike many other countries which adopted metering for single family homes (although not commonly for apartments), for England (and London), a property tax charge remains the normal form of cost recovery. But where metering exists either for domestic or non-domestic properties, the costs of all other services (foulwater and surface water collection and treatment), and also the charges for draining the roads, are charged as a standard multiplier of the charge for potable water. Although now the cost of providing sewerage services exceeds the cost of providing potable water, it would obviously never be economically viable to charge individual households on the basis of the volume and pollution load of the wastewater they discharge. Indeed, it is not economically viable to charge the majority of households on the basis of the water they consume (Green 2003).

The two exceptions to these general principles are large firms who are charged for wastewater on the basis of the volume and load on the basis of the Mogden formula (OFWAT nd). The second exception is that for non-domestic users, separate charges are being introduced on a company by company basis for surface water runoff. On the other side of the equation, the WaSCs and WoCs not charged either for abstraction or discharge.

How well is London doing?

Sustainable development requires doing more with less; in the case of water, water is an intermediary resource and we want to achieve more using water more effectively. We want more bang for the Euro. At the same time, water management is simply part of sustainable development: sustainable water management is not an end itself. There are thus some high level of measures of sustainable development (Defra 2005) from which those for water management must be both derived and be consistent.

Ideally, we want efficiency measures: some ratio of one or more desired output to some input. That would require that we have defined, measurable societal objectives. In the short term, we can simply measure the technical efficiency with which water is used; some output achieved relative a water input.

For cities which have already achieved the Millennium Development Goals (United Nations 2009), **Table 3** sets out some possible performance targets, building upon the concept of water neutrality (Environment Agency 2009), together what is achievable in at least one city now and what is technically possible:

- **Water imports**: best practice now (e.g. Germany, Copenhagen) is for household water usage to be at the level of 120-125 l/p/d. A target of 80 l/p/d is achievable using existing technology, and the cost of achieving this target has been calculated, for new dwellings, as being effectively zero down to 105 l/p/d and around £2500 to achieve the 80 l/p/d (Cyril Sweett 2007) and the cost to retrofit an existing dwelling to achieve that 110 l/p/d to be £680 (Environment Agency nd). The target refers to imported water ONLY; the utilisation of rainwater falling on the city can be fully utilitised in addition. Setting a target for non-domestic usage is more problematic in that aggregate water usage is dependent upon the structure of the economy.

- **Water outputs:** Cities typically export more water than they import (Green 2003) because they are very effective rainwater harvesting systems. A target can then be expressed in terms of the difference in runoff between what is produced and that which would have occurred in natural conditions.
- **Food usage:** if domestic water consumption need not exceed 80 l/p/d, the water required to grow the food eaten by each individual is of the order of 3-6 tonnes a day (Molder 2007). Most cities import the majority of the food eaten in the city and hence very large quantities of 'virtual water' (Allen 1998). It is, therefore, appropriate to include imported food water in total city water usage. A radical shift back towards a low meat diet is required both to free sufficient water to feed the world (Molder 2007) and to achieve the UK's greenhouse gas targets (Audsley 2009).
- **Other virtual water**: again, manufacturing goods also uses and consumes water. Hence, cities are to a greater or lesser extent importers or exporters of 'virtual water' (Chapagain and Orr 2008). The appropriate measure here is not the water used during the production process but the water lost (e.g. through evaporation) during that process or incorporated in the product.
- **Greenhouse gas emissions**: water is heavy and incompressible and hence lifting water requires a lot of energy. Since there are typically economies of scale in water management, shifting to sustainable water management is likely to increase energy usage and hence potentially greenhouse gas emissions. In addition, wetlands, a highly effective approach to dealing with many water management problems, are producers of both methane (CH3) and nitrous oxide (N20), both highly aggressive greenhouse gases (Mitsch and Gosselink 2000). In the UK, more energy is used in the home and by non-domestic users in making use of supplied water than in supplying the potable water and dealing with the wastewater (MTP 2006). A shift to decentralised systems can be expected to increase the energy requirement.
- **Phosphorus recovery**: since phosphorus is both an essential plant nutrient and a fossil resource, long term human survival depends upon recycling phosphorus (Cordell et al 2009). Hence, the long term aim must be to recover 100% of the phosphorus from wastewater.
- **Impact on riverine environment:** cities have a dramatic effect upon the downstream riverine environment in terms of flows (Leopold 1968) as well as pollution loads (Beck 1996). The Water Framework Directive's use of 'good ecological quality', since that depends upon the flow regime, water quality, and the morphological form of the channel, provides a basis for defining a performance target in terms of how far downstream of the river the ecological state of the receiving water is not significantly different from if there were no city there. Urban areas also necessarily have an impact on upstream areas as a result of water

abstraction but how far that impact extends depends upon the local climate. Setting a target in this area would effectively be to argue that some existing urban areas would have to be relocated.

- **Proportion of household income spent upon water services:** in the UK, the term 'water poverty' has been defined as spending more than 3% of household income on water and wastewater services (Walker 2009). Obviously, it is the lower income groups who are most likely to be in water poverty, and whilst the London area has one of the lowest total charges for water and wastewater, the 3% limit is already exceeded for the lowest income groups (Walker 2009).

Table 3

	Targets										
	Food usage	**Other virtual water**		**Water inputs**	**Water output**		**Affordability**		**Greenhouse gas emissions**	**Downstream impact on watercourse**	**Phosphorus recovery**
Minimum performance now	2000 tonnes/ person/ year[8]	500 tonnes/ person/ year		Domestic – 130 l/p/d Non-domestic – 130 l/p/d	Total annual outflow not >er than 2 x non developed land Outflow in peak not greater than non-developed land in 1:20 year event		Maximum 5% of households in lowest income quintile spend more than 3% of household income to access a min of 80 l/p/d and equivalent wastewater services			20 kms	10%
Actual	1238 tonnes/ year (wwf 2008)[9]	399 tonnes/year [10] (wwf 2008)		Domestic – 150 l/p/d[11] Non-	Average runoff coefficient for London =		6% of the lowest three income deciles spend		0.30[15] – 0.44[16] CO2 tonnes/ML – water	60 kms?[18]	72% of sludge in the Thames Water area goes to

[8] Chapagain A and Orr S 2008 UK Water Footprint: the impact of the UK's food and fibre consumption on global water resources, Godalming: WWF; national and not London figures

[9] Chapagain A and Orr S 2008 UK Water Footprint: the impact of the UK's food and fibre consumption on global water resources, Godalming: WWF; national and not London figures

[10] Chapagain A and Orr S 2008 UK Water Footprint: the impact of the UK's food and fibre consumption on global water resources, Godalming: WWF; national and not London figures

[11] London Assembly 2003

			domestic – 188 l/p/d[12] (GLA on london water)	0.53[13]	more than 3% of their income on water and wastewater services[14]	0.35 CO2 tonnes/ML wastewater[17]		agriculture; it is almost certainly lower in London as Crossness has an incinerator for sludge disposal[19]
Target performance	1000 tonnes/ person/ year[20]	Zero net water	Domestic – 80 l/p/d[21] Non-domestic – 80 l/p/d	Total annual outflow not >er than for non developed land Outflow in peak not greater than non-developed land in 1:50 year event 3 hr event	0% of households in lowest income quintile spend more than 3% of household income to access a min of 80 l/p/d and equivalent wastewater services	Greenhouse gas emissions not greater than zero	0 kms	100%

[15] Thames Water 2009 Corporate Responsibility Report 2008/09, Reading: Thames Water
[16] Veolia 2007 Corporate Responsibility Report 2007, London: Veolia Water
[18] Environment Agency 2009 Water for life and livelihoods: River Basin Management Plan Thames River Basin District, Bristol: Environment Agency
[12] London Assembly 2003
[13] Calculated from the land use statistics given in Land Use Statistics (Generalised Land Use Database) 2005 (Enhanced Basemap), assuming that green spaces have a runoff coefficient of 0.25 and all other areas one of 0.95.
[14] Walker 2009
[17] Thames Water 2009 Corporate Responsibility Report 2008/09, Reading: Thames Water
[19] Thames Water 2009 Corporate Responsibility Report 2008/09, Reading: Thames Water
[20] Molder 2007
[21] CLG 2008

Comparators

For comparisons over time, and between cities (benchmarking), a number of secondary indicators could be used:

- Average reuse ratio: ratio of water used to water imported.
- Average energy usage per tonne of water imported and exported.
- Average value added per tonne of water imported.
- Water usage by commercial, industrial and public sector per person per day.

Improvements in each are likely to contribute towards achievement of the performance targets.

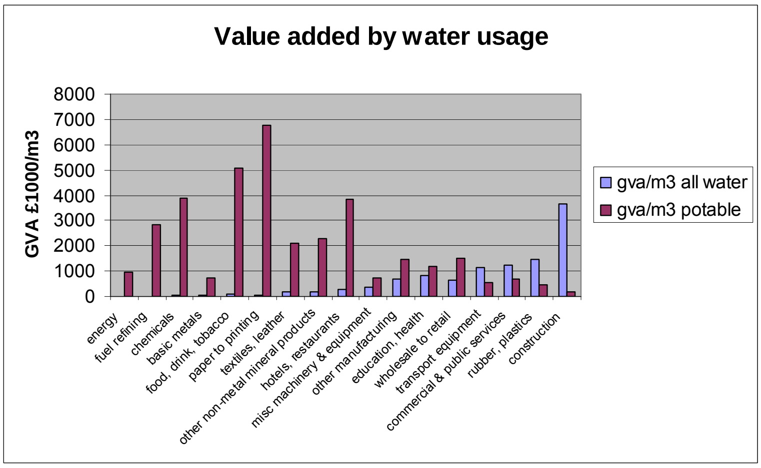
Table 4

Comparator	**London's current performance**
Average reuse ratio	No data available
Average energy usage per tonne water imported	No data available
Average energy usage per tonne water exported	No data on the total volume of water exported
Average value added per tonne of water imported[22]	National figures are given in **Figure 11**
Water usage by commercial uses per person per day	Only national data available
Water usage by industrial uses per £ production	Only limited data for some industries available from Envirowise
Water usage by public sector uses per person per day	Only national data available

Clearly, the context and starting point of any urban area will influence the difficulty of moving to these targets. Those cities with very high per capita household consumption, such as those in North America and Australiasia, should be able to move more dramatically towards the water consumption targets than those countries where water consumption is already reasonably good. Conversely, those cities in North America and Australiasia are typically very low density and hence it should be easier to fit SUDS systems than areas like the City of London which are almost entirely built up. Thus, overall, the difficulty of the task for London in shifting to sustainable water management is middling.

22

Figure 11 **National averages**



A number of possible indicators are deliberately excluded. 'River restoration' (Vivash and Biggs 1994) is one such exclusion. London has many 'lost rivers', many so lost that their exact original location is no longer known (Barton 1962). Rivers, such as the Fleet, were built over several hundred years ago, and became part of the sewer network, and the historic streetscape developed around and over these culverted rivers. The drainage system of which they were part comprehensively altered, not least by the construction of the canal network in the early nineteenth century. Hence, defining an indicator in terms of restoring a drainage pattern that existed several hundred years ago would be Disneyland. Instead, the logic is to derive appropriate goals from the Biodiversity Action Plans (Defra 2007).

Finally, there are a number of indicators of technology takeup which are suggestive of comparative performance but do not define it. These include:

- the proportion of properties adopting rainwater harvesting
- the area of green roofs in the inner London area (that part with the lowest area of green space and the highest proportion of impermeable area, coupled to the greatest Heat Island effect).
- The proportion of impermeable area converted to SUDS.
- The breakdown of consumption for different sectors by usage. Internationally, data availability is limited and in some cases of questionable quality,
- The proportion of grey water that is reused; given that grey water reuse competes for rainwater harvesting for usage, this is a weak indicator for London.

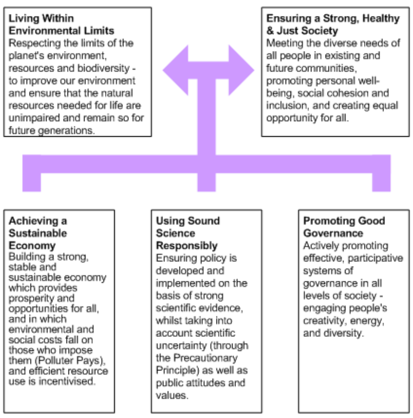
Why did the change happen?

The shift to sustainable water management is being piggy-backed onto the wider shift to sustainable development in particular and to adaptation to climate change in particular. To a significant extent the drive for this shift is coming from outside the water community; both the Sustainable Development and Climate Change communities having much greater influence on policy development than the water community which is any case a follower rather than a leader. Thus, an important driver for the adoption of green house roofs is to reduce the heat island effect (GLA 2010) and demand management has been driven as much by the requirement to reduce energy consumption (MTP 2006) as by the environmental consequences of abstraction.

Both sustainable development and climate change mitigation and adaptation are cross-government initiatives. The independent Sustainable Development Commission is the official advisor to the UK government, reporting the Prime Minister, and to the First Ministers of the devolved governments of Scotland, Wales and Northern Ireland. The most recent UK government definition (Defra 2005) of sustainable development has five components (**Figure 12**). Importantly, strategic spatial land use plans and their associated documents are required to undergo an independent sustainability assessment.

In turn, Sustainable Development has spawned a series of initiatives, notably those to promote waste minimisation (e.g. Envirowise) and, more recently, a shift to sustainable production and consumption (e.g. the Market Transformation Programme run by DEFRA). One of the consequences of both has been the recognition of how inefficiently water is currently being used. Thus, the Envirowise programme routinely demonstrates that industry and commerce could reduce water usage by 30-50% whilst increasing profitability. That is, adopting changes with a payback of two years or less. Much of this savings is achievable because water usage frequently saves money four times: in terms of the costs of potable water, of wastewater, of energy usage, and resource consumption. The major firms in the foods and drinks industry in England and Wales has thus signed up to a programme to cut water and effluent bills by 30%, with a longer term aim of a 50% cut. Similarly, the Market Transformation Programme is now probably the leading source on the comparative statistics of water usage by types of technology and forms the knowledge base to underlie regulatory programmes.

Figure 12



Climate change has been recognised since 1989 by successive UK governments as perhaps the most important threat facing the world. That recognition, in addition to supporting international action, has resulted in two threads of action: those on mitigation through the reduction of greenhouse gas emissions and those on adaptation. Both have had implications for water management, the former by focusing on energy usage. The Climate Change Act sets mandatory targets for greenhouse gas emission reduction and requires annual reports to Parliament as to progress on reaching those targets. The National Adaptation Programme requires emissions of carbon to be reduced by 34% by 2020 and 80% by 2050. The UK Climate Impacts Programme (UKCIP) produces the independent assessments of future climate change as well as promoting climate change adaptation.

In the case of both sustainable development and climate change, the national organisations are mirrored by London initiatives. Thus, in London there is the London Sustainable Development Commission and, for the Olympics, the Commission for Sustainable London 2012 is the monitoring agency. For climate change the London Climate Change Agency has now been incorporated into the London Development Agency. In addition, there are a number of voluntary initiatives such as the London Sustainability Exchange and the London Accord, the latter being centred on the City of London and financial institutions.

There have been a number of important champions for the different technologies. Amongst those that can be identified are:

Brian D'Arcy, Chris Pratt: SUDS
Richard Vivash, Nigel Holmes: river restoration
Dusty Gedge: green roofs
David Howarth, Jacob Tompkins: demand management

What is notably about each champion is that they were involved in the formation of an organisation with a mission to promote the particular approach and associated technology, and that organisation has been a vigorous disseminator of material on the approach and technologies.

Another strategy that has been used is the 'never waste a crisis' approach: in any event which is perceived as a crisis, the media and politicians ask why it happened and what could be done to reduce the risk of it occurring again. Both droughts have been used through the media to promote demand management and floods to promote SUDS. Similarly, an extreme heat wave would be an opportunity to promote green roofs and walls.

Explaining how the change happened is more obscure; it is the same argument as in other forms of history between the actions of individuals or the tides of history. In particular, much of the dynamics is hidden. If England is a highly centralised country, this centralisation overlays multiple webs of both formal networks (e.g. CIWEM) and informal networks (e.g. the series of conferences run by multiple bodies) and actors, such as the various policy 'think-tanks', which typical have a more or less overt ideological basis (e.g. the 'Adam Smith Institute' which provided the intellectual support for the actions of the Thatcher government). What can be said is that for a policy change (xxxx) to take place – and the occasions on which policy change did not occur are at least as interesting as those on which it did - there must be:

1. some argued disadvantages associated with the current policy; and
2. some identified alternative which can be argued to avoid these disadvantages without equal disadvantages being identified as associated with it.

My feeling here is that whilst there were many actors, it was the gradual coalescing of a coalition about the change, where that coalition supported it for a number of different reasons, that was important. Conversely, one policy player has asserted that two people who understand the political system in England can induce a policy change.

Equally, the water community has been arguably slow to adjust to the new reality. Thus:

- The department of Communities and Local Government's 'Code for Sustainable Homes' sets an immediate target for domestic consumption of not greater than 110 l/p/d for new social housing, moving over time down for all new housing of 80 l/p/d (CLG 2008).
- The Department of the Environment, Food and Rural Affairs, the ministry with mainstream responsibility for water management, most recent policy document indicate a target of reducing household water consumption to 130 l/p/d in 2030. This target has been criticised as being extremely modest (EFRA 2009), given that it is higher the consumption figure in Germany now (122 l/p/d) and higher than that achieved by a number of water supply companies in England now (OFWAT 2007)
- The companies were required by the price and quality regulator (OFWAT 2007) to set out long term Water Resource plans (Thames Water 2009); these generally anticipated an increase in per capita household water usage. Equally, the government sponsored Cave Report (2009) on competition and innovation in the water and wastewater industry was predicated on the assumption that demand would increase.

Thus, in effecting change, the water community and the water industry in particular has been essentially abandoned, the changes being implemented through spatial planning and building regulation rather than through water management per se.

How is the change being implemented?

The obvious advantage of being a follower rather than a leader is that by then the technology is relatively mature and readily available. Thus, in the case of sustainable urban water management, much of the technology is simply being imported, along with the design standards, notably from Germany. But there is a rapidly growth of SMEs involved in developing and installing the relevant technologies. Equally, the market is said to be growing very rapidly.

I have argued (Green 2010) that the powers to influence the behaviour of others can be expressed as a continuum from a requirement to act on one extreme to a prohibition from acting in a particular way at the other extreme (**Figure 13**). There are then two additional dimensions: the range over which the power exists (e.g. householders, local authorities) and the strength of the power (how effective it is in inducing the desired change in behaviour).

Thus, the approaches adopted in London can be arrayed in terms of the type of effect from required to prohibited, and the range of the effect (**Figure 13**). Regulations can require or prohibit, subsidies encourage, charges discourage and awareness campaigns can either encourage or discourage. Whilst there are a number of 'green taxes' in the UK, this policy instrument has not yet been applied to water. Making judgements about the strength of the power is more problematic. It is clear that on their own prices are ineffective in changing behaviour; the price-elasticities of water demand are, at least over the short term, very low. Using those figures (e.g. Dalhuisen et al 2001) to obtain the 50% reduction in domestic demand required under the Code for Sustainable Homes would require increasing water prices by 200 to 500%. Equally, the lesson from the Envirowise studies is that firms are not operating efficiently in terms of using water even when they are already metered and being charged for by quality and volume for the wastewater they discharge.

But, pricing mechanisms do have two useful roles to play as part of a coherent package of measures. Firstly, they are a way of raising revenue which can then be spent on implementing sustainable water management. For example, a metered charge for external water uses such as swimming pools could be used to fund the retrofitting of other properties with water efficient appliances. Secondly, prices are a way of signalling undesirable behaviour which is not sufficiently undesirable to be banned as part of a wider package of measures to shift to behaviour to that which is desirable.

Figure 13 summarises the different forms of power that are being used to induce the shift to sustainable water management. What is noticeable in this figure is the gaps: the forms of power which have not been used to date.

Figure 13

Range	**Power**				
	Required	**Encouraged**	**Information**	**Discouraged**	**Prohibited**
Existing buildings				Surface water charges (but not in London), water metering	
Commercial organisation		Tax incentives	Envirowise, other		

		for water efficient appliances ○[23]	programmes		
All new buildings and major works	Building regulations	Strategic plans, BREEAM ○[24]			Water fitting regulations
Commercial organisations		Waste minimisation clubs under Envirowise	Envirowise		
Government			Various department initiatives e.g. for schools, hospitals[25]		
Dwellings	Code for sustainable homes	Strategic land use plans			
Manufacturers			Market Transformation Programme		

There are two lead ministries which influence the move towards sustainable water management: Defra (Department for the Environment, Food and Rural Affairs) whose responsibilities include water management, and the Communities and Local Government department (CLG) responsible for local government including planning. Defra set out its vision for water management in 'Future Water' (Defra 2008), which is consistent with the concept of sustainable water management if unchallenging in its expectation of achievement. Thus, its goal for per capita household water consumption in 2030 exceeded that already existing in parts of the country and was considerably higher than the level achieved in Germany today. Defra is also the lead ministry with respect to climate change mitigation and adaptation, and the focus for sustainable development initiatives.

Defra has a number of regulatory instruments available to the either require or prohibit particular forms of behaviour by others.

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[23] Direct subsidies have not yet been used but their use is under discussion (London climate change partnership 2009)

[24] At present, whilst the Mayor of London wishes to introduce a programme of subsidies for green roofs, similar to that adopted in Germany and other cities such as Toronto and Rotterdam, no such programme exists at present.

[25] DfES 2004 Energy and Water Benchmarks for Maintained Schools in England, London: DfES; Department of Health nd Water management and water efficiency: best practice manual, London: Department of Health

The Floods and Water Management Act 2010 is essentially concerned with flood risk management but included some outstanding issues where a long standing need for legislative change has been recognised. Thus, it is not a coherent or coherent attempt to set up a framework for sustainable water management. It did seek to promote the usage of SUDS by making the local authorities responsible for operating and maintaining these systems but failed either to provide a funding stream to do so or to recognise that SUDS are both systems and can serve other purposes in addition to reducing runoff. But crucially, it did remove the longstanding legal right of a property owner to connect to a surface water sewer.

The Market Transformation Programme was established to support UK government policy on shifting to sustainable production and consumption, particularly in relation to energy, and therefore to inform future regulatory and other action.

Further reductions in the use of phosphorus in detergents for clothes and dish washing are now intended to take place (Defra 2008).

The Communities and Local Government instruments are those of spatial planning, notably the Acts under which spatial plans are required and the guidance provided on their preparation. Since those plans must be approved by the Minister, that guidance is generally highly effective. The most important guidance is that for the regional spatial plans, Regional Spatial Strategies of which the London Plan is one. As yet, the CLG has not prepared any overall guidance as to how water issues should be incorportated into spatial planning: not surprisingly since there is said to be only one person in the CLG working on water issues. What was produced was planning guidance in regard to surface water management and flooding (CLG 2006).

Of greater importance and effect is the Code for Sustainable Homes (CLG 2008) which sets out standards to be met for housing. Code level 3 has been compulsory since the start of 2008 for social housing and for land built upon land owned by English Partnership, the government agency responsible for selling on and the subsequent development of former government land. Code level 3 sets a maximum per capita daily consumption of 105 litres. From this year, all new housing must reach this standard and by 2016 all new housing must reach level 6 which sets a water consumption limit of 80 l/p/d.

The Building Regulations are set by the government and enforced by the local authorities; they set minimum standards that must be achieved by all new buildings and major works to existing buildings. The revised Part G came into force on the 6th April 2010 (CLG 2010), a delay of nearly four years from its original planned date. It sets a maximum water usage figure of 125 l/p/d for dwellings. Other changes in this section set out the conditions under which rainwater or greywater can be used within buildings, and the use of composting toilets.

A final change was the removal of the conversion of front gardens to impermeable areas from land use changes which did not require planning permission. In discussing possible changes to the types of development for which planning permission was not required, the CLG originally proposed to continue to exclude such conversions, but after the consultation process, the regulations were changed (CLG 2007).

Other types of building are appraised using the BREEAM system (e.g. Building Research Establishment 2008) which includes points for the adoption of sustainable water management technologies.

Other ministries also are involved in actions which can promote the adoption of sustainable water management. Commercial organisations, those that make profits and are taxed on those profits, have been provided with tax incentives by the finance ministry (H M Treasury) to adopt the technologies associated with sustainable water management. Companies can write off 100% of the first year capital allowance against tax on approved equipment in a series of categories. The categories of equipment so far included in this Water Technology List are:

- Efficient washing machines
- Flow controllers
- Leakage detection equipment
- Meters and monitoring equipment
- Rainwater harvesting equipment
- Small-scale slurry and sludge dewatering equipment
- Vehicle wash water reclaim units
- Water efficient industrial cleaning equipment
- Water management equipment for mechanical seals
- Water reuse

The Envirowise programme developed a number of years ago as an initiative from the trade and industry ministry; thus, originally, it was seen as a way of improving industrial and commercial productivity.

As discussed earlier, the Mayor of London was established to provide a strategic perspective for London but lacks any financial resources and the Mayor's other powers are indirect (Mayor of London 2010). The London Boroughs are thus expected to take account of the strategic guidance set out by the Mayor. The main guidance document are the various elements of what was the Regional Spatial Strategy for London, now the London Plan (Mayor of London 2009a). At the core of the Plan is a strategic spatial plan for London. Like all such plans in England, it is required to be accompanied by an independent sustainability assessment before an independent hearing in public is held and a decision is then made by the Minister to approve the plan. Unusually, both Mayors also choose to prepare a water strategy document (Mayor of London 2007, 2009b) along with the statutorily required elements of the plan.

Figure 14

		Power						
		Positive Negative						
New buildings		Requiring	subsidising	promoting	informing	discouraging	charging	Banning
	Demand management	●[26]		●[27]			○[28]	●[29]
	Green roofs	●[30]						
	Green walls	●[31]						
	SUDS	●[32]					●[33]	
	reuse		●[34]					●[35]
	recycling		●[36]					

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Existing buildings								
	Demand management		●[37]	●[38]	●[39]	●[40]	○[41]	
	Green roofs			●[42]				
	Green walls			●[43]				
	SUDS			●[44]			○[45]	
	reuse		●[46]					
	recycling		●[47]					

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Technology	**Policy tool**
Demand management	Tax incentives, regulations, awareness campaigns
Green roofs	Development control
SUDS	Development control, Building regulations
Reuse/recycling	Tax incentives
Rainwater harvesting	Tax incentives

There has been a strong use of iconic buildings to adopt sustainable water management techniques. An early example was the use of rainwater harvesting in the Millennium Dome and the new Terminal 5 at Heathrow Airport is now the largest rainwater harvesting project in London. The largest example is the Olympics 2012 development which it is intended will be the greenest ever Olympics. That features SUDS, rainwater harvesting, demand management, reuse, green roofs and green walls, and river restoration (London 2012 2009). Similarly, corporate buildings are also targeted; the Barclays Bank building has one of the better known green roofs in London although those in London Zoo and the café in St James Park, centred between such major tourist attractions as the Houses of Parliament and Buckingham Palace, are seen by more people.

Starting advantages and disadvantages

London started off with two major advantages:

- A relatively long history of development control (since 1947), with a high level of compliance.
- A low level of corruption.

Land use planning and development control is now part of the fabric of society. There is no data on the level of compliance with conditions made as part of the grant of planning consent and very limited data on breaches of building regulations. But construction without valid planning consent is virtually unknown, not least because neighbouring land owners would immediately complain.

The question with corruption is: why is there not more of it? Well into the nineteenth century, the UK was very corrupt but now both the level of corruption is low, and what is deemed to be corruption. Thus, the recent scandal of Members of Parliament’s expenses claims evoked public outrage whilst in other countries, it would be viewed as a sign of a lack of ambition. Explaining the process through which the UK shifted to a country where both the definition of what is corrupt action expanded, and the level of corruption fell, appears to have been under-researched (Rubinstein 1983).

The two advantages are linked: over much of the world, especially those areas where mass migration to urban areas is taking place, development control is either ignored or bypassed by corruption. Depending upon on the country, planning consent may be corruptly gained, or the planning requirement corruptly bypassed, or the planning requirement simply ignored. In countries where there is a large scale pattern of informal settlements, ignoring land ownership, it would be fantasy to call for implementing sustainable urban water management through land use management.

An almost intangible advantage is that London is both growing and the capital. It is easier to include sustainable water management in new buildings than in existing building and that it is a capital can be used as a powerful argument for the adoption of modernism in the form of sustainable development. The Thames Gateway development in particular has been useful as a basis for arguments as to what constitutes sustainable development (e.g. Environment Agency 2009).

The obvious major barrier at present is affordability at all levels: consumers, companies, government, country. Concerns are already being expressed about water poverty, the proportion of consumer paying more than 3% of their income on water and under current model, bills will continue to rise as a proportion of income (Walker 2009). The WaSCs and WoCs are highly geared (NERA 2009) – a large proportion of investment being funded by borrowing rather than shareholder capital. As gearing increases, the investment rating of the borrowing falls and so the required interest rate increases. Conversely, shareholder capital is more expensive so either reducing gearing or expanding the amount that can be borrowed whilst maintaining the same rate of gearing will also increase the cost of capital. Following the financial crisis caused by the banking failure and the resulting deep recession, it was necessary for the UK government to find very large sums, over 10% of national income, to prevent the collapse of the banking sector and to maintain liquidity in the financial markets. That recession in turn resulted in reductions in revenues all round, including to the government who also were faced with increased costs.

Secondly, the inheritance inhibits change. For example, to set up an Ecosan system (Esrey et al 1998) would require:

- Adjusting the wastewater charge and separating it from the charge for water supply.
- Adjusting the Building Regulations to provide a regulatory base: such changes came into effect this April.
- Ensuring that insurance coverage was available for installation and operation.
- Setting up a collection system.

Thirdly, as discussed through this paper, municipalities have few powers and little scope for action in England; London having more freedom of action than other local authorities in the country.

Fourthly, in many countries, municipalities are responsible for ensuring that their citizens are provided with a number of services, of which water and sewerage are specified, and also for land use management. That is, the situation corresponds to that which had been achieved in England by the end of the nineteenth century but which has subsequently been disassembled. In the old system, a municipality bore the costs of its land use planning decisions in terms of the costs of providing water and wastewater services.

Fifthly, government planning guidance has sought to promote four different principles:

- The redevelopment of brownfield sites
- The adoption of minimum densities of development
- The incorporation of social (i.e. low cost) housing in all new housing developments
- The use of SUDS

These different principles all have cost and spatial requirements and so the developer has to resolve the conflicts between them.

Traditionally, UK governments have been reluctant to provide subsidies to encourage people to behave in particular ways. Equally, the finance ministry has traditionally been opposed to hypothecated taxes. In other countries, most adopters of green roofs give subsidies to those who adopt green roofs (Lawlor et al 2006), following the German example (Ngan 2004). In London, the Mayor hopes to be able to fund such subsidies for green roofs (GLA 2010) as part of his desire to increase the area of green roofs in London by 2012 by 200,000 m2.

Next, prior to the recession, housing stock was being added to at the rate of 1% per annum and replaced at the rate of 0.1% each year (Commission for Sustainable Development 2005). The rates of addition and replacement of non-domestic buildings are somewhat higher but the country has to deliver sustainable development in the face of climate change very largely with the existing stock of buildings. Hence, the primary problem is to retrofit existing stock rather than make the change through replacing the existing stock. This will be a more difficult and expensive process. A number of studies have been done on the scope for retrofitting SUDS (xxxx); unfortunately, that is easiest where it is least needed, that is in areas where the proportion of green areas is already high. Similarly studies have been done for demand management to housing (xxxx) and it has been shown consistently that significant reductions in water usage by industry and commerce can be achieved whilst increasing profitability.

Whilst Japan has a modest length of permeably paved roads in urban areas (Sera 2006), the feasibility of converting significant lengths of existing roads in London to permeable pavements may be doubtful. The existing pipe and cable network below the roads may be too shallow to allow for the depth required for a permeable road. **Figure 15** shows the excavations to replace water pipes at one of the main centres in London as part of the works to build a new trans-London high speed rail link and expand the existing London underground station. It can be seen that pipes and cables are very close to the road surface.

Figure 15

Finally, the country as a whole is deeply geared: personal borrowing is high and personal savings are low, as is company and government borrowing. It does not ultimately matter who borrows money, it has to be repaid. Thus, to make space for a change to sustainable urban water management either other investments will have to be rescheduled or current consumption reduced.

The first of three general lessons are that the adoption of new technologies is promoted if national standards are developed for those technologies; this gives confidence to the potential adopters that the risks associated with using the technology are low. A related but unexplored issue is the availability of the different forms of insurance for the different involved parties, notably the manufacturer, installer and building owner. A refusal to provide insurance cover for a particular technology would have a very damping effect on its adoption.

The second general lesson is the critical importance of transaction costs. Coase (1991) showed that the relative magnitude of the transaction costs associated with the adoption of different options will determine which is the economic option to adopt. Thus, the historic preference for charging for water by a property tax rather than metering, and convenience of charging for all water and wastewater services as a crude multiplier on the charge for water. Equally, the introduction of separate charges for surface water runoff has depended on the development of GIS technologies.

Finally, we can see path dependency in play, but particularly technological path dependency. Whilst there are advantages and disadvantages of England's lacking any written constitution, an advantage of the lack of such a constitution is that if institutional change is considered desirable, it can be made relatively easily; that is, through an Act of Parliament. Mistakes, in particular, can be rectified; adaptation made to changing circumstances; and learning incorporated. For example, when licensing for abstraction was introduced under the Water Resources Act 1963, existing abstractions were grandfathered in perpetuity. The Water Act 2003 changed this to a time-limited licenses.

What can be seen on the ground

- River restoration is now mainstream with some 60 completed projects covering 22 kms of water courses (out of 650 kms), and another 100 potential projects identified (The River Restoration Centre 2009).
- There are an estimated 200,000 m^2 of greenroofs with the ambition to double this by 2012 (Mayor of London 2009c).
- Rainwater harvesting: an estimated 400 systems a year (other than water butts) are being installed across the UK as a whole; this includes systems as Terminal 5 at Heathrow and the 02 dome at Greenwich.
- Groundwater use for toilet flushing e.g. the City Hall, London.
- The proportion of buildings in which demand management measures have been installed is unknown; by observation, waterless urinals are now quite widely adopted.
- No figures are available as to the extent to which SUDS have been installed.
- There is apparently very limited greywater reuse except for some garden watering; the BedZED development originally used a greywater reuse system but abandoned it on the grounds that it was too energy inefficient.

The Environment Agency has produced a number of summaries of good practice case studies (e.g. Environment Agency 2009).

Changes required

Part of the problems are created by retrograde EU Directives, notably the Urban Wastewater Directive, and also the Water Framework Directive. Both are directed towards end of pipe fixes rather than shifting water management in the direction of sustainable development. In turn, they are diverting investment and attention towards short term fixes rather than to a longer term strategy of delivering sustainable urban water management. The EFRA Select Committee (2009) recommended that the maximum use be made of the derogation provisions of the Water Framework Directive rather than divert investment to short term band aid solutions and away from a longer term strategic delivery of sustainable urban water management. Unfortunately, the Urban Wastewater Directive has no such provision for derogations and the diversion of resources to the Thames Tideway scheme was noted above. These are problems which can largely only be solved at the European level.

The problems with the water and wastewater industry can then only be solved at the national level. Indeed, because of the highly centralised nature of England, London's problems can currently only be solved at the national level.

Thirdly, there are outstanding questions as to the performance of a sustainable urban water management system in terms of the effect upon the performance of existing networks, the response of catchments to varying distributions of SUDS, and the reliability of water supply to localised water storage.

In terms of increasing difficulty, change may be implemented in London by:

- Using existing powers
- Creating powers using secondary legislation[48]
- Creating powers using primary legislation
- Creating powers using international (e.g. EU) legislation

Most regulation in England is through so-called secondary legislation; Acts of Parliament creating the power for a Minister, Local Government or another body to prepare and enforce regulations or to take other action. Traditionally, regulations, bye-laws and similar powers were created using little oversight by Parliament or the Courts. Hence, they have been an attractive means of making change and equally the temptation in preparing Bills to go before Parliament of including sweeping powers so that subsequent events can be responded to using the secondary legislation powers rather than getting a new Act through Parliament.

So far, most of the changes implemented have been done through secondary legislation. But the necessary changes to the incentives for the water and wastewater industry in the form of the price and quality regime will require primary legislation. So too will sorting out the boundaries of the different institutions involved. Unlike the nineteenth century when Acts followed each other at short intervals, a major water Act can now be expected to have a life of ten years or so, other policy areas taking higher priority. Thus whilst a junior minister in the 1997 government has said that they wished to make

[48] Primary legislation, Acts of Parliament, is required to create the scope for secondary legislation; Secondary legislation is then the national, local or specific regulations made using the powers created and defined under primary legislation.

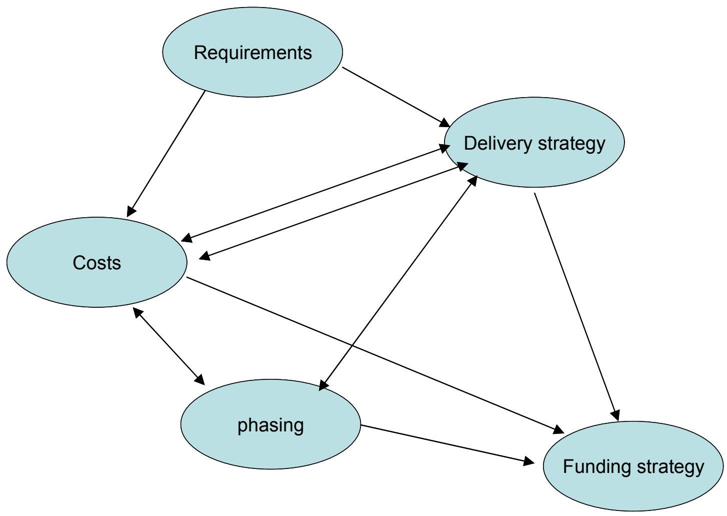
changes, they were unable to make those changes without primary legislation and Defra were unable to gain a slot in the government's legislative timetable. Hence, there is a need to get such a Sustainable Water Management Bill right before submitting it to Parliament for scrutiny, examination and amendment.

By now, it will have become apparent that what I would want to see that Bill focus upon:

- clearly defining roles and the limits of those roles so setting boundaries;
- providing effective and appropriate incentives for the different parties to act to implement the common vision. Those incentives need to include those to promote inter-organisation co-operation. The Floods and Water Management Bill does include a duty to co-operate but creating a duty to co-operate is rather like creating a duty for couples to stay in love. Those incentives have to be sufficient to overcome the barriers to co-operation; for example, as public companies, employees of the companies are bound by the Financial Services Act not to reveal any data that might affect the share price of the company.

The basis for that Act needs to be a long term vision of how sustainable water management is to be delivered; defining that programme is a multi-dimensional problem (**Figure 16**). Costs are partly dependent upon the phasing and overall timeframe for the programme and the delivery strategy adopted. The funding strategy, including cost recovery, has to reflect affordability not only at the consumer end of the equation but also for the delivery organisations and the country as a whole; investment in water management will be competing with the investment required to deliver other aspects of sustainable development, notably shifting to a carbon neutral economy.

Figure 16



A major constraint is the existing structure of the industry; there is a very large pile of debt which has to be serviced whilst demand falls. The vision is of a reduction in water demand of around 50% and already the Floods and Water Management Act's allocation of responsibilities for SUDs to the local authorities means that over the long term, all surface water drainage will progressively transfer to the local authorities. So, a careful analysis of future costs and revenues as demand falls is required. The concern is with ensuring that there are sufficient revenues to cover current loans and, to a lesser extent equity capital, is with the future. If regulatory risk is perceived by the market to have increased then the costs of capital in the future will increase and perhaps not just in the water field but across the country as a whole.

Whilst if we were starting from scratch, the water and wastewater industry would ideally not have been privatised in the way that it was, the need is to deal with the problem as it is. That is, to restructure the incentives for a privatised water and wastewater industry so that it delivers sustainable water management efficiently.

In a competitive market, successful firms earn a high return on their equity capital and weak firms fail, the equity owners losing all or part of their capital. The high return is earned by taking risks and the consequent possibility that the equity will be lost. Success is determined in the market, successful firms being those which better satisfy consumer requirements than do competing firms.

Conversely, loan capital is cheaper precisely because it has a lower risk; the loan is secured against either a secure stream of income or some asset which has a secure resale value. The recent financial crisis was the product of loans which turned out to be secured against assets which produced neither a secure stream of income nor had a secure resale value. In a competitive market, successful firms earn a high return on their equity capital and weak firms fail, the equity owners losing all or part of their capital. This is the discipline of the market which overall promotes efficiency; if there are no failures, then there is no efficiency, the market being Darwinian.

The problem therefore in the case of water management is to introduce incentives for the companies to deliver sustainable water management efficiently. Where it would be efficient to do so, then competition is the economist's rote response but water is beset by economies of scale and scope and high transaction costs (Green 2008) where those factors can easily wipe out the hypothetical gains from competition. It is necessary to learn the appropriate lessons from the failure of privatisation in the nineteenth century or rather the superior performance of the municipalisation of water management in that period (Hassan 1985). One hypothesis to explain the superior performance of the municipalities over the private companies is simply that the municipalities were able to raise more capital, and thus capture economies of scale, and more cheaply than the private companies.

For competition, there needs to be payment by performance rather than the current differentiation between capital investment and operations. At the same time, there is a requirement to ensure that companies just do not run down assets; the current pressure to reduce O & M costs whilst funding capital investment tends to operate in the opposite direction.

A change that has already been proposed (EFRA 2009) is that some organisation ought to have a statutory duty to ensure the effective drainage of urban areas. The EFRA Select Committee proposed that such a duty should be imposed upon local authorities. That they should have such duty does not imply that they have to perform the function which is currently performed by a miscellany of organisations including the WaSCs, Internal Drainage Boards where these exist, the Highways Authority, and the Environment Agency. Instead, the logic is that they should contract out the responsibilities. Therefore, the WaSCs should cease to charge directly for surface water and highway drainage; the appropriate LA instead charging for both. That charge should be set according to load imposed as determined by the impermeable area, after taking account of such features as rainwater harvesting, green roofs and SUDS. Together, this would introduce an incentive on property owners to take action to reduce runoff from existing properties, development controls taking care of new properties. A small degree of competition would also be introduced between suppliers of drainage services.whilst promoting the spread of WaMCOs.

In the energy field, companies have developed (Hopper et al 2007) – ESCOs (Energy Supply Companies) – to supply packaged energy services to a site, There appears nothing to prevent a similar approach to water management services: a WaMCO (Water Management Company). Whilst the site remains linked to the conventional water mains and sewers, the role of the company is to ensure that the site owner pays the minimum total for the water used on site by, for example, introducing demand management technologies. The introduction of separate charges for surface water management, whilst weakening the incentive to introduce demand management, will provide an incentive to adopt SUDS.

If the market were operating efficiently, there would be no scope for WaMCOs but a fleet of studies from Envirowise and others have shown that there are significant water and cost savings to be had across non-domestic users. The problem is to reduce the spread between those land users who are using water relatively efficiently and those who are not.

A variety of contracts between the WaMCO and the site owner are likely to develop mirroring the variety of contract forms that have developed in other countries in conventional water services; various splits being possible between the site owner and the WaMCO as to the funding of capital works. Owners of large estates (e.g. the various branches of the National Health Service, large retailers, leisure chains, Housing Associations) could let the operation of water management on different tranches of their estate out to competitive tender,

A large variety of potential suppliers appear to exist and thus to create a competitive market. The existing ESCOs are one possible entrant because a large fraction of water usage on site involves heating or cooling; hence reducing energy consumption simultaneously requires reducing water consumption. The existing water and wastewater companies ought also to be entrants and the advantage of the proposal is that all would then be free to compete with each other across the entire country. As a non-regulated business, neither funded by the general water consumer nor subject to price regulation, the successful entrants should find it profitable, Conversely, the less successful companies will, as is required in order to have competition, suffer losing both bulk water and wastewater demand in their own territory and failing to win any WaMCO contracts.

The effect of the introduction of WaMCO's over time is likely to be to split the water and wastewater industry into two main elements:

- The existing WaSCs and WoCs managing bulk supplies, transfer and treatment where there are strong economies of scale or scope.
- The WaMCO's working at an individual site level to the extent to it is possible to efficiently reduce demand.

The risk is that existing private household consumers, for whom a WaMCO would not be efficient, would be left to cover the costs of running the bulk water and wastewater system whilst revenues from non-domestic users contract. One way of protecting those consumers by providing an incentive for the companies to seek to reduce household consumption is a charge on all water abstracted by the water companies where that charge is based on the per capita amount of water delivered to domestic consumers as that amount deviates from a specified target figure. The charge levied on the water abstracted by companies delivering water in excess of the target would not be allowed as a cost pass through by OFWAT. Conversely, any company achieving better than the target would receive a rebate from the revenue raised from those companies who exceeded the target. Hence, the overall effect would be revenue neutral across the water supply industry as a whole whilst providing an incentive on companies to do better than the target consumption figure. The charge rate would be set for revenue neutrality over the medium term rather than annually since the companies need some stability in expected income. However, the target household per capita consumption figure would be ratcheted downwards over time. Thus, for example, the target per capita household figure might be set to fall to 100 l/p/d by 2030, thus be set to fall, on average, by 2.5 l/p/d annually.

Setting a target only for household water consumption avoids the complexities of the different proportions of consumption taken by non-domestic users in different areas. But simultaneously it provides an incentive for the water companies to seek to reduce water consumption in the non-domestic sector where it would be cheaper to reduce consumption in those areas than in the household sector.

It is strongly advised that the charging system be kept simple, like the German systems for charging for abstraction, wastewater discharges and surface water runoff. Economists will want to introduce all sorts of complications in order to 'optimise' the water abstracted against the costs of doing so. As it will not be possible to accurately reflect the real costs of abstraction, adding complications will simply add costs and uncertainty. Changes to the simple system should only be introduced to correct for any perverse incentives and unexpected consequences.

The individual companies will obviously make special pleadings that there are structural reasons why their domestic demand is unusually high. In the particular case of external uses of water, these have not traditionally been treated as water demands which the companies have any statutory duty to supply. Hence, companies should be free to adopt whatever charges and conditions that they can justify to any consumer who wishes to use water for such purposes (e.g. garden watering). **Table 5** shows how such a charge would work under a variety of conditions:

Table 5

			150	l/p/d	
population	per capita abstraction l/p/d	target per capita household consumption l/p/d	charge rate - domestic pence/litre	fraction of final consumption that is household consumption	charge on company £/year
1,000,000	400	160	0.5	0.4	8,000,000
1,000,000	500	160	0.5	0.4	10,000,000
1,000,000	400	160	0.5	0.2	4,000,000
1,000,000	300	160	0.5	0.4	6,000,000
1,000,000	400	150	0.5	0.4	0
1,000,000	300	160	0.5	0.5	7,500,000
1,000,000	500	150	0.5	0.4	0
1,000,000	300	140	0.5	0.6	-9,000,000
1,000,000	400	140	0.5	0.6	-12,000,000
1,000,000	400	140	0.5	0.6	-12,000,000
1,000,000	500	140	0.5	0.6	-15,000,000
1,000,000	500	140	0.5	0.6	-15,000,000
1,000,000	400	140	0.5	0.6	-12,000,000

In this case, pricing is expected to be an effective form of power whereas it has proved ineffective at influencing demand by the individual consumer. Whilst there is no economic theory explaining when prices will be effective and when they will not, the hypothesis here is that consumers' attention is limited and therefore only spent upon high priority requirements. Thus, since in most circumstances, water services are relatively unimportant as compared to other factors, pricing water can be expected to be ineffective; that ineffectiveness being compounded by the further requirement to spent money changing technologies if water consumption is to be reduced. Conversely, for the water and wastewater industry, water is its business and it can be expected to dedicate more attention to its use. A second consideration is that policies are probably more likely to be effective if they are coherent and prices are used as part of the overall system of signals and incentives.

The price regulation system for the WaSCs and WoCs needs to be revised, both to remove the existing perverse incentives and to ensure the financial viability of the companies when water management becomes sustainable. Those perverse incentives have already been discussed, notably the distinction between capital investment and O & M, and in particular how that provides an incentive to avoid adopting SUWM. From the consumers' perspective, the objective is provide the lowest annual cost means of delivering some specified standards of service.

Reducing water consumption by perhaps 40%, with corresponding changes in wastewater flows, will affect variable costs to some extent but the German experience (Schiller and Siedentop 2006) is that these costs may actually increase, it being necessary flush out supply lines and sewers as a result of the lower flows. For water supplies that are metered, the reduction in demand will feed directly into a reduction in revenue, as will reductions in surface water flows. The revenue risk is a further reason, on top of the standard efficiency case against metering, to avoid adopting water metering. What changes in water usage have resulted in the collapse of the demand for water in the eastern lander of Germany needs investigation as demand is reported to have fallen to only 93 l/p/d (Schleich and Hillenbrand 2007).

But loan costs will continue to have to be covered and the German experience is that the fall in revenue can exceed the reduction in costs leading to financial difficulties for the water or wastewater company. In Germany, there have been a number of significant problems in those parts of the country where both the population and per capita consumption has dropped dramatically (Hummel and Lux 2007). Companies may be left with a number of stranded assets on which loans must still be repaid; at the same time, it is necessary to avoid creating any incentive for companies to build assets which will become stranded but on the capital invested they would have an entitlement to earn a return.

In addition, assuming that further significant investment is necessary, then it is essential to maintain the 'AAA' grading of bond issues as this minimises the cost of borrowing. All these issues suggest that substantial modelling exercises should be adopted before introducing a new system of price regulation.

Lessons

The two fundamental questions set out at the beginning were:

- Why was there a change? And,
- How was the change induced?

As compared to the targets set out earlier, the physical change on the ground is only just beginning.

London has some comparative advantages in making the change:

- It has a strong and effective system of planning and building regulation; that is, a system with which there is a high level of compliance.
- It has had a system for collecting and disposing of solid waste since the middle of the nineteenth century and hence the pressure on using component of water systems to dispose of waste is reduced.

- Compared to Asian, African and South American cities, it has a low population density and also a very large ratio of open space to total area.
- It has a temperate climate; whilst overall rainfall is small, it is entirely adequate to support rain fed agriculture, and rainfall intensity and both inter- and intra-year variability is low.
- It sits on an old flood plain and hence is relatively flat, and importantly is not down stream of a mountainous area.

To address the 'why' question, the changes have been piggy-backed in on the two higher profile issues of sustainable development and adapting to climate change. This has been helped by the much low costs of delivering sustainable urban water management than of carbon neutral energy services. It has been seen that successive UK governments have, since 1989, defined climate change as perhaps the biggest threat facing the country and have reacted accordingly. That piggy-backing can be seen as a version of the commonly used approaches of attaching some proposed change to some vision of modernism and the invocation of some moral principle; now, the avoidance of 'waste' whilst the moral principle attached the nineteenth century reforms was the attack on 'filth'. Those opposing any change are consequently framed as being out-of-date and immoral. In the ways in which it is implementing that change, it is adopting both the experience and technology from other countries, notably Germany.

How is change being effected? The direct and obvious answer is by using those powers that exist already. That has meant a reliance upon powers under secondary legislation, and particularly those relating to building and planning controls. Here there a mixture of specific, local lessons, plus transferable positive and negative lessons.

A specific local lesson is that the political context of London has also helped: a directly elected mayor and an Assembly partly elected through proportional representation (unlike most elections in the country). In the three elections for Mayor to date, the electors have shown a preference to elect a Mayor of the same party as the government but with a high degree of independence from that party. The advantage of proportional representation can be argued to be that it resulted in Green candidates being elected to the Assembly and forced sustainable development issues further on to the table.

Of the transferable lessons, a positive lesson is the use of high profile developments; for example, Terminal 5 at Heathrow is the largest rainwater harvesting installation in London, there is an obvious emphasis on incorporating sustainable urban water management into the 2012 Olympics (ODA 2009), and the Thames Gateway (Environment Agency 2009). Similarly, companies are under pressure to demonstrate a commitment to sustainable development; hence prestige company buildings have been a particular focus for the adoption of green roofs (e.g. Barclays Bank building).

A wider general negative lesson is that in considering integration, the key question is what is the most important form of organisational integration?

Thus, what other forms of integration must necessarily be sacrificed to promote this key form of integration? As with other things, with integration the issue is one of priorities; what should be given up in order to achieve a higher priority? In water management, the traditional argument has been upon integrated catchment management and certainly in England other forms of integration have been sacrificed to this end. Conversely, I would argue that in order to deliver sustainable urban water management, the key form of organisational integration is between land and water management. In London, there are two entirely different formal systems of planning; one for spatial planning and the other for water management, spatial planning through the local authorities and water planning through the Environment Agency.

In turn, two key aspects of integration are clearly defining the boundaries and then providing incentives for the different stakeholders to act in an integrated way. The problem is necessarily to deliver integration from a fragmented mosaic of organisations. Those boundaries need to be defined at the linkage points between responsibilities and physical systems within different responsibilities. In England, doing both is perhaps inhibited both by the political enthusiasm to act which precludes thought and the way in which legislation is constructed. Any new Act will introduce some new clauses, modify clauses in some existing Acts and delete clauses from those existing Acts. So far national legislation has established neither clear boundaries nor the appropriate incentives.

Secondly, centralisation creates consistency at the cost of diversity and thus potentially at the cost of innovation. In England, it is reformers who have always favoured centralisation: in the nineteenth century, it was the sanitarian reformers who favoured central government action and removing autonomy from local government. Now, it is the environmental NGOs who favour the same centralisation. In both cases, part of their motivation was the belief that autonomous local authorities could not be trusted to do the right thing. Centralising power meant greater access to power by first the sanitarian reformers and now for the NGOs.

A third negative lesson is that in considering privatisation it is necessary to both recognise the nature of water management (Green 2008) and think what realistically may be the possible advantages of privatisation, and the disadvantages. Water management is capital intensive, and the cheapest form of capital is loan when the risks are seen by the investors as low. In principle, water management and fixed income investors are a perfect fit: a low risk, achieving the required ‘AAA’ investment grading, low return investment for those who want a low risk return over the long term. Indeed, the two crucial steps for urban water management might be argued to be: ensure that a bond market exists which can provide sufficient investment and secondly to ensure that the water management options will achieve an ‘AAA’ rating.

Next, water management is characterised by both economies of scale in capital works and economies of scope; both drive against the introduction of competition.

In addition, water is a low unit value bulk so transaction costs are critical as they will be large relative to resource cost of the water distributed or removed. Any notional improvement in efficiency will be lost if the additional transaction costs are greater. Thus, water metering down to the individual apartment is rare because the additional transaction costs of metering over a simple tax typically exceed any possible efficiency gain from reduced water consumption (Green 2003). Similarly, the introduction of separate charges for surface water drainage is only viable because GIS systems are now in place which means that the marginal additional cost of setting charges at a property by property rate are low enough to be feasible.

Finally, all water management is done by people; if privatisation of itself is to make a difference it can only be by introducing different people or different incentives to people. Hence, designing the incentive structure is critical to success and the system in England is now a block to the delivery of sustainable urban water management.

The next stage in urban water management in England should therefore present some positive lessons. It is not possible to undo water privatisation (except when as in the precursor to the current Welsh Water, the company effectively goes bankrupt). So, we will have to make the existing ownership pattern work, using the above principles and constraints, by introducing the appropriate incentive structure.

A clear lesson from the appended short history of water management in London is that a primary purpose of institutional change was to increase access to capital either or both by creating access or by providing a large enough revenue base to support the investment. This can be seen in Metropolitan Board of Works. In a different sense, it was a primary driver behind privatisation: shifting the debt from the public sector to the private sector, albeit at the cost of increasing the cost of capital servicing.

Appendix a short history of water management in London

The key to the early history of water management in London is that it was a country of a weak king or state whereas London was a strong city. Historically, the state didn't have any money but the cities had increasing wealth. Money was the basis for its power which they then turned into political power. The history of the nineteenth century is one of increasing municipal power which was then progressively eroded by the central government in the twentieth century, reaching its nadir when the Thatcher government abolished elected government for London. Thus, the state did not carry out 'great works' in London but it had to provide the institutional framework through which communities could provide the necessary services.

The development of water management in London followed the classic path of European cities. Initially, the provision of a limited water supply through conduits and water carriers (Flaxman and Jackson 2004); from 1245, the Great Conduit channelled water to the centre of the city (Keene 2001). By 1600, there were an estimated 20 conduits (Hardy 1984). Conduits appear to have been the preferred technology well into the C18th: the Royal palaces of Hampden Court and Greenwich were so supplied as was the subsequent development of the Hospital for Seamen at Greenwich.

Domestic water consumption must have been low because water was considered, and was, too dangerous to drink, weak beer being used for drinking instead. Washing both of the person and of clothing was also rare, clothes often being washed in the rivers. There are also signs that some rainwater harvesting was practised. Industrial wastes from tanneries, breweries, dairies and the like were deposed of to the watercourses, along with such solid waste as dead dogs and the like.

The second concern was with surface water drainage, Commissioners of Sewers could be appointed with a responsibility to ensure the effective drainage of areas in those areas where it was deemed necessary. The Bill of Sewers of 1531 making permanent what had been previous practice with an Act passed in 1427 and renewed at irregular intervals thereafter (Darlington 1970). The Commissioners of Sewers were nominated by the Lord Chancellor and either the Lord Treasurer or one of the Lords Chief Justice (Halliday 1999). The Commissions appointed for London were given wider powers than other Commissions, an Act of 1605 giving them powers of over all discharges to the river Thames within 2 miles of the City of London. This remit was further extended geographical by a further Act in 1690 (Darlington 1970). The geographical extent of the Commissions were extended again by an Act of 1807. That Act also officially permitted for the first time the connection of house drains to sewers provided that design and construction was approved by the Commissioners (Darlington 1970).

The last Commissioners of Sewers in England were not abolished until the Land Drainage Act 1930 although the eight which covered London had been replaced by the Metropolitan Board of Works in the mid-nineteenth century. These original sewers were only for surface water drainage, the discharge of foul wastes to them being strictly forbidden until 1807. Sanitation was provided through cesspits, or where there was a convenient watercourse, privies, the wastes being reused for various purposes. Chadwick estimated that in the 1840's there were some 200,000 cesspits in London (Halliday 1999).

However, at this time the primary importance of rivers was for power, fisheries, and navigation. Some 6000 water mills were listed in the Domesday Book (Newson 1997) and tidal mills were important on the Thames and its tributaries, supplemented by water mills on the river Lea (Keene 2001). Water power continued to be the primary source of industrial power well into the nineteenth century (Crafts and Mills 2004); in the nineteenth century there were an estimated 20,000 mills in operation in England. Rivers, notably the Lee were improved for navigation purposes well before the first purpose built canals were constructed (Rolt 1950).

What is seen until the nineteenth century is ad hoc local improvements promoted through private Acts of Parliament to provide navigation, Enclosure and associated drainage works, some water supply systems such as the New River in London (Ward 2003), and canals with their associated reservoirs (Rolt 1950). Importantly, well to the end of the nineteenth century, a large number of bills were private bills seeking the permission and the powers to take defined action in a particular location. Those permissions and powers included those to set up an organisation be it a company or a local board. The same was true of joint stock companies until the Acts of 1846 and 1856. There was no regulatory structure which could devolve such decisions to the government. The obvious result was a shotgun blast appearance of local legislation, each Act confirming different powers. Thus, in London there were some 300 bodies operating 250 local Acts with one parish, St Pancras, having 16 boards responsible for roads acting under 29 Acts (Midwinter 1968).

On the water supply side, a succession of local water companies to serve different districts of London as local monopolies were established, starting with the London Bridge Water Works in 1581 and From the C16th onwards, private companies were formed to provide water supply, essentially on the basis of local monopolies. The most famous was the New River Company, set up under Acts of 1606 and 1607 (Graham-Leigh 2000). This brought water 40 miles through an open channel to Islington (Ward 2003). These companies were able to provide only an intermittent, low pressure supply because water was distributed through pipes from bored out elm logs. Supply had to be intermittent and pressure low because otherwise the leakage rate would have left the streets permanently flooded. Thus, the Chelsea Water Company's slogan was: "water three times a week for three shillings a quarter" (Halliday 1999).

Flow was low, household connections being defined in terms of a quill, the tube part of a swan's feather, and available only to an underground tank. Higher pressures and hence higher flows and more continuous service only started to become possible with the adoption of iron pipes with satisfactory joints; the spigot and socket lead sealed joint being introduced in 1785 (Graham-Leigh 2000). The majority of companies obtained their supplies from the tidal Thames, close to the outfalls of sewers, and the water was put into supply without any treatment.

Thus, in the nineteenth century, water supply was provided by a mixture of private companies, wells and conduits; sanitation was provided by cesspits, and surface water drainage by sewers built and operated by the Commissioners of Sewers. By the 1670s, the population was already around 500,000; by 1760 it had reached an estimated three-quarters of a million; the first reliable census of 1801 recorded a population of 1.1 million. In 1860, the population had reached 3.2 million. By the early nineteenth century, the same time, WCs were starting to be adopted (Eveleigh 2008) which both significantly increased the demand for water and overloaded the cesspits used to store the waste products. Thus, in 1850 some 270,000 houses in London used an average of 160 gallons a day but this had grown to 244 gallons a day for 329,000 dwellings in 1856 (Halliday 1999).

The performance of the private water companies was widely criticised for both inadequate performance and for the high charges (Graham-Leigh 2000). In addition, this was a period of social reformers, including the sanitarian reformers lead by Chadwick (Halliday 1999), partly in response to the very high morbidity and mortality statistics for British cities. Sanitarian reformers were primary against dirt and for fresh air, the primary mechanism for disease transmission being seen as 'bad smells', the miasma theory of disease. Chadwick's 1842 Report on the Sanitary Conditions of the Labouring Population of Great Britain included the following recommendations (Cooper 2001):

- provision of water supply to every home
- use of WCs rather than either earth closets or privies
- discharge of domestic wastewater to sewers
- sewers to convey sewage to sewage farms

But in 1828, the then nine water companies were supplying 164,000 households out of a city of 200,000 dwellings and a population of 1.5 million (Hardy 1984).

At this point, there were essentially three parallel systems: for water supply, for surface water drainage, and for human wastes. With the adoption of water closets from the close of the eighteenth century onwards, the three systems began to collide. The adoption of the WC greatly increased the demand for water and made the continued use of cesspits impracticable when a WC was adopted.

The roots and origin of cholera are unclear (Hamblin 2009) but the second pandemic reached Europe in 1830, with London suffering its first major outbreak in 1831-32 with over 6,000 deaths, the largest number of deaths being recorded in the outbreak of 1848-49 (Halliday 1999). In spite of the work of John Snow and others (Johnson 2006), the miasma theory of disease transmission remained the primary theory. What Snow's work also shows is that wells remained a primary source of water supply for much of the city, Snow identifying the cause of the outbreak to the contamination of a well (Johnson 2006). He had previously analysed the incidence of cholera amongst two companies serving parts of London south of the Thames and showed a higher incidence of deaths amongst those supplied by the Southwark and Vauxhall water company than their neighbours supplied by the Lambeth water company; the latter having moved their intake upstream. It was not until the Koch and Pasteur essentially invented microbiology that the miasma theory of disease was finally laid to rest (Hamblin 2009) and it was not until about 1920 that the water supply was chlorinated (Hardy 1984).

Again, the formation of the Metropolitan Drinking Fountain and Cattle Trough Association in 1859 specifically to supply filtered water also demonstrates the lack of reach of piped water supplies (xxxx). In 1861, some 85 such fountains had been erected; 140 by 1870; and 500 by 1900.

The nineteenth century reform movement concentrated upon the provision of water and sewers through the municipalities (Best 1971; Hietala 1987; Taylor 2002). The Metropolitan Building Act 1844 now required all buildings to connected to the common sewer, completing the reversal of the historical prohibition of using sewers for other than the disposal of surface water. The Nuisances Removal and Diseases Prevention Act 1846 then enabled the Privy Council to make any regulations that might be necessary to prevent disease so enabling the Council to require properties to connect to the common sewer.

The 1848 Public Health Act allowed the creation, and in some cases required, the formation of local Boards of Public Health with the purpose of improving the sanitary condition of towns. Where one was established, it was required to clean the streets in its district, removing dust, ashes, rubbish, filth, dung and soil. The Boards were given responsibility for maintaining Public Sewers and allowed the provision of potable water supplies (Sellers 1997). Another Act, the Metropolitan Sewers Act, forbade the construction of houses without suitable drains and required them to be connected to a public sewer if there was one within one hundred feet. All new houses also had to be fitted with either a water or an earth closet (Halliday 1999).

It is outside of this paper to speculate upon why this transition took place but some general points can be suggested. The sanitarian model clearly shows the influence of the Age of Enlightenment emphasis on reason applied to understanding nature and the focus upon experimentation. Rubinstein (1983) develops the interesting argument that the driving force was Utilitarianism following from Jeremy Bentham (Chadwick being a noted follower of Bentham); the desire was 'efficient' social relationships, the application of reason to social relationships. In turn, he argues that the common stress on the laissez-faire was in turn only a means and not seen as an end in itself but only as a response to the 'Old Corruption' of central governments and the old aristocracy. In turn, the shift to municipalisation could then be seen as part of this attack on 'Old Corruption', local government having been reformed both as part of the Great Reform Act of 1832 and by The Municipal Corporations Act of 1835.

Secondly, an unequal society was confronted with diseases which refused to accept this inequality; for example, Prince Albert, the husband of Queen Victoria, is believed to have died of typhoid, contracted in the royal palace of Windsor Castle. Being rich or politically powerful did not reduce the risk of contracting disease, and cholera had a high mortality rate amongst the rich and poor alike. The miasma theory of disease was particularly equalising in its effect: if you could die from a bad smell, and those smells were carried by the wind, it was difficult to remove yourself from the risk. Finally, it was a time of political change; it is certainly an interesting coincidence that in 1848 when most of Europe was swept by revolution, England passed a Public Health Act.

At this time, very little was done about water pollution; the 1876 River Prevention of Pollution Act made some forms of polluting rivers a criminal offence; and the Thames Conservancy Board, and later the Lee Conservancy Board, were created (Kindersley 1988). But the sanitation boards created under the 1876 Act are held to have had very little effect (Woods 2006).

The Metropolis Water Act 1852 required that from August 1855 all water company intakes to be above the tidal reaches of the Thames and that by the end of that year, all water was to be filtered, using the slow sand filters first adopted by the Chelsea Water Company. But the rest of the century was one of constant complaints about the performance of the companies, and attempts at legislative reform which were blocked by the interests of the companies; the New River Company being, for example, to be the most profitable company in the world (Ward 2003). Only at the end of the century, with the Metropolis Water Act of 1902 which established a Metropolitan Water Board were the companies combined together into a single municipal water companies (Graham-Leigh 2000), the cost of buying out the companies being some £46.9 million (Falkus 1977).

It was the 'Great Stink', fermenting raw sewage in the Thames, of the summer of 1858 which made the Houses of Parliament almost uninhabitable that lead to the construction of Bazalgette's sewer network. Plans had been discussed for two years but arguments about the distance downstream before discharge and the cost implications of discharging far downstream had stopped a decision being made. Indeed, in June 1858, at the peak of the Great Stink, the Board voted to defer all consideration of plan until October. As a result, Parliament passed the Metropolis Local Management Amendment Act (1856) which in practice allowed the outfalls to be located at Beckton and Crossness rather than the 16 plus miles downstream that had previously been demanded (Halliday 1999). It also allowed the Board to raise up to £3 million by bonds or debentures against a scheme cost estimated at £2.1 to £2.4 million.

This great system of trunk sewers was constructed primarily to remove this dangerous smell, the miasma believed to cause cholera.. Equally, the required shift of the water intakes and the installation of slow sand filters as a result of the Metropolis Water Act of 1852 were the effective reasons for the subsequent reduction in the incidence of cholera; the 1848-49 outbreak resulting the most deaths, with progressively falling numbers of deaths in the outbreaks of 1853-54 and 1866. The provisions of the 1846 and 1848 Acts with regard to the connection to sewers must also have reduced the number of wells contaminated by sewage. So, benefits of Bazalgette's system were probably primarily aesthetic and Paris had already, from 1850 onwards, constructed a great system of sewers which can be regarded as a more sophisticated system than that adopted in London.

Perhaps, therefore, the greatest change effected by the Great Stink was that in governance. At that time, in addition to old City of London, local government for the rest of London's 2 million people was made up of 90 parishes (and similar units, including oddities such as the 'Liberties', such as the Liberty of the Savoy, which were administered by non-London bodies: the Liberty of the Savoy by the Duchy of Lancaster), and some 300 different boards created under 250 different Acts.

The 1848 Metropolitan Sewers Act amalgamated the existing eight London Commissions of Sewers into a single Metropolitan Commission of Sewers and extended the area covered by the Commission to a radius of 12 miles around St Paul's cathedral (but notably exempted the City of London itself). In the six years of the existence of the Commission, it succeeded in eliminating 30,000 cesspits and channelling all house and street refuse to the Thames, albeit at the cost of sewage flooding house basements in the time of rainstorms. Importantly, the Commission arranged for a detailed map of all existing drains and sewers as well inviting proposals for a strategic sewerage system.

The Metropolis Local Management Act 1855 left the parishes responsible for building and maintaining local sewers but created Metropolitan Board of Works with the power to build interceptor sewers and levy a property tax for that purpose. The members of the Board were elected by the councils of the parishes covered by the Act. However, all plans for interceptor sewers by the Board had to be approved by the government (Commissioners of Her Majesty's Works and Public Buildings). The Board had other responsibilities in addition to sewers including the paving of streets (Halliday 1999). As outlined earlier, after some tribulations, it was the Board and Bazalgette who finally built the interceptor sewer network.

Bazalgette's sewers discharged downstream of London at Beckton on the north bank of the Thames and Crossness at the south bank. As with other cities, the drive in the nineteenth century was to reuse sewage either directly through sewage farms or indirectly through selling the manure (Sheail 1996). As late as 1904, some 45,000 tons of manure were being shipped from Paddington canal basin to Hertfordshire farms but the introduction of guano in 1847 resulted in a collapse in price for human waste (Halliday 1999).

Consideration of receiving water quality was a much later concern, and also depended upon the development of the appropriate technology. Until the end of the nineteenth century, techniques to remove pollutants were simply not available; salmon disappeared from the Thames in 1833 (Halliday 1999), along with most of the fishery.

Early treatment was limited to settlement, the Imhoff tank being invented in 1906, with biological treatment only appearing at the end of the nineteenth century. Biological treatment was only developed from 1890 onwards (Cooper 2001), and its use rapidly expanded in the UK between 1890 and 1910. However, the Rivers Pollution Prevention Act 1876 had sought to reduce river pollution, banning the discharge of solid waste to rivers, including sewage, it was almost wholly ineffective (Hardy 1984). The Local Government Act 1888 sought to remedy that by giving powers to the County Councils to enforce the 1876 Act – the municipalities being primary polluters and the powers under the 1876 Act being inadequate (Robinson 1894).

The Royal Commission on Metropolitan Sewage Disposal of 1882 recommended that the discharge of raw sewage to the river should cease. At least as late as 1869, it was believed that the tidal movement of the river provided sufficient self-purification (Hardy 1984). Chemical precipitation of solids was introduced at Beckton and Crossness between 1887-89 (Doxat 1977). But Crossness has only chemical treatment until 1920 when three experimental biological plants were installed whilst in 1928 an activated sludge plant was installed at the Beckton outfall with a capacity of 10 million gallons a day. Work was in progress to expand the Beckton activated sludge capacity to 60 million gallons a day at the time war broke out in 1939 (Doxat 1977). Activated sludge treatment, now defined as 'secondary treatment' had only developed in 1913; and the Mogden plant in west London was the first activated sludge treatment works in the city to be built from scratch. Effective denitrification techniques were only developed in the 1960s and for phosphorus removal in the 1970s (Cooper 2001). At this time, the river Thames was effectively biologically dead (Doxat 1977).

This new series of duties on the municipalities and on boards had to be funded. This was only possible by massive borrowing and thus the creation of mechanisms by which borrowing could be undertaken. Municipal financial instruments, given a property tax basis for revenue, are attractive to the fixed income investor. Wilson (1997) quotes research as having shown that capital investment by the municipalities made up over 95% of all public investment in the country and between 13 and 19% of all investment in the UK. Thus debt rose quickly, particularly from the 1870s onwards, rising from £84.2 million in 1874 to £652.6 million in 1914 (Wilson 1997). Falkus (1977) reports that in 1914-15, the total outstanding debt for water was £131.9 million. The growth after 1874 is ascribed by Wilson to improvements in the capital markets. Thus, the Metropolitan Board of Works, responsible for amongst other things the construction of the sewer network, had borrowed over £8 million. Wilson stresses the attempts by the Treasury, the ministry of finance, to control and limit the municipalities access to the capital markets, a constant preoccupation of finance ministries being to stop anyone spending any money. At the same time, as everywhere in Europe, municipalities were expanding into providing basic infrastructure in the form of docks and harbour, gas and electricity, and tramways (Hietala 1987).

Bazalgette's trunk sewer scheme was thus paid for by an initial loan of £3 million, to be repaid over 40 years by a rate of 1.25p per £1 property value. In 1863, the Board was given the power to raise a further £1.2 million on the same basis as the original loan (Halliday 1999). What this also illustrates is the capital requirement needed to provide what was then a modern water and sanitation system. Falkus (1977) notes that in terms of capitalisation, some municipal water companies ranked amongst the largest ten firms in the UK, and that the total capitalisation of the 50 largest companies in the UK was, in 1905, approximately the same as the total borrowing of municipalities to provide water, sanitation, gas, electricity and tramways. There are then arguments as to whether the capital requirements of expanding these services diverted capital away from industry and commerce and contributed to the UK's relative economic decline.

Most of this borrowing was done on the commercial money market but the government's Public Works Loan Commissioners were a source of limited financing, particularly after the 1863 Public Works (Manufacturing Districts) Act. Loans so raised increased from £11 million over the period 1848 to 1870 to £84 million for the period 1871-1897 (Jenson 2008).

One way of going around the Treasury's restrictions on borrowing was to promote an Act of Parliament. This was still the time when probably the majority of Acts of Parliament were private Acts, promoted by companies or municipalities, rather than government Bills. Thus, Wilson reports that over 50% of all capital raised was obtained on the basis of private Acts. For example, following the formation of the Metropolitan Water Board, it raised £32.2 million.

The key legislation over the later nineteenth century as it affected London is summarised in **Table 6**. Perhaps because London was the capital or perhaps because it had so much larger a population than any other population centre, many of the legislative provisions that were adopted across the country were first applied in London.

Table 6 Key legislation of the nineteenth century

Date	Act	Area to which applied[49]	Key provisions
1844	Metropolitan Building Act	London	Required all new buildings to be connected to the common sewer

[49] The geographical specification of what constituted London varied from Act to Act.

1844	Joint Stock Act	nation	Removed the restriction that joint stock companies could only be created by a private Act of Parliament or by a Royal Warrant
1846	Nuisances Removal and Diseases Prevention Act	nation	Created powers for requiring existing properties connect to the common sewer
1847	Waterworks Clauses Act	nation	Fixed methods of charging; required the supply of water for reasonable purposes including fire-fighting. Required the consumer to provide cistern and ensure that water was not wasted. Limited the return allowed to shareholders
1848	*Public Health Act*	*nation*	*Created local Boards of Public Health with the responsibility of maintaining Public Sewers and with the power to provide water BUT excluded London*
1848	Metropolitan Sewers Act	London	Amalgamated the existing eight London Commissions of Sewers into a single Metropolitan Commission of Sewers
1852	Metropolis Water Act	London	Required water intakes to be above tidal reaches of the Thames and the use of slow sand filters
1855	Metropolis Local Management Act	London	Created Metropolitan Board of Works with the power to build interceptor sewers and levy a property tax for that purpose.
1856	Public Health Act	nation	Extended the scope for municipalities to borrow money
1856	Joint Stock Act	nation	Set up a simplified system for registering the creation of a joint stock company
1863	Public Works (Manufacturing Districts) Act	nation	Extended scope of borrowing by municipalities from the Public Works Loan Commissioners
1871	Metropolis Water Act	London	Gave the metropolitan authority power to require the constant supply of water
1876	Rivers Pollution Prevention Act	nation	Made polluting rivers a criminal offence and created Sanitation

			Boards to manage wastewater treatment
1888	Local Government Act	nation	Created county councils and specifically the London County Council which took over the roles of the Metropolitan Board of Works Gave the county councils powers to enforce 1876 Act.
1902	Metropolis Water Act	London	Set up the Metropolitan Water Board, taking over the assets of the existing private companies

Flooding only seems to have become an issue in London in 1928 when a tidal surge flooded a number of river front properties. This generated the very long process which ended with the construction of the Thames Barrier from 1974-1984 (Gilbert and Horner1984). It is probable that the progressive canalisation of the Thames from the Roman period onwards increased the risk of flooding but there must have been tidal floods before 1929 but these were clearly nothing like as traumatic for the city as the cholera outbreaks of the mid-nineteenth century, let alone the Great Fire of London.

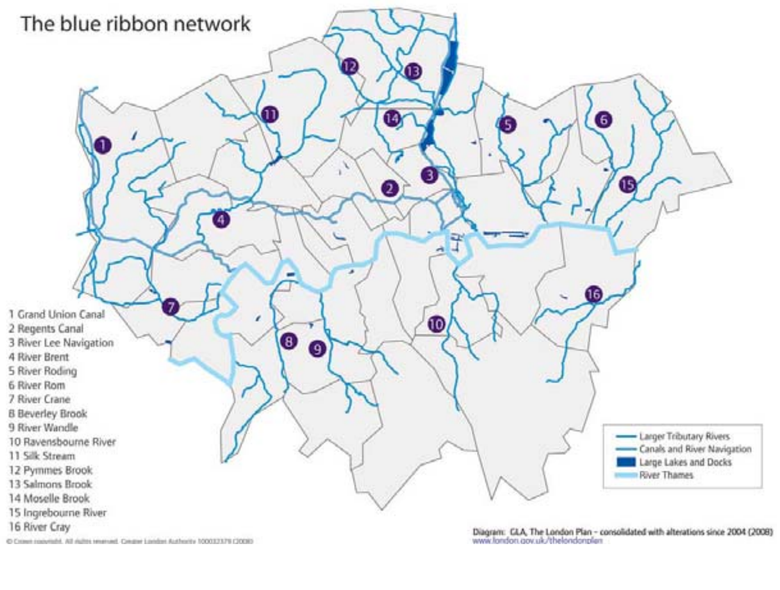
Fluvial flooding does not seem to have been a particular concern at any point prior to the twentieth century for a number of reasons. Firstly, until comparatively recently it was the risk to agriculture that was the focus of flood risk management. The Medway Letter of 1933 (www.wlma.org.uk/uploads/medway/letter.pdf) which set out the basis of flood risk management for the next fifty years or so is quite dismissive about the effect of floods on urban areas. More generally, in comparison to the other risks which had to be faced, flooding was probably seen as a relatively minor problem. Secondly, the nineteenth century provision of parks was reduced the likelihood that the expanding development in the outer areas of London would be on flood plains. Thirdly, most of the tributaries of the Thames are no more than streams and so flooding was limited in extent. The one major exception is the river Lee where extensive flood protection works were undertaken after the flooding of 1947 and completed in 1976, and this exception may be explained by both the relative size of the river and its importance as an industrial area, notably for the armaments industry. For example, the Royal Ordnance Factory was the producer of the Enfield rifle which was the basic infantry weapon of the British Army for over half a century.

More recently, the risk of pluvial flooding has come into focus. Certainly, that existed from the nineteenth century onwards, some areas of London being notoriously prone to such flooding. However, it is only in the last five years that it has been recognised as a problem (Pitt Review 2008). So far there has not been any major flooding of underground installations such as the underground railway system (although that has been significantly flood proofed) and shopping areas, certainly nothing comparable to the experience in Japan.

In relative economic terms, the UK has been steadily declining since the middle of the nineteenth century when it was the largest economy in the world in nearly all senses. That decline has centred upon the decline in industry, the industry having declined particularly markedly in London. Hence, concerns with promoting socio-economic regeneration have coincided with the availability of large areas of brownfield land of former industrial development. The extent of that brownfield land has been increased by the technological obsolescence and hence replacement elsewhere of the nineteenth century industrial activities that used to occupy that land. In London, large areas of brownfield land became available with the shift out of coal based gasworks, the move to container shipping and thus the requirement for both very large ships and large areas for container parking, and the reduction in the armaments industry – at its peak, the former Woolwich arsenal employed 80,000 people. That brownfield land was differentially located by navigable water, either canals or rivers converted for navigation, or by the Thames.

Socio-economic regeneration has focused in recent years on environmental improvements and because of the frequent close proximity of brownfield sites to rivers and particularly canals and docks. A particular advantage of redevelopment around canals and navigable rivers has been the existence of a towpath and thus public access. Thus, apart from the various dockland developments, major developments have taken place on and around such sites as Paddington Basin. Equally, signed walks have been established along many of the rivers or using the parks located along the rivers (www.walklondon.org.uk). The London Plan now is adopting the 'Blue Ribbon Network' (London Assembly 2006) as a central strategic principle for socio-economic regeneration in London.

Figure 17



River restoration activities started in the UK in the early 1990s with the river Skerne and Cole demonstration projects (Vivash and Biggs 1994). Some sixty, largely small scale, river restoration schemes have now been completed in London on both tidal and fluvial river sections (The River Restoration Centre 2009).

Part of the nineteenth century public health reform programme was the need for fresh air and thus parks, together with the later emphasis on the necessity of playing fields to support the sport seen as necessary to improve the health of the age groups who would, if necessary, form the basis of armies. Both parks and playing fields differentially located to flood plains. Thirdly, the fall back option for brownfield sites has been to create public open space. For example, east of the city is the Lee Valley Park, much of which is based around former industrial sites including gravel workings.

What is noticeable about this short history is the constant interplay of technology and governance. Similarly, until there is a possible technological solution, there may be a problem but there is not a choice to be made. Until there were iron pipes and good joints plus steam power, only intermittent, low pressure water supply was possible. Equally, until the different techniques of primary, secondary and tertiary treatment of wastewater were invented then the only feasible method of treating sewage was via a sewage farm and where that was impractical, to discharge it to the tidal estuary.

That technology is to some extent an expression of scientific knowledge, although early engineering was pragmatically based. Hamblin (1990) demonstrates that chemistry was the only discipline involved in assessing water quality over most of the nineteenth century, and the limitations of such a focus upon what could be determined through chemical analysis. Moreover, as Johnson (2006) shows John Snow's alternative epidemiological approach (his "On the Mode of Communication of Cholera" was first published in 1849 and an extended version covering the famous Broad Street pump cholera episode in 1855) was not an instant bolt of knowledge that overnight transformed the paradigm. It was instead largely ignored. Thus knowledge was contested as it is now. A transformation in understanding waited until the microbiological innovations created by Koch and Pasteur (Hardy 1984).

Secondly, some of the approaches adopted were either lucky or instinctively right: both slow sand filters and Balzagette's sewer system were built whilst the predominant mode of disease transmission was believed to be bad air and sand filters happened to be effective at removing bacteria as well as the suspended solids which was their intended purpose.

In turn, technology forced changes in governance: Bazalgette's trunk sewer system could not have been built under the previous system of eight Commissions of Sewers. Nor equally without the adoption of a system whereby municipal bodies could borrow money for investment could the capital have been raised. More widely, looking over this history, a generalisation that might be made is that the history of water management in London is about how to raise the capital necessary for works. A history that runs from the sale of privileges to foreign merchants to raise money for the construction of the Great Conduit, through the legal monopolies that enabled the private water companies and the loan by the King to half fund the New River Company, to the invention of joint stock companies and a municipal bond market in the nineteenth century. In considering the history of water management in London (and indeed England) it is necessary to remember that the state had very little money: even as late as 1911, only 11% of national income was collected by the state (Wilson et al 1993). Hence, intervention by central government was necessarily very limited.

Further, there was a struggle to find the right institutional framework through which water and sewerage services could be delivered; this is illustrated by the torrent of Acts in the 1840s and 1850s (**Table 6**) where institutional structures are constantly being revised.

Again, the role of private companies in water supply, they had no role in the waste and surface water management, was always contentious and over most of the nineteenth century involved both battles to regulate them and to replace them with a municipally managed system as happened elsewhere in the country. It has also to be recognised that until the 1856 Joint Stock Act, there was no simple institutional framework through which to set up a joint stock company, an inhibiting factor.

In London, the final driver for the change to municipalisation was the problem of poor water supplies for fire fighting (Hardy 1984). By 1903 when the Metropolitan Water Board was created, municipalisation had occurred over most of the rest of the country, with, in practice, major improvements in the quality of service provided and the control of costs (Hassan 1985).

There is then an historical pattern of emphasis, crudely:

- Water supply
- Surface water
- Wastewater collection
- Wastewater treatment
- Flood risk management
- Socio-economic regeneration
- Sustainable water management

That historical pattern was determined by the development of technology and scientific knowledge, together with the interplay with crises, notably the successive outbreaks of cholera from 1832 onwards. Again, the sinking of the pleasure steamer ‘Princess Alice’ with the death of over 500 people, and the attributed of some of those deaths to the sinking off the main Beckton sewer outfall and death of those passengers in raw sewage has been ascribed as a driver to the introduction of primary sewage treatment – then the only form available.

Finally, what is noticeable about the development of water management in London was how long it took, roughly 100 years, and how difficult it was to achieve a recognisable modern system of water management. This first transition has lessons the ongoing transition to sustainable water management. Looking at the earlier transition, there are a number of parallels. Firstly, there were a lot of champions most noticeable Chadwick, an example which shows both success and also how not to go about championing since he upset a great many people for little purpose. Equally, there were champions who failed; the Rev. Moule and his support for earth closets rather than water closets (Eveleigh 2008) being the exemplar. Chadwick also created supporting organisations and used all available means of spreading his message, including the media. The use of the 'never waste a crisis' approach was what enabled the final implementation of a sewerage scheme and the 'Princess Alice' disaster was used to promote the treatment of wastewater. Similarly, the cholera outbreaks were used to get both the water intakes moved and the introduction of slow sand filtering mandated. It was also the time of the mass growth of NGOs, it was perhaps the peak of what is now termed 'civic society' and a whole variety of NGOs were active in promoting sanitation; for example, the Metropolitan Sanitary Association founded in 1849 and the Social Science Association. The coupling of 'filth' and morality to health was a powerful message to induce change: it was difficult to be either for filth or against health. Similarly, now being against waste and for sustainable development is a coupled argument that is being deployed effectively. As then, scientific opinion is commonly employed by government; in the nineteenth century there were nearly as many Royal Commissions to hear and collect scientific evidence as there were Acts of Parliament. To-day, the same approach is evident both in standing advisory groups such as the Sustainable Development Commission but also in ad-hoc inquiries such as the Pitt, Walker and Cave reports. Finally, the water industry then was largely an obstacle to achieving what we now term the Millennium Development Goals. The solution then was to municipalise the industry; the solution now will be to introduce the appropriate incentives to the industry. It is noticeable too how exactly the same arguments about service standards and the return to capital were played out in the nineteenth century as we see today. Then the perceived impropriety of allowing a private company to levy what is in effect a tax, a charge for water services based upon the value of a property, lead to the conclusion that water services should be provided by the municipalities. Now it is used to argue for water metering.

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