Thames Tideway

Measures to protect the river environment from the adverse effects of waste water discharges

with Addenda 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 &11.

by

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Executive summary

Central London has a **combined sewer system** which, in 2000, had 57 overflows which spilled into the Thames up to 50 times a year causing aesthetic, environmental and health impacts.

The **Urban Waste Water Treatment Directive's** aim is to protect the environment from the adverse effects of waste water discharges. The Tideway was required to meet the requirements by 2000.

The **Thames Tideway Strategy Steering Group** studied the Tideway from 2000 to 2005. There are no specific numeric standards in the UWWTD so the TTSS came up with three objectives specifically focussed on the Tideway covering aesthetics, environment and health. Based on the information available then, the TTSS proposed that, to meet these objectives, three sewage treatment works be upgraded and a storage/conveyance tunnel be constructed from Hammersmith to Beckton STW at a cost of £1.7bn for the tunnel. The total cost of the tunnels has now risen to a total of about £4.8bn.

The **current works of upgrades** to the Tideway sewage treatment works and the Lee tunnel, will reduce the volume of spill from the current about 39 Mm3/year to about 18 Mm3/year, much reduce the number of dissolved oxygen failures, and has much reduced the spills from Mogden STW which was primarily responsible for the fish kills in 2004 and 2011 in the Kew/Chiswick area.

The TTSS **aesthetic objective** is to limit the pollution caused to the point where it ceases to have a significant adverse impact. The EA classified 36 CSOs as unsatisfactory. However the assessment is subjective and has no aesthetics data to support it. The defra criterion for classifying CSOs as unsatisfactory is "*historic justified public complaints*". The EA reported that there were "*few formal complaints"* from the public about aesthetics. Now two litter collectors are working, Mogden STW discharges have much reduced, and the Lee tunnel will more than halve the remaining discharges. Thus post Lee tunnel, about 2014, it would appear that the aesthetics objectives may well be met.

If appropriate, discharge of sewage debris in the river could be reduced yet further by installing **booms** around most of the CSO outlets covering some ¾ of the spill volume. The retained debris can be collected. The existing skimmers and new oil skimmers could be used in the river to collect that which escapes or where booms cannot be fitted.

The TTSS **ecological objective** is to have a sustainable fish population. Fish are considered the most sensitive ecological species and dissolved oxygen (DO) standards have been set, based on fish trials. The current works of the improvements to the sewage treatment works, and the Lee tunnel, go a long way towards reaching the DO standards. Evidence from the 28th May 2013 spill at Mogden STW indicates the upper Tideway is now sustainable for fish. The Environment Agency (EA) has provided a schedule of recorded fish kills in the Tideway for the last 10 years. Compared with the modelled 24 there were only 3 fish kills casting doubt on the reliability of the models. From the Tideway CSOs there was only one recorded fish killed. Thus, post the Lee tunnel, it would appear that the objective of a sustainable fish population will be met. The existing mobile bubbler boats would supplement the fixed system where necessary.

The Tideway is used by rowers and sailors for **recreation**. The TTSS recreation objective was to substantially reduce the number of elevated health risk days. The Tideway is not a designated bathing water and is not subject to the Bathing Water Directive. For navigation reasons, the PLA has recently banned bathing in the Tideway except with a special licence. The HPA carried out an analysis of the illness of rowers in the upper Tideway. This showed that the rowers were ten times less likely to get gastric problems than the general public. Standard Quality Adjusted Life Year (QALY) analysis shows that it would only be worthwhile **spending a maximum of £1.5million** to deal with the gastric problems of the rowers.

Since then Thames Water (TW) have upgraded the **Mogden STW,** where spills have reduced from about 110 a year to about 20 smaller ones, have much improved water quality in the Mogden/Hammersmith stretch of the Tideway where there are many rowers. A warning system has been provided to warn rowers in the Upper Tideway when CSO spills occur.

Thus it would appear that, when the Lee tunnel is completed about 2015, the **current works** will meet the three TTSS objectives set to meet the UWWTD objective to protect from adverse effects.

If thought appropriate, **further mitigation measures,** including booms around most of the higher spilling CSOs, in river aeration, oil skimmers, and treatment of the top up water to the docks could be used to improve conditions further in the next two to three years at a cost of about £20m.

The European Commission has taken the United Kingdom to **European Court** as it considered that the collecting systems spilled more often than "*unusual conditions*" as set out in Annex 1(A) of the Directive 97/271 (UWWTD). The Court ruled in October 2012 that this was so, and that the UK had not established disproportionate (excessive) cost as it had decided to implement the tunnel, and thus that the United Kingdom had failed to fulfil its obligations under the directive. However the Court did not rule that the tunnel be adopted, merely that an appropriate solution be adopted.

The Environment Agency appears to assume that about 10 spills a year would be the limit. During the infraction proceedings the European Commission proposed, and the Advocate General agreed, that a **spill frequency of up to 20 spills a year would be acceptable**. Thus the EA assumption should be changed. The upgraded Mogden STW has already spilled 20 times in 10 months, a spill frequency of about 20 spills a year, with no adverse impact on fish, as confirmed by the EA. Thus the EA does appear already to have approved a spill frequency of about 20 spills a year in the Tideway.

TW assumed in its sewer model analysis that **sewer flows would increase** with increasing population and constant per capita demand. The increase from the base date of the calculations of 2006 to 2035 , based on the histogram provided, is some 270 Ml/d. However the TW WRMPs show that water supplied is projected to decrease by some 100Ml/d. This is a reduction of nearly 20% on the sewer dry weather flow assumed by TW, thus reducing the spill frequency , not increasing it.

At the time of the TTSS, 2003, there was limited information about **sustainable urban drainage systems** and there was very limited experience of how well they worked. Thus the TTSS was unable to recommend them as a viable solution to meet a European Directive.

A pilot study of **Sustainable Drainage System** (SuDS) was carried out in the **Putney** area in 2009 and Appendix E to the Needs report showed that spills would be 10 /year or more. SuDS here were therefore rejected. However the sewer model was subsequently corrected by Thames Water but the Putney analysis has not been redone. However it would appear that the spill frequency with 50% SuDS would be below the EC 20 spills a year, within the EC limit. Further, although there are significant areas of terrace gravel in the Putney area, the study team was instructed by TW that "*infiltration was deemed not viable*". Thus, with infiltration, the spill frequency would be lower still.

The EA assessment of SuDS says that the scope for **infiltration** in the London sewer catchment is limited. The Bloomberg report, based on the BGS data, states that 67% of the area could be developed for infiltration, subject to some technical adjustments and bespoke measures. The Hammersmith Borough is claimed by the EA to only have 2% suitable for SuDS but the Farm Lane area is shown by BGS to be have high permeability but to suffer from a groundwater level less than 3m below the surface. However SuDS can be done with less than 3m of terrace gravel. Geotechnical investigation in Farm Lane, Fulham, has shown no water table within 3m of the surface from December 2010 to August 2011. Thus there would seem likely to be reasonable expectation that

infiltration, albeit with special measures in some areas, would be possible within about 2/3rd of the sewerage area.

The **TW 2010 sewer model** was run for London with 50% impermeable area eliminated. This showed excessive spill frequency. However the model was based on increasing sewer flows and assumed no infiltration and is therefore pessimistic and should be run again using appropriate conditions.

Anyway flow in the sewer interceptors could be reduced by various methods including reducing the amount of **water entering the sewers** by connecting part of the sewerage system to another STW, Mogden or Hogsmill, or to the existing Thames/Lee water transfer tunnel.

The implementation of widespread **SuDs and BGI** would also increasingly reduce storm flows from entering the sewers.

Whereas total separation of the sewer system would be uneconomic and very disruptive, there appears to be significant scope for local **separation** of the sewers, particularly of developments along the Thames and other local rivers, as well as areas where the sewers are already largely separate.

Remaining spills from the sewers into the Tideway could be reduced further by **removing restrictions** in the sewer system, increasing pumping capacity at the STWs and implementing **real time controls/active system controls** and **detention** tanks. The Environment Agency requires active system control to be considered for all schemes but it hasn't been.

The WFD requirement is to make judgements about the most cost-effective **combination of measures**. Whilst a number of studies have been done by TW about how well individual measures would work and how much they would cost, I have been unable to identify any study about how a combination of measures would work for London and how much that would cost.

The Commission has since stressed in its policy Communication the importance of **Green Infrastructure**. It would be open for the UK government to discuss such an approach for London with the Commission

Defra **Cost Benefit Assessment** 2011 study claimed a benefit of some £4bn to £5bn. My then unchallenged assessment of the report and was that the benefit should be £290m, now £180m. However, with only one fish killed and fish sustainable post Lee tunnel the benefit reduces to £180m.

Considering the high cost of the tunnel at £4.1bn in 2011 prices, and the increase in customer bills throughout the Thames valley of about £80/household/year, then the alternatives of SuDS, infiltration, real time control, detention tanks, sewer separation, and other associated measures, along with corrected model data, should be **studied** to check if a **combination of such measures** could meet the required spill frequency. This should be done independently and positively.

To check **resilience** TW have projected conditions in the Tideway to 2080, increasing sewer dry weather flow and water temperature, reducing river flow, changing rainfall and ignoring SuDs. The extent of these is challenged and they should be reconsidered.

if found to be appropriate, such an approach should be discussed with the **European Commission** with a view to being implemented. This could result in a major reduction in expenditure at a time of difficult economic circumstances, along with reduced future customer bills in the Thames Valley.

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1.Introduction

Almost all modern urban conurbations have separate drainage systems for foul water and storm water. However, for historical reasons, Central London, loosely from Hammersmith in the west to Greenwich and the Lee valley in the east, has a sewerage system which combines both foul and storm water into one sewer pipe. This led to very serious pollution of the River Thames through London. In the 1860s a series of interceptors were built running parallel with the river to convey the combined sewage to treatment works and discharge points at Beckton and Crossness, downstream of London. However these interceptors, although large, had a finite capacity and the system was designed so that in the event of a medium sized storm , the interceptors would over flow into the River Thames through combined sewer overflows. Since then London has become more built up and the roads have changed from cobbles to tarmac, thus increasing the peak storm runoff. There are some 57 combined sewer overflows in the system, and under the current arrangement some of the CSOs spill into the Thames about 50 times a year. These spills have resulted in some impact on aesthetics conditions, reduced dissolved oxygen conditions for fish, and affected some health conditions for recreation.

The Thames Tideway through London was required to meet the Urban Waste Water Treatment Directive (UWWTD), whose aim is to protect the environment from the adverse effects of waste water discharges, by 2000.

The Tideway was studied by the Thames Tideway Strategy Steering Group (TTSSG). This group was composed of senior representatives from defra, Thames Water, Environment Agency, Greater London Authority, and ofwat in observer status, with myself as the independent chairman. The work started in 2000. Objectives for ecology, aesthetics, and health impact have been set for the Tideway as set out in the Thames Tideway Strategy Steering Group (TTSS) 2005 report.

The alternatives studied were limited to those that were sufficiently known at the time. This included (Environmental statement; Non-Technical Summary doc 6.1 page 3-1).

a whole new sewer network, very expensive but meant near zero sewer spills so beyond the UWWTD requirement.

Sustainable drainage systems to reduce rainwater entering the drainage systems. Experience was very limited, disruption significant, and such a system would take many years to implement fully, so it was not then supportable.

Screens, not a satisfactory system as they do not give secondary treatment.

No consideration was given to real time control/active system control, partial separation where economic, booms, or of a combination of measures.

The TTSSG reported in 2005 that, based on information available at that time, the optimum solution was a tunnel from Hammersmith to Beckton and Crossness STWs at a cost of £1.7bn. The Thames Tideway Tunnel would achieve reduce spills to about 4 spills a year.

The cost of the tunnel has now escalated to about £4.2bn for the section from Hammersmith to Abbey Mills and about £0.6bn for the Lee tunnel from Abbey Mills to Beckton, a total of £4.8bn at 2011 prices.

The tunnel would increase the charges to Thames Water's sewage customers, ie almost all those in the Thames Valley catchment, by some £80/household/year. This sits uncomfortably with the government Water White Paper published in December 2011 " *to protect poorer households."*

The Thames Tideway Tunnel was selected by Government in 2007 but the tunnel cannot be operational until about 2023. However the European Commission has taken out infraction proceedings against the UK for not having implemented measures to meet the Directive. In 2012 the European Court found against the UK on the Thames Tideway, see Appendix D for a review of the judgment. Thus it is possible that infraction fines could be imposed for late compliance. I am advised that they would be based partly on the *"Environmental impact of non-compliance* " and partly on the length of time between the date for completion assumed by the Commission and the environmental impact being deemed satisfactory. Presumably this would be when the Thames Tideway tunnel becomes operational or any other system reaches a satisfactory situation. My information is that these fines could be substantial. Based on the tunnel becoming operational in 2023 possibly as high as Euros 1.5bn.

This report considers the objectives to be met in the Tideway as set by various Directives and the TTSS. It considers the extent to which the existing STW upgrades and Lee tunnel contribute towards meeting the objectives, and the more recent information which, in several instances, supersedes the analyses on which several key decisions were based, making those decisions flawed. These updates appear to have been ignored in several other reports.

The TTSS was only able to consider measures that were available at that time, effectively 2003. There is much recent experience in certain of these measures such as SuDS and real time control. However there is no report that I have been able to find that considers a combination of all the measures that are now available and whether they can meet the objectives for the Tideway at significantly lower cost.

On the supposition that the tunnel will be built, then it would not be operational until about 2023. This report also looks at ways that the "*environmental impact of non-compliance*" could be reduced during the interim period until the tunnel is operational. These would be relatively cheap and quick to implement. After completion about 2023 the tunnel would still spill several times a year and these measures, such as the booms, could also provide long term benefit. In addition measures which reduce the sewer flows in the interceptors would reduce the volume of spill into the tunnel and hence reduce the energy and cost in pumping out the tunnel, as well as reduce the operational CO2 emissions.

I have discussed this report in early draft and later draft form with the Environment Agency and in working draft form three times with Thames Water and have adapted it according to their comments. However Thames Water and the Environment Agency have declined to do the analyses as to how a combination of measures could be adopted to reduce the environmental impact of waste water spills.

After completion of the October 2013 edition of this report, on 23rd October 2013 I was passed the Environment Agency report "An assessment of evidence on sustainable Drainage systems and the Thames tideway Standards." October 2013. I prepared a Response to that dated 30th October 2013. However this resulted in new information becoming available which I have now incorporated into this report. This includes information about the robustness of the Appendix E analysis (the key parts of which appear to be inaccurate and flawed), real time control which has been found to be beneficial elsewhere and sewer separation.

2. Objectives to be met

Urban Waste Water Treatment Directive

The objective of the Urban Waste Water Treatment Directive (UWWTD) in Article 1 is "*to protect the environment from the adverse effects of the above mentioned waste water discharges."* The UWWTD makes no reference to any actual level of protection or any numerical standards.

In Annex 1 section D para 5 footnote 1 it says *"Given that it is not possible in practice to construct collecting systems and treatment plants in a way such that all waste water can be treated during situations such as unusually heavy rainfall,"* Thus the UWWTD accepts that collecting systems can overflow during unusual rainfall events. However nowhere in the UWWTD does it specify what "*unusually*" means.

Note also that the Water Framework Directive which is viewed as "umbrella" water legislation was passed into law after the UWWTD and requires a more thoughtful approach to protection of the water environment than just setting an arbitrary number of CSO spills.

The footnote continues " *Member states shall decide on measures to limit pollution from storm water overflows. Such measures could be based on dilution rates or capacity in relation to dry weather flow, or could specify a certain acceptable number of overflows per year."* Thus it would appear to be open to Member States to choose the criteria to limit the pollution.

Thames Tideway Strategy Steering Group objectives

The UWWTD does not take account of the quality or size of the discharge water, for instance whether it is almost entirely sewage or almost entirely rainwater derived stormwater, or of the size or quality of the receiving water, whether it is a small stream or an ocean. Thus the TTSS decided to set specific objectives for the Tideway to achieve. The broad aspirational aim is to work towards "*To reduce the impact of intermittent sewage discharges, and to further improve water quality in the Thames tideway, to benefit the ecosystem and facilitate use and enjoyment of the river."*, Steering Group report February 2005. Page 19.

Spill frequency criterion.

There is no specific spill frequency in the UWWTD.

The TTSSG was advised by defra in the Working Paper of March 2004. Para 28 (iv) "*For those operating in conditions less severe than storm or unusually heavy rainfall, the appropriate solution must stop the discharges from occurring in such conditions unless they are not having an adverse effect on the Tideway"*

The EA report An assessment of evidence on Sustainable Drainage Systems and the Thames Tideway standards October 2013 states on page 9 about the TTSS objectives "*A target of 4 spills a year was set to meet the ecological, aesthetic and health risk objectives."* I, as Chairman of the TTSS, have no recollection of such a target being set. The TTSS Steering Group Report 2005 page 20 states the spill should not be more than several times a year. No number is set out in any TTSS report that I can find. My memory is that TTSS was guided towards 6 to 8 spills a year based on what was thought at that time to be the general approach in Europe.

Further, my memory is that the 4 spills a year, which is what the tunnel is designed to achieve, was based on engineering and cost, if one was going to have a tunnel then that would have been a

sensible size to have it, the cost of the tunnel being of limited extra cost to achieve a higher standard. Thus, whilst the tunnel meets the UWWTD, it cannot set the standard of spills to be met.

The Environment Agency in its report An assessment of evidence on Sustainable Drainage systems and the Thames Tideway Standards October 2013 on page 14 mentions "*10 spills per typical year*", but makes no mention of any specific requirement.

The European Commission Additional Reasoned Opinion dated 27/11/2008 states in clause 21 "*Assessing this information"* about spill frequency in other countries *" also in the light of developments since the Directive has come into force, the Commission would conclude that an acceptable spill frequency taking into account best available knowledge not entailing excessive cost cover a* ***range of up to 20 spills per year*** *taking place at times of heavy rainfall with a varied spill frequency depending on local situations and in particular the status of the receiving waters in each case*." My emboldenment.

However the Advocate General's Opinion of the infraction proceedings, January 2012, states in para 48 "*On several occasions, however, both in the pre-litigation stage and before the Court, the Commission did indicate that, as a rule, exceeding* ***the limit of 20 overflows a year*** *would be a cause for concern, suggesting a possible failure to fulfil obligations. Despite all its limitations and without prejudice to the need for a case-by-case assessment,* ***a numerical criterion of that nature may be reasonable and acceptable as it had been determined by comparing the practices existing in the various Member States****."* Emboldenment added by me.

The ECJ judgement October 2012, para 28, states that the Commission "*does not propose a strict 20 spill rule but points out that the more an overflow spills, ...the more likely it is that the overflow's operation is not in compliance with Directive 91/271."* Thus, considering that it would appear, see later in this report, that the Tideway would meet the environmental aims of the directive post the completion of the Lee tunnel, it is possible that a spill frequency of about 20 spills a year would be appropriate for the Tideway.

As an instance, the approved uprated Mogden STW has spilled 20 times in the 10 months April 2013 to January 2014 which would indicate that an annual average spill frequency of about 20 times a year has been accepted by the EA, (see next chapter).

This contrasts strongly with the Thames Water Application for Development Consent Resilience to Change Doc 7.23 page 1 "*The LTI*" London Tideway Improvements" *are designed to reduce the frequency of CSO discharges to a tolerable level, which is characterised by no more than four CSO discharges in a typical year."*

This is an exaggeration. Thus, whilst the up to 20 spills a year criterion was not formalised by the EC or by the British Government, such a criterion would appear to be acceptable, particularly where environmental conditions would be likely to be met, as shown to be likely later in this report.

However the objective of the UWWTD is "*to protect the environment from the adverse effects of the above mentioned waste water discharges."* Were it to be shown that the effects of a higher number of spills on the environment were not significant then it is quite possible that a higher number than 20 could be allowed.

"Gold plating"

Thus, the tunnel at 4 spills a year has a much higher performance than would appear necessary to meet the "unusual spill" criterion of the EC, proposed as up to 20 spills a year.

The Coalition in its Our Programme for government section 2 Business has stated "*We will end the so-called "gold-plating" of EU rules, so that British business are not disadvantaged relative to their European competitors."* In this case the disadvantage would be the cost on business and people in paying the substantially increased sewerage charges if it were found that a combination of measures were able to meet the criteria at a lower cost.

Environmental objectives

Three specific objectives were identified by TTSS covering the three key aspects relevant to the Tideway; aesthetics, ecology, and recreation.

The **aesthetics** objective was "*To reduce the frequency of those discharges that cause significant aesthetic pollution, or to limit the pollution caused, to the point where they* ***cease to have a significant adverse impact."*** Emboldenment by me.

For the **ecology** objective the Thames Tideway Tunnel and Treatment (TTTT) report, 2006 Vol 1 Objectives states "*since it is generally recognised that* ***fish are the most sensitive indicator*** *of ecological quality, the decision was taken to* ***derive standards that are protective of relevant fish species."*** My emboldening. Thus the ecological objective set in the Thames Water report Objectives and Compliance Working Group Report 2006 is "*To limit ecological damage by complying with the DO standards specified in the table above."* The Table above is,

Dissolved Oxygen (mg/l)	Return period (years)	Duration (tides)
4	1	29
3	3	3
2	5	1
1.5	10	1
Note: The objectives apply to any continuous length of river >=3km. Duration means that the DO must not fall below the limit for more than the stated number of tides. A tide is a single ebb or flood. Compliance will be assessed using the network of Automatic Quality Monitoring stations (AQMS)		

This table had been prepared following lethality studies on a suite of fish thought to be representative of those fish actually in the Tideway. Thus the Table is focussed on the specific conditions of the Tideway and the fish species thought to be in it.

The main recreational users of the Tideway are rowers and sailors. The objective set by the TTSSG for **health and recreation** is *"To help protect river users by* ***substantially reducing the number of "elevated health risk " days*** *following CSO discharges."* My emboldenment.

Best Technical Knowledge Not Entailing Excessive Cost (BTKNEEC)

In Annex 1 the UWWTD directive says "*The design, construction and maintenance of collecting systems shall be undertaken in accordance with the best technical knowledge not entailing excessive costs, notably regarding;*

- *limitation of pollution of receiving waters due to storm water overflows."*

The defra Working Paper written by its lawyer and submitted to TTSSG states in para 30 "*The BTKNEEC requirement does not introduce a cost/benefit analysis that would allow for a decision not to provide any solution at all. Rather, it demands that the best technical knowledge be used to provide a solution that meets the requirement. If there is more than one solution to the problem,*

there would be a strong argument that any solution more costly than the least expensive could be viewed as excessive cost, so long as the solution chosen fulfils the objective and requirements of the directive."

One of the general objectives of the TTSS was "*"To comply fully with the requirements of BTKNEEC*."

Thus, if there is a solution, or a combination of measures, which might well meet the relevant objectives at a lower cost, then, to comply with the requirements of BTKNEEC, they must be studied and, if they are able to meet the objectives, they should be adopted.

However the situation since then is that the 5 sewage treatment works are being upgraded to improve dissolved oxygen conditions in the upper, middle, and lower Tideway and the Lee tunnel is being provided to halve the spill volume. The NERA cost benefit assessment report shows that it is not worth spending more than another £1.5m. The Environment Agency has provided a schedule of fish kills showing that in the last ten years only one fish has been recorded as being killed in the Tideway as a result of a spill from the CSOs which would be collected by the Thames Tunnel. Thus how could the expenditure of a further £4.1bn not be excessive cost under BTKNEEC ?

National Infrastructure plan 2011

The National Infrastructure Plan section 3.114 states that "*the Government wants to ensure fair and affordable water and sewerage services while maintaining excellent drinking water and protecting and enhancing the ecological status of water bodies such as lakes and rivers.*" TW Planning Statement 7.01 , para 7.5.16. TTSS agreed that fish represent ecology and I examine the fish situation in chapter 4.

"*7.5.19 This ambition tanslates to the following three key areas for water and sewerage infrastructure identified in Section 3.122:...*c... *ensuring water and sewerage services are provided at prices households can afford."* I believe, but cannot currently source, that Thames Water has said that the tunnel will, on average, increase customer sewerage bills by £70-£80 per household. It is true that Thames Water sewerage charges are the lowest in England. However even in Thames Water's sewerage area, there will be customers who will find such a large bill increase difficult to afford. Thus it would appear that the tunnel cannot meet this key area of the NIP.

Solutions reviewed

The TTSS looked at a number of alternative complete approaches, including storage, screens etc and concluded that the Tideway tunnel would meet the objectives reliably whereas the others would not. Sewer separation was considered as a total solution, ie effectively near zero spill, and found to be too expensive by itself.

At the time there was little knowledge of, or experience of, the SuDs and blue green infrastructure approach and, on the basis of the information available then, TTSS concluded that such an approach was not viable. Since then such methods have developed and there are now examples of this and other techniques in a number of other countries. Thus an option of a number of **measures acting together** including the construction of the Lee tunnel, reduction of flows into the sewers, certain in sewer measures, along with SuDS and real time control was not considered by TTSS. They are considered in outline below to assess whether they are worth considering as a combination of measures.

Water Framework Directive

The Tideway is classified by the Water Framework Directive (WFD) as a "*heavily modified water body*". Those are supposed to reach good ecological potential. The Tideway Fisheries review states on page 30 "*It is a HMWB with Moderate Ecological Potential"*, and "*good status will not be met in the middle reaches, even with the solutions in place."* page 37. Thus it seems almost certain that, under the measures proposed, the Tideway would continue to be moderate status. Thus, if the tunnel were built or just the current works completed, the Tideway would appear to meet the WFD requirement of no derogation of status, which I understand is now set as the condition in 2008.

Sustainable drainage systems.

Defra (2005) Making space for water: taking forward a new Government strategy for flood and coastal erosion risk management in England set out the Government's commitment to ensuring that take-up of Sustainable Drainage Systems (SuDS) techniques is facilitated where appropriate.

The Flood Risk Regulations 2009 transposed the European Floods Directive into law and came into force in 2009. Evidence shows that SuDS will most likely be part of the techniques used to mitigate these risks.

Flood and Water Management Act of 2010. In order to meet approval the drainage system must meet the proposed national standards for sustainable drainage.

The Water White Paper: Water for Life (Dec 2011) sets out how the Government intends to encourage the use of SuDS.

The defra National Policy Statement for Waste Water states on page 8 "*The Government is taking measures to reduce the demand for new waste water infrastructure in England by requiring the use of sustainable drinage systems (SuDS) to reduce run-off in the built environment."*

Thus the government policy is now to encourage the use of SuDS.

European Commission Communication on Green Infrastructure-Enhancing Europe's Natural Capital.

On 6th May 2013 the European Commission issued its Communication on Green Infrastructure, COM(2013)249 final. This was after the NPSWW was issued by the British Government. This Communication states" *The roadmap identifies investing in GI as an important step towards protecting natural capital. The EU Biodiversity Strategy to 2020 includes a commitment for the Commission to develop a GI strategy....It also helps avoid relying on infrastructure that is expensive to build when nature can often provide cheaper more durable solutions....GI solutions are particularly important in urban environments in which more than 60% of the EU population lives. GI features in cities deliver health-related benefits such as clean air and better water quality....In the Commission's proposal for the Cohesion fund green Infrastructure is specifically identified as one of the investment priorities...The Commission is committed to developing an EU GI Strategy that helps to conserve and enhance our natural capital and to achieve the Europe 2020 objectives...By the end of 2013, the Commission will develop technical guidance setting out how green Infrastructure will be integrated into the implementation of these policies from 2014 to 2020...Green Infrastructure can contribute significantly to achieving many of the EU's key policy objectives."*

Thus the European Commission has, since the decisions by the British Government on the NPSWW, swung behind a policy of Green Infrastructure.

Review of alternatives and combination of measures.

The defra River Basin Planning Guidance Vol 2 August 2008 states "9.4 *As river basin planning principle makes clear the Environment Agency should consider the* ***full range of measures*** *which are available.""The WFD requirement is to make judgements about the* ***most cost-effective combination of measures, so it is important that the Environment Agency considers the inter-relationship between measures.***" My emboldening. Thus the requirement now is to consider not just a single solution, as was done by TTSS, but also combinations of measures. The EA SuDS assessment report is just a consideration of a single alternative, SuDs, without even considering infiltration. The Thames Water leaflet "Why does London need the Thames Tideway Tunnel?" considers a range of options but only as stand-alone solutions, not as a combination of measures. I have failed to find any document considering a combination of measures being used across London where they are most effective. Thus I believe this requirement has not yet been met.

The letter from the European Commission to Mr Roland Gilmore of 1st July 2013 states "*However any proposal made by the United Kingdom to remedy the excessive spills occurring in London will also need to look at the potential environmental impact of the solution proposed and the viable alternatives under the requirements of Directive 2011/92/EU on the effects of certain public and private projects on the environment."* Thus the EC acknowledges that it is still open for the British Government to propose an alternative solution to the Tideway.

Thus a combination of measures has to be studied. Presumably, to meet this requirement, this must take account of current technology and up-to-date information.

Application for Development Consent

The final paragraph of the Executive Summary of the Planning Statement 7.01 states "*The economic, ecological, health and reputational consequences of the project not being allowed to proceed would be severe.*" In this report I consider the ecological and health benefits. The economic benefits are considered in my review of the defra Cost Benefit analysis of 2011. In this I find that, on the basis of the latest information on recoded fish kills, the benefits would be about £180m compared to the cost of about £4.1bn. Thus the TW words are not robust and should be ignored.

Summary

Thus the main requirement of the UWWTD is that spilling should only occur under unusual rainfall conditions, proposed by the European Commission as 20 spills a year. In addition the TTSS also set objectives for river ecology (fish), aesthetics, and health/recreation. The Commission now promotes Green infrastructure. Government policy requires the study of the most cost-effective combination of measures but this does not appear to have been done..

3. Benefit provided by works currently being or recently constructed.

The works already under construction or completed include upgrading of the Mogden, Beckton, and Crossness STWs and increasing the storm water tanks to reduce the spill frequency as well as the Lee tunnel connecting the Abbey Mills pumping station to the Beckton STW..

Mogden STW

General spills

The information provided by Thames Water to Shirley Passmore 29th March 2011 about Mogden overflows is that

2008 total volume 7.9 million m3, number of discharges 160

2009 total volume 9.2 million m3, number of discharges 121

2010 total volume 3.1 million m3, number of discharges 59

Fish kill on 3rd August 2004

On 3rd August 2004 there was a storm event which resulted in many thousands of fish deaths in the Kew area downstream of the Mogden STW outfall but well upstream of Hammersmith Pumping Station. The radar plot shows high rainfall over the Mogden catchment and little over the Beckton catchment. This and other fish kills are described in detail in my report Thames Tideway-aspects of fish benefit January 2014.

July 2009 fish kill event

There was another fish kill event at the beginning of July 2009 when 20,000 m3 of raw sewage escaped into the Thames killing fish in the river in the river at Kew and Brentford. This was caused by a CSO at the Mogden STW spilling following heavy rain. The BBC reported "*Thames Water's re-oxygenation vessel has been at the site of the spillage since Friday and the company's hydrogen peroxide station at Barnes is also being used to ensure other fish survive the waste discharge."*

June 2011 fish kill event.

There was another fish kill reported on the 5th and 6th June 2011. The NPSWW states, page 18, that 900,000 m3 of storm sewage was released into the River Thames causing 26,000 fish deaths along a 2km stretch of the river between Barnes and Chiswick. I understand that this 2km was between Chiswick Bridge and Barnes Bridge. This is downstream of the Mogden STW. However this is some 3km upstream of the first major Tideway CSO at Hammersmith. Whilst some spill from Hammersmith could have been carried upstream on the tide, there is no report of fish kill near the Hammersmith CSO so it would appear that the spill was caused primarily by Mogden STW.

Environment Agency fish kill schedule

On 13th January 2014 I was provided with the EA schedule of fish kills over the last 10 years, see Appendix E. This is discussed in greater detail in the ecology section of this report. However the number of recorded fish kills are Mogden 3, Abbey Mills 2, and tideway CSOs one fish kill of one recorded fish. It is believed that the upgrade to Mogden will deal with fish kills from there. The three in ten years remaining compare with the Standard Table and modelling which for threshold 3 shows there were expected to be about 40 fish kills during this period. Thus there must be serious doubts about the reliability of the modelling. Of importance, once the Lee tunnel is operational, there will be no spills at Abbey Mills. Thus the situation would be one fish killed in the Tideway during the last ten years and this would be within the limits of sustainability of all species. Thus, once the Lee tunnel is operational, there would be no justification for building the tunnel for fish.

Mogden post upgrade spill frequency

Thames Water publish a Sewage Discharge Notifiation whenever Mogden or Hammersmith spill into the river. Since completion of the STW upgrade at the end of March 2013 until 21st January 2014, ie

9.7 months, I find that Mogden has spilled 20 times. Since the winter has been unusually wet it would be reasonable to assume that this is equivalent to an annual average of about 20 spills a year. This is a dramatic improvement on the previous situation of 60 to 160spills a year and all involved should be congratulated. However the new spill frequency is well above the 10 spills/year to which the EA have alluded, but about the 20 spills/year proposed by the European Commission. **Thus it would appear that the Environment Agency have effectively approved a spill frequency of about 20 spills a year.**

Post upgrade water quality

So how much has the water quality of the river improved? The much reduced spill frequency means that the more polluting first flush goes to storage. Thus not only has the volume of spill reduced dramatically, but also that which is spilled is the less polluting later storm water. This is demonstrated by the large rainfall event on 28th May 2013. This was a heavy rainstorm such that the storm tanks filled but the STW became tide-locked by a very high spring tide and no normal discharge could take place. Some 80,000 m3 of storm flow was discharged into the river. However the EA reported that "*the discharge did not have a significant effect on Tideway water quality. This was evident from the water quality monitoring of the estuary: Dissolved Oxygen saturation in the upper Tideway remained above 80%, which as we know is pretty good. We did not receive any reports from the public of any of the normal polluting effects that we might expect to be associated with discharges, such as fish in distress, or dead."* Darryl Clifton-Dey email 6th September 2013. 80% dissolved oxygen content would be about 8 mg/l (depends also on temperature), well above the threshold of any of the objectives, the highest for mortality being 3mg/l. Further, the critical time of year for dissolved oxygen sags is the summer when the water temperatures are higher, and hence the river would be more sensitive to DO sags, and the river flow lower.

Thus it would appear that the Mogden STW upgrade means, first that the spill frequency has reduced from an average of about 110 times a year to about 20 times a year. All those involved should be congratulated. It is at the limit of 20 times a year suggested by the European Commission, and presumably accepted by the EA. The previous associated low dissolved oxygen conditions, the main source of fish kills in the Upper Tideway, has been dealt with even though the spill frequency is about 20 spills a year.

Crossness STW

In addition to the benefit of considerably improved effluent quality, the Table of performance in Appendix A shows the storm tank overflow at Crossness STW would be reduced from 308,000 m3/year to 50,000 m3/year. This upgrade is due for completion in 2014.

Lee tunnel benefit

Once all the upgrades and the Lee Tunnel are completed, about April 2015, the volumes of stormwater discharged to the river will fall from about 39 Mm3/year on average to about 18 Mm3, less than half, see Table, in Appendix A, provided by Thames Water.

Modelling of the river system has been done by Thames Water and shown in the Needs Report 2010. Plots have been prepared of the number of breaches in the 34 years of modelling on the y axis and the distance upstream and downstream of London Bridge on the x axis. The plot below shows the situation with the 2mg/l DO standard. The red line shows the number of breaches with the previous CSO and STW system. Thus there would currently be about 130 failures/fish kills in the 34 years of record, ie about 40 fish kills in the last 10 years.

The standard to be obtained is shown by the dark blue horizontal line.

The mauve line shows the situation after the Lee tunnel and STW improvements have been completed. This shows that the current works go a long way towards meeting the required dissolved oxygen standards. The situation with the other three standards is set out in Appendix A.

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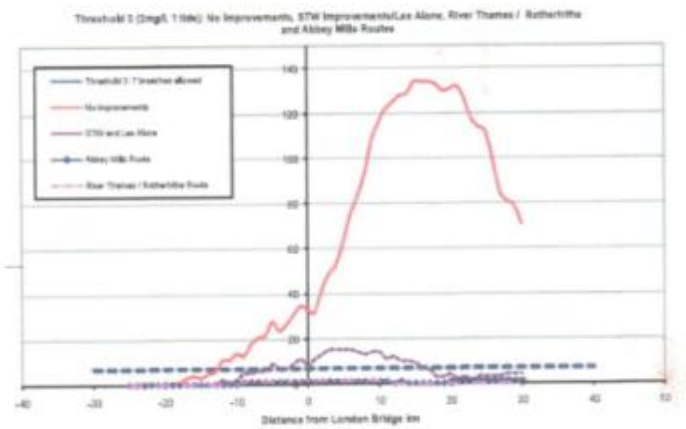


The TW Application for Development Consent, Resilience to change 7.23 Table 3.1 page 10 shows more recent modelling. This shows 99 exceedances of the 2mg/l threshold in 41 years of modelling. This amounts to 24 failures in 10 years.

The post STW improvements and Lee tunnel is given as 12 failures in 41 years against a target of 8 failures. However this is shown as being the condition in 2020 whereas the improvement works and Lee tunnel will be commissioned in 2014/5.

Future spill volumes to the Tideway

For the Tideway, ie excluding Mogden STW, the current situation is a spill volume of about 39 Mm3/year. Once the main STW upgrades and the Lee tunnel has been completed the spill volume will reduce to about 18 Mm3/year.

Future spill frequency

It is believed that this modelling was done with the assumption that the per capita demand for water would remain the same and that household water use would rise in line with population thus the dry weather sewer flows would be increased by about 14% by 2012. This is discussed in more detail in a later chapter. Since the modelling was done, TW have shown in their draft Water Resources Management Plan 2014 that water use per person would be reduced due to demand management measures such as the provision of more water efficient appliances and the implementation of much more metering (which generally reduces water use by about 10%) and then by the implementation of incentive tariffs which are believed to reduce PCC in metered households by about a further 5%. However in later years it is assumed by TW that water use per person would level off so the water into supply would start to increase.

Thus the dry weather flows in the sewers would reduce, in turn reducing the amount and frequency of CSO spills in the future. As shown later the reduction in sewer flows by 2035 would be nearly 20% compared with the Thames Water assumptions of sewer flow. Thus the sewer and river water

quality models over-predict the future numbers of dissolved oxygen failures that would occur. Thus the post Lee tunnel number of failures would be lower than the 12 failures quoted. Thus it is quite likely that once the improvement works are completed in 2014/15 that the Tideway will meet threshold 2 modelled requirement of 8 failures in 41 years.

Were measures such a SuDs or Active System Control , as discussed later, to be implemented then it would be even more likely that the Tideway would meet, and continue to meet, the modelled dissolved oxygen conditions relevant to fish kill.

Further, as shown elsewhere, the Standards and the modelling show there should have been about 24 failures/fish kills in the last 10 years in the main Tideway. The EA records, see Appendix E, show only 3. This casts serious doubt about the reliability of the standards and modelling.

Conclusion

With the completion of the sewage treatment works upgrades which both improve effluent quality and much reduce spills from the works, the quality of the effluent discharged into the Tideway will be much improved.

The upgraded Mogden STW spills at about 20 spills a year so the EA has accepted this spill frequency into the much smaller Upper Tideway.

The volume of discharge from the main Tideway CSOs will reduce post upgrade and Lee tunnel works from 39 Mm3/year to about 18 Mm3/year.

The post current works situation, when completed in 2014/5, is likely to meet the modelled failure requirements.

Further the EA schedule of fish kill shows that, post the Lee tunnel being operational, the Tideway will be sustainable for fish.

4. Protection of the ecology.

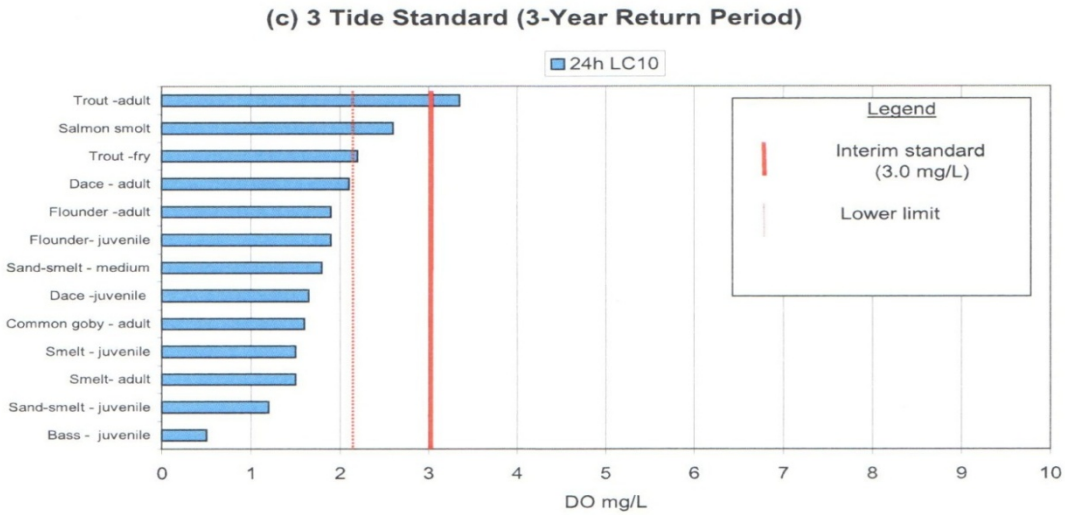
The Thames Tideway Tunnel and Treatment (TTTT) report, 2006 Vol 1 Objectives states "*since it is generally recognised that fish are the most sensitive indicator of ecological quality, the decision was taken to derive standards that are protective of relevant fish species."*

This was interpreted by the TTSS as an objective "*to limit ecological damage by complying with the dissolved oxygen standards specified in table 1"*

Thus the objective is effectively "*to limit ecological damage by ensuring that fish species are sustainable."*

This is considered in more detail in my report Thames Tideway-Aspects of fish benefit January 2014.

Fish trials were carried out to establish the sensitivity of a representative suite of fish to low dissolved oxygen conditions.



Following this a Table of DO standards was established.

Table 3 DO Standards for the Tideway

Dissolved Oxygen (mg/l)	Return Period (years)	Duration (tides)
4	1	29
3	3	3
2	5	1
1.5	10	1

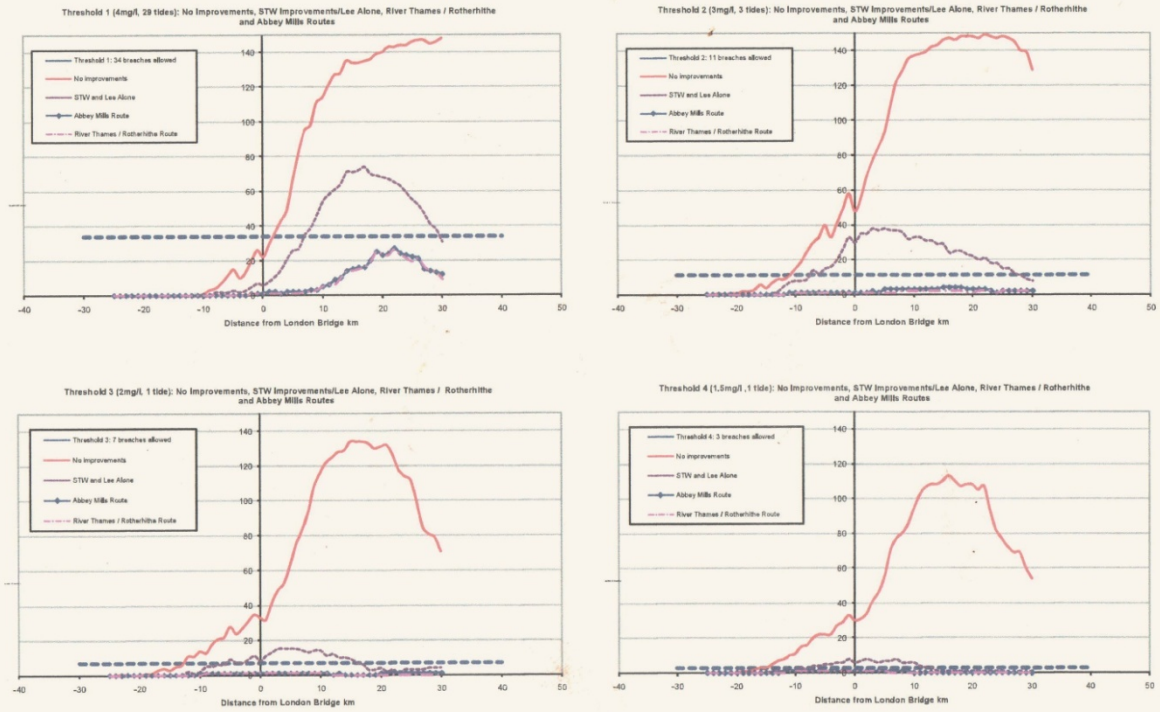
Since then WFD standards have been set which are similar. However "*The TTSS standards should apply as the proposed WFD standards are best suited to managing continuous discharges*." TTT vol 1 page 8.

It should be noted that the 4mg/l one week standard "*was selected to ensure protection against chronic effects; these would include e.g. effects such as depression of growth and avoidance of hypoxic area.*" Tideway Fisheries Review Jacobs 2009 page 5. Thus the 4mg/l standard would not cause any fish mortality but could delay any salmon trying to migrate at the time of any failure of Threshold 1.

"*The major influence on the "chronic" standard of 4mg/l is the performance of the STWs, and the planned upgrading largely achieves this standard."* TTT vol 1 page 8.

Post the Sewage treatment works upgrades and the Lee tunnel the dissolved oxygen failures, mauve line, are much reduced but still exist, as shown in the plot below.

Figure 5.2 Comparison of Dissolved Oxygen Standards Compliance – (a) No improvements, (b) STW improvements and Lee Tunnel, (c) River Thames/ Rotherhithe routes and (d) Abbey Mills route (negative figures refer to distances upstream of London Bridge)



Thus it can be seen that the model shows that the current works go a long way to meeting the standards. Threshold 1, 4mg/l, is only there in that salmon tend to avoid such conditions. It is not there to protect against any fish mortality. Looking at the plots of the Threshold 3 and 4 criteria, then one would **currently** expect regular extensive fish kills in the river downstream of London Bridge. Taking Threshold 3 the2013 model shows there to be 99 failures ie fish kills, in 41 years of record. That would be about 24 fish kills in a 10 year period. Only 3 have been recorded by the EA.

In the 2010 Tideway Fisheries Review by Dr Turnpenny it was stated that there were sustainable mortality rates for different species. This assumes that fish with more reproductive year classes are able to sustain a higher mortality in a single year. Thus the sustainable mortality varies from 10% mortality up to 20% for dace and 30% mortality for salmon, and bass.

Table 3-4 ***Values used for sustainable mortality. It is assumed that fish with more reproductive year classes are able to sustain a higher mortality in a single year.***

Species	No. of Reproductive Age classes	Sustainable Mortality %
Salmon	3	30
Bass	10	30
Sand smelt	2	10
Dace	4	20
Smelt	2	10
Flounder	7	30
Common goby	2	10

Thus, as the study progressed, the objective became to ensuring fish species were sustainable using a Fish Risk Model which incorporated the individual species mortality.

Prior to the TTSSG study there had generally been a reasonable return of salmon to the river, about 100 to 300 a year between 1980 and 1995, hence salmon were included in the suite of fish considered. The numbers in the table were adopted as "*the most sensitive species* " salmon " *showing significant mortality at 3mg/l and behavioural impacts at less than 4 mg/l."*TTT Vol1 December 2006 page 7.

Fish choice

The fish species chosen are mostly resident in the Tideway. However migrant species such as salmon, are only in the Tideway for a limited period, spending much of their life at sea, migrating up through the Tideway and then spending the last part of their life in freshwater to spawn.

Tideway fish Risk model

The Tideway fish risk model assesses sustainability by considering life stage, population residence, effect of spill on water quality, and mortality of each fish species. This appears to have assumed that all salmon were resident in the Tideway throughout their migration period whereas only a small proportion would have been in the zone at risk at any one time. Even so the FARL report 2005 said

"the existing conditions are at least close to allowing for sustainable fish populations. *With proposed capital improvements at Beckton and Crossness"* STW*" under AMP4,"* now nearing completion*" the DO-profile predictions given in the Steering Group report indicate that the* ***baseline condition should improve considerably,*** *and the impact of CSO spills on DO status in the Tideway's middle reaches will be greatly ameliorated by these measures alone."* My emboldening.

"Tideway fish populations should already be sustainable, *which potentially undermines the case for improvements."* Tideway Tunnel Fisheries review Appendix F to the Needs case 2010. p 16.My emboldening.

Future years

The water quality conditions in the river in the future will be dependent on sewer spills and hence sewer dry weather flows, changed rainfall due to climate change, increased water temperatures, and changed fresh water flows. As shown in chapter 10, the sewer model does not appear to correctly reflect future sewer flows or freshwater flows and may not correctly reflect 2080 temperature, and takes no account of increasing SuDs, and appears not to include STW upgrades. Thus, the future modelled dissolved oxygen conditions do not appear to be robust and need reconsidering.

Salmon

Salmon returns to the Tideway in recent years are shown in the image below

The Atlantic Salmon Trust End of Year Review 2013 "*Marine survival of wild Atlantic salmon has*

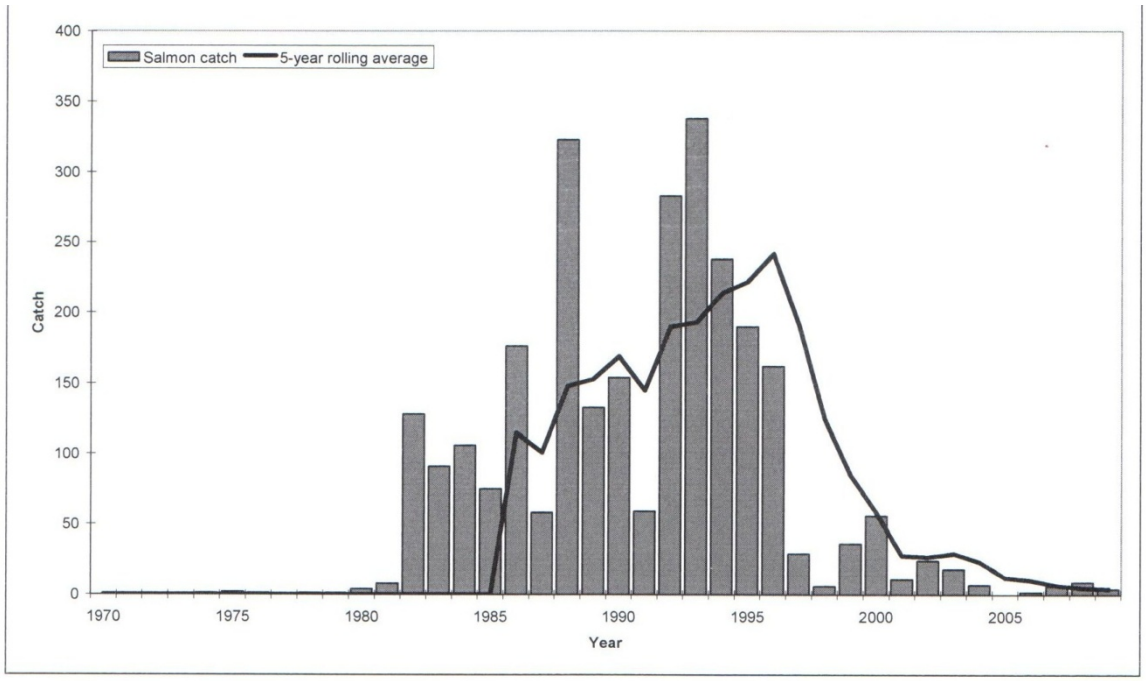


Figure 1 - River Thames recorded salmon catch and five year rolling average

collapsed from nearly 30% to less than 10%- to the point where today less than one salmon returns to its native river for every ten smolts that leave it."

The EA state "*...it is very unlikely that a self sustaining salmon population is viable in the Thames over the short to medium term (ie next ten years)*."

In March 2010 the Atlantic Salmon Trust held a conference on "Managing River Flows for Salmonids: Evidence-based Practice. This states on page 74 *"There is also reason to expect northward movement of the thermal niche of anadromous salmonids with decreased production and* ***population extinction in the southern part of the distribution areas."*** My emboldening.

Dr Friedland concluded "*Ocean thermal conditions in key post-smolt nursery areas are expected to continue to change,* ***making marine survival unsustainable*** *for segments of the stock complexes from both north America and Europe*." My emboldening.

The notes of the meeting of 31st May 2012 states ***"...there is currently no evidence to challenge the hypothesis that salmon may not be sustainable in the longer term due to climate change."*** My emboldening.

Thus there seems no reason to consider the most sensitive fish species, salmon, in the fish suite.

Other sensitive species

The dissolved oxygen standards for salmon could still be appropriate if other fish species took the place of salmon. Sea trout are similar to salmon but there are also few of them. Apart from 2009 the average number entering the Thames over the previous decades has been about 15. The TTSS considered this too small a number to be included as a fish of conservation interest.

Lamprey and eel can tolerate low dissolved oxygen conditions. Sturgeon are endangered or critically endangered and are likely to continue to be very rare visitors. Twaite shad are rare visitors, and are reported to be more tolerant of low dissolved oxygen content than salmon. Thus no appropriate alternatives species to salmon that are as sensitive to low dissolved oxygen conditions, were identified.

Environment Agency schedule of recorded fish kills.

Taking Threshold 3 the 2013 model shows for the existing situation there to be about 99 failures ie fish kills, in 41 years of record. That would be about 24 fish kills in a 10 year period, see the TW Application for Development Consent, Resilience to Change Doc 7.23 Table 3.1

The Environment Agency has provided me with a schedule of recorded fish kills in the Tideway over the last 10 years, see Appendix E. This shows 3 due to Mogden STW spills, 2 due to Abbey Mills spills, and one due spills from the CSOs to be connected to the Tideway tunnel.

The covering email states "*Often, because these incidents occur during storm events, or at night, or in areas where there is little public access or use, there can be large mortalities of fish, particularly juveniles , that will pass unnoticed*." When fish die many float or are left on the foreshore. I have been told by the EA at the meeting on 16th January that 70% sink and 30% float. Thus significant fish kills occurring at night would be seen during daylight the next day. Secondly the majority of fish kills occur in summer when temperatures are high but then there are more hours of daylight. Thirdly fish kills are not just spot situations but would occur where the water had too low a dissolved oxygen content, probably several hundred meters. The tide would also carry dead fish up and down river so any Tideway event would spread over an appreciable distance. The Tideway has extensive public access to the river side and there is also significant river traffic on the Tideway, thus any significant fish kill would be seen. Certainly two of the fish kills in the Barnes/Chiswick area were extensively reported. Thus more fish may be killed in any one incident but it would be most unlikely that any significant fish kill on the Tideway would not be identified and recorded.

EA continue " *it is preferable to use the much more comprehensive data obtained for the Tideway Tunnel Strategic Study."* I chaired the TTSS but have no recollection of any fish kill event mentioned then bar a major fish kill on 3rd August 2004 due to Mogden STW spills. I have been unable to find any other data from that period. I have also asked the EA on 15th January 2014 for the data to which they refer but so far, 11th February, none has been provided.

Thus I believe the information in the EA schedule of recorded fish kills in the Tideway due to the CSOs and Abbey Mills to be sufficiently robust.

Reliability of the fish standards and model outputs

Mogden is not included in the Tideway water quality model. Thus there were only 3 recorded fish kills in the Tideway in ten years. That would indicate that the Table and dissolved oxygen modelling see Appendix A, at threshold 3 which shows 135 failures/fish kills in 34 years, ie some 40 fish kills in 10 years, do not reflect the actuality of 3 fish kills over the same period. The output of the latest modelling over a 41 year period is shown in Table 3.1 from TW Resilience to Change 7.23. This shows 99 failures/fish kills in 41 years which is equivalent to 24 fish kills/10 years.

Table 3.1 Scenario compliance against dissolved oxygen standards

Dissolved Oxygen Standard	1	2	3	4
Dissolved Oxygen concentration duration threshold	4 mg/l for 29 tides[1]	3 mg/l for 3 tides	2 mg/l for 1 tides	1.5 mg/l for 1 tides
Allowable exceedances in 41 years	41 (1:1 year)	13 (1:3 years)	8 (1:5 years)	4 (1:10 years)
Scenario modelled	**Maximum number of exceedances of thresholds**			
Existing System	**211[2]**	**193**	**99**	**60**
STW improvements and Lee Tunnel (2020)	**75**	**40**	**12**	**7**
STW improvements with Lee and Thames Tideway Tunnels (2020)	21	4	1	1

Threshold 1 is for hypoxia and does not cause mortality. Threshold 3, 99 failures in 41 years is the equivalent of 24 failures/fish kills in 10 years. This does not fit at all with only 3 fish kills recorded in ten years by the EA. Thus the Table of Standards and the modelling appears to be so much in error that the results cannot be used for decision making and they need to be reconsidered.

Fish kill due to CSOs spilling direct to the Tideway.

Mogden STW has been dealt with by the Mogden upgrade. The Lee tunnel, now completed and operational in 2015, will transfer the excess storm water direct to Beckton STW so would eliminate Abbey Mills spills. That leaves one fish kill of one fish in the Tideway over 10 years due to the Tideway CSOs.

In the 2010 Tideway Fisheries Review by Dr Turnpenny it was stated that there were sustainable mortality rates for different species. This assumes that fish with more reproductive year classes are able to sustain a higher mortality in a single year. Thus the sustainable mortality varies from 10% mortality up to 20% for dace and 30% mortality for salmon, and bass.

Since the report of the Mogden fish kill of 2011 was that it killed 26,000 fish then the fish in the Tideway are likely to exceed 100,000 in number. Thus, depending on species, one could presume several thousand fish could be killed each year and still maintain a sustainable fish stock. However there is only one fish recorded in the last ten years as having been killed by discharge from the CSOs that discharge directly into the Tideway.

The Application for Development Consent Environmental Statement 6.1 para 30.3.2 states" *Significant beneficial effects would be likely once the Thames Tideway Tunnel is operational. This is due to a reduction in the occurrence of dissolved oxygen related fish mortalities..."* Since, under the current arrangement, only one fish has been recorded as having been killed in the last ten years as a result of spill from the CSOs that would be connected to the tunnel and the STW upgrades and the Lee tunnel will improve matters further, it is difficult to see how significant benefits can occur. Thus the statement in the application is at least misleading.

Thus, post the Lee tunnel, fish would be sustainable in the Tideway and fish sustainability could not be used as a reason to support the cost of the tunnel.

Conclusions

Fish are assumed to be the best indicator of ecological health.

Fish can withstand a certain mortality and still be sustainable. The post STW upgade and Lee tunnel fish risk model, once corrected for one anomoly, shows that the fish species would be sustainable.

The table and the dissolved oxygen model show there should have been about 40 to 45 fish kills in the Tideway over the last ten years. Records show only 3 fish kills. Thus there must be serious doubt on the reliablity of the table and dissolved oxygen model to replicate tideway conditions sufficiently accurately.

With only one fish recorded as having been killed in the Tideway as a result of Tideway CSO spills in the last ten years, fish are sustainable and do not warrant expenditure on a large tunnel.

Analysis of future conditions uses sewer and water quality models which assume increasing sewer flows whereas the TW WRMP show water into supply being lower since 2006. Thus the sewer and dissolved oxygen model of the future is not robust and should be reconsidered.

Further dissolved oxygen improvement.

Further measures

Were it thought necessary to improve the dissolved oxygen conditions further, then there are several ways of raising dissolved oxygen in the Tideway.

Evidence from elsewhere

In the upper Tideway, a land based oxygen injection system has been used to raise the dissolved oxygen content in the Chiswick/Barnes stretch of the upper Tideway to reduce dissolved oxygen sags emanating from the historic Mogden STW. I believe this is actually based on the Mogden effluent outfall. It has been utilised in the past to reduce the impact of Mogden storm tank discharges into the Upper Tideway. Thus it has shown that such a system can work.

Floating bubblers

Should a dissolved oxygen sag become an issue then the monitoring system would enable the two existing mobile bubblers to be despatched promptly. However this would only be a standby measure and not part of the routine measures to raise dissolved oxygen levels in the river.

Thames Water , in their Stage 2 consultation in the note on options page 3 state "*We currently use "mobile" boats to reduce the impact of untreated sewage overflowing to the River Thames...so our bubbler boats inject oxygen into the river helping fish survive sewage discharges...There are severe limitataions as to where these boats can go due to tides and bridge heights."* That may be true at present when the most damaging condition is an overflow of final tank effluent from Mogden STW which can then be taken upstream by the tide. However the restrictions of air and water draft in the main Tideway up to Hammersmith would be minimal.

Dryden air/oxygen injection system.

Dryden Aqua make fine bubble diffusers. Their web site page headed lake & pond aeration, states *"Dryden Aqua manufacture a very fine bubble diffuser that has its own internal ballast. The diffusers*

are semi flexible tube type diffusers that have the best of ceramic diffusers and membrane diffusers but without the disadvantages...Air is passed through the diffusers and the fine diffusion cloud of air passes through the water... The aeration system will dissolve oxygen into the water, one diffuser code 6.2.10 diffusing 10cum/hr of air will add at least 25 kg oxygen to the water per day..."

Thus one could have a system of diffusers attached to pipes down the river. The diffusers would not be the coarse discs used in Cardiff harbour and elsewhere to turn bodies of water over, but fine bubble air diffusers designed to increase the oxygen content of the water body. The large surface area of the fine bubbles aids oxygen transfer through the bubble water interface, but also because more water is moved there is also an increased transfer between the surface of the water and the air. Each diffuser is designed to input 1kg of oxygen from the air to the water each hour.

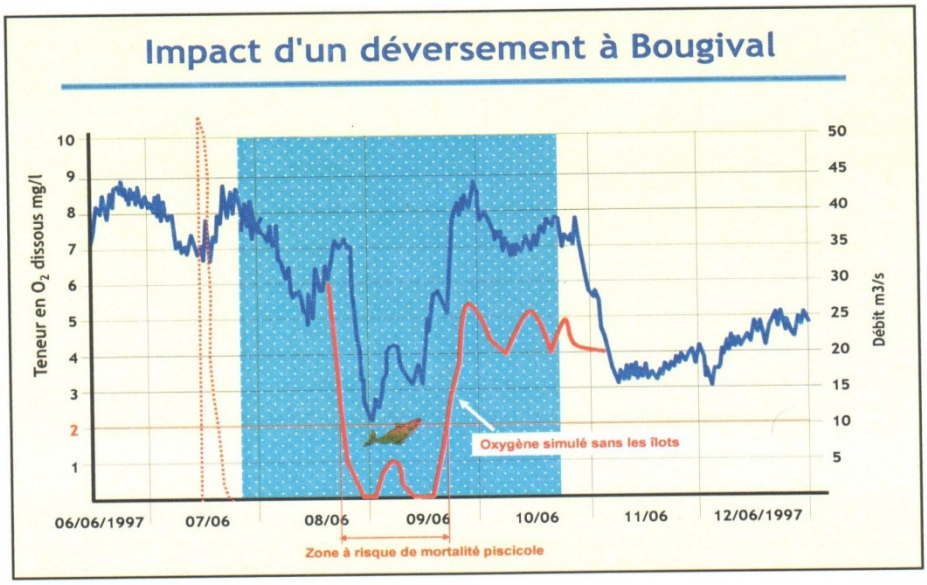
Dryden Aqua comment by email" *We went through a similar exercise for the Manchester ship canal, which is on the same scale... The diffusers will create a path for the migratory fish will follow. Also if the aeration system does not maintain a complete path, each air diffuser can act as a life support island of oxygen to support the fish. One diffuser can support around 1 tonne of fish, and will provide a safe zone during period of heavy pollution or during the DO drop that will occur at night."*

System used in Paris

In Paris the French have used a system of pipes and diffusers to inject oxygen to raise the dissolved oxygen content of the River Seine, see Appendix B for details. This has been used to raise the dissolved oxygen content of the Seine to provide "islands of refuge".

Oxygen injection system in the Seine in Paris

The image below shows the modelled dissolved oxygen content of the river following a storm in red and the actual conditions achieved in blue, in that case an actual rise of 2mg/l.



Since its introduction, salmon are reported to be now returning to the River Seine. Thus such a system does appear to meet the objective of significantly improving environmental conditions.

Monitoring

A near real time monitoring system could be provided, similar to that at Cardiff Harbour, to measure the dissolved oxygen content in the river every 15 minutes and to give prompt warning of any issues and unusual dissolved oxygen conditions. There are already several monitoring points in the river but it may be necessary to provide a few more.

However the Needs case modelling figure 5.2 , see Appendix A of this document, shows that, with the Mogden STW improvements and the Lee tunnel, the base case, there would be no half tide failure further upstream than 8kms above London Bridge. With a half tide flow of another 7km, there would be no failure of the standard further upstream than 15kms. This is downstream of Hammersmith Bridge. Thus Hammersmith Bridge would generally be the upstream limit of operation.

Conclusion

If thought necessary to raise the dissolved oxygen further, a system based on injecting air or oxygen through fine grained diffusers to raise the dissolved oxygen content could be developed and work satisfactorily to raise the dissolved oxygen sag and alleviate the environmental impact further.

In any case, in the River Seine in Paris, the authorities have provided bubbler systems to provide islands of refuge for fish and these have proved very effective. There seems no reason why similar could not be instated in the Tideway if thought appropriate.

5. Effect on aesthetics

Objectives

There is no specific clause in the UWWTD dealing with aesthetic pollution. The TTSS adopted as an objective *"To reduce the frequency of operation and limit pollution from those discharges which cause significant aesthetic pollution, to the point where they cease to have a significant adverse effect."* This was re-endorsed in the TTTT Objectives report of December 2006.

Impact of sewage litter

It is generally accepted that sewage derived litter makes up 10% of the total litter. This figure is from the Tidy Britain Group**.** There is limited evidence to support this figure but it is a generally used figure. Thus 90% of the litter/debris is not sewage derived. However some condoms, panti-liners and blue plastic cotton buds do occur. There is also a brown oil build up on boats in certain parts of the tideway. This is believed by some to be sewage derived such as cooking oil, car oil, or other sources.

"*Shortly after discharge floating matter disseminates relatively quickly so the plug of sewage effluent moves unnoticed with the ebb and flood of the tide."*HPA Recreational Users report page 52.

There would certainly have been complaints if sewage was regularly sighted in the middle reaches through central London. The fact is that the sights and smells of the Great Stink, or anything like it, are no longer with us, and the great majority of the population see nothing. That is why it is possible to sell vast amounts of new residential property directly overlooking the Tideway without complaint and at high prices.

Jacobs Babtie Review for ofwat.

As part of their review Jacobs Babtie team did a trip on the Thames on 31st August 2005 and reported "*...several days after the most recent rainstorms, floating debris was seen in several locations. The slicks that the TTSS describes in its reports were observed, and, on close inspection, it was clear that some of the debris contained in them was sewage-derived. However, our opinion is that it would not be immediately apparent to a casual observer that the debris was any more than windblown litter and vegetation- a fact reflected in public responses obtained during the TTSS*." Independent review for ofwat Feb 2006 page 8.

Jacobs Babtie continue on page 9 "*In addition to the slicks, litter was seen to have accumulated on the banks of the Tideway. However much of this is coarse debris which is likely to have originated from sources other than the CSO discharges. Much of the bankside of the Tideway is overlooked from adjoining residential and commercial buildings or is accessible to the public, albeit access to the actual waterside is made only infrequently. Numerous leisure vessels provide visitors to London with river tours. Thus bankside litter deposits may be considered a very visible aesthetically feature from the public standpoint."*

In which case the collection of all litter by skimmers would be a significant aesthetic improvement.

On page 11 Jacob Babties quote from the eftec report The Market Benefits of Options for the Thames Tideway appended to the TTSS Cost Benefit Working Group Report which they say states

"...although reducing CSO events would be associated with reduced amounts of sewage litter, this is currently only a small (10 per cent) proportion of the total litter and debris in the Tideway at any one time, and what there is appears to be invisible much of the time, at least as far as individual perceptions are concerned.

Therefore, little aesthetic change in the water is to be expected due to Tideway Strategy options, and this, together with the low correlation between riverside residence and involvement in river-based water sports, suggests that any impact of the Tideway options on property prices is likely to be minor."

These statements were made about the baseline in 2006. Since then the baseline now includes the Lee tunnel, in itself removing more than half the spill volume, as well as improvements to the water

quality and storm overflows from the 5 London sewage treatment works. Thus the effect from sewage litter would be even smaller for the new baseline.

On the Tideway Tunnel, Jacobs Babtie concluded: *"in general the public are unlikely to detect much visible difference."* from implementing the Tideway tunnel.

In river debris collection

Since then TW have provided two in-river debris collection skimmers which collect floating litter, including that sewage derived, thus reducing sewage litter and also improving the general appearance of the river.

There are two such vessels Clearwater 1 and Clearwater 2 which together cost £4m and were commissioned in September 2007. They were designed to operate as far upstream as Kew and to navigate London's bridges. In operation, the screens sit 450mm deep below the river surface. Debris is direcetd on to the screens by the inner hulls of the vessel, where the debris is picked up by mechanical screening equipment and conveyed to the rear of the vessel where it is drained ready for disposal into a refuse barge. In March 2008, after 6 months service Thames Water stated " *The vessels which have collected over 40 cubic metres of litter from the River Thames since September 2007 have greatly contributed to improving its environmental and aesthetic quality, ensuring it is fit for river users, and for this years Oxford and Cambridge boat race crews. To date, the skimmer vessels have been a real success story, enabling us to collect large volumes of litter, which overflows from the sewers during periods of heavy rain."*

Thus the overall aesthetic effect has been beneficial. In the future, with the Lee tunnel and the STW upgrades removing more than half the spill volume, and in particular the Mogden STW great improvment, it is likely that no extra litter skimmers would be needed. Thus the craft would continue to operate but now concentrating in the areas where the larger CSO spills occur likely to be Hammersmith, Lots Rd, Heathwall, and Greenwich, a more compact area.

Environment Agency Assessment

It is very difficult to identify which CSOs are providing debris that results in a significant adverse effect. The Environment Agency developed a protocol. This identified areas of the river which are

sensitive to aesthetics impact. In broad terms these were the river from Kew down to Westminster, around Greenwich, and around the Thames Barrier.

The EA then assumed that "*the volume of discharge is a key factor in determining the extent of the adverse aesthetic impact created by a particular outfall. Thames Water sewer models were used to estimate the mean volume discharged from each for 21 historic rainfall events. CSOs that discharged an average of greater than 50,000 m3 were assumed to make a significant contribution to the aesthetic impact, whilst those that discharged less than 1,000m3 were assumed to cause no significant impact. CSOs that discharged between 1,000 m3 and 50,000 m3 were assessed for the nature of the area into which they discharged, by reference to figure 1... 35 CSOs were deemed to be unsatisfactory because of the contribution they make to the aesthetic impact of storm sewage discharges."*

Data supporting the EA assessment

Whilst the choice of paramters has some intelectual basis, no data is presented to support either the criteria, the numbers, or even the choice of CSO that is considered to be unsatisfactory. The numbers arrived at are just that, numbers with no units. I have not been able to find any specfic data to support the choice of 50,000 m3/year as the level at which a CSO must have an adverse impact. Thus I believe this analysis is a subjective assessment of very limited robustness and certainly not one to support the expenditure of £4bn on a tunnel.

Comparison to analysis of health impact

Further, the EA has applied a similar approach to the identification of 19 CSOs that result in a health impact. However, as considered under my chapter on Recreation and health protection, the health impact one would expect would be gastric problems. However the HPA study showed rowers have more than **ten times fewer gastric problems than the general public**. This demonstrates the lack of robustness of the method of analysis used by the EA.

Consideration of current works.

Since the EA aesthetic assessment includes classification of Abbey Mills as an unsatisfactory CSO yet post the current works there would be no spill from Abbey Mills, it is clear that the EA aesthetics assessment does not include consideration of the benefit of the works currently being constructed. The Lee tunnel will reduce the CSO spill volume from 39 Mm3/year to 18 Mm3/year thus appreciably reducing the debris in the river Lee and the lower Tideway. Further the works at Mogden have reduced the spill frequency there from about 110/year to about about 20 spills a year and the spill volume into the upper Tideway from about 4 Mm3 to year to less than 1 Mm3/year (I dont have an accurate number). Thus the EA assessment does not include these considerable aesthetic benefits.

Standards to be met

The DETR 1997 guidance on the UWWTD states that to identify an unsatisfactory CSO it would need to have "*a history of justified public complaint*." The Environment Agency have stated in 2012 " *the number of formal complaints regarding sewage debris is relatively few."*Bain email. Thus there do appear to be only a few complaints from the public and not enough to meet the criteria of classification as unsatisfactory when the selection of the CSOs that were unsatisfactory was done in 2004, and again in 2006. Since then, with the provision of the two skimmer boats, the situation has improved.

Future works

Were measures to be implemented to reduce the CSO spills by SuDS, infiltration where appropriate, real time control and other such measures, the sewer spills would reduce further and reduce any remaining aesthetic effect further.

If thought appropriate booms could be constructed around most of the CSO outlets thus retaining much of the floating debris which would then be collected by floating craft. The cost has been quoted as about £2m. This is considered in Appendix D.

If thought necessary, oil skimmers could be provided to pick up slicks not otherwise collected by the booms and existing litter collectors.

Summary

The Environment Agency have identified 35 CSOs as contributing to the aesthetics impact. That assessment is not apparently based on any actual aesthetics data, and is a subjective assessment.

The requirement to identify an unsatisfactory CSO is a "*history of justified public complaint*". During the period 2004 to 2012 the EA acknowledge there were few public complaints. There did not appear to be sufficient public complaints to warrant selection of the CSOs as unsatisfactory.

There are two litter skimmers provided since the original unsatidfactory CSO assesment was made in 2004. These are quoted by TW as "*ensuring the river is fit for river users*". However there is no mention in the EA assessment of the benefit these now bring.

The impact does appear to be relatively low and to be below the TTSS objective of significant aesthetic pollution. The Tideway appears to meet the criterion for litter/aesthetics.

Should it still be deemed appropriate to reduce the aesthetic effect further, then, where practical, booms could be fitted around the CSOs . More informaton is provided in Appendix D.

6. Recreation and health protection.

Objective set by the TTSSG *"To help protect river users by substantially reducing the number of "elevated health risk " days following CSO discharges."* The TTT in 2006 changed this to "*To help protect river users by* ***substantially reducing the elevated health risk due to intermittent sewage discharges."*** My emboldening.

The Environment Agency carried out several assessments of those CSOs which were unsatisfactory for health reasons. The latest I have is dated 2010. These were done on a similar basis to that for litter with assessments of the location relative to recreational activity, frequency of discharge, and volume of discharge. This resulted in 19 CSOs being classified as being unsatisfactory on health risk grounds.

The Health Protection Agency Thames Recreational Users Study 2007 page 48 "*As a background level the 95% concentrations of indicator organisms in the upper tideway permanently remain above the WHO microbiological standards for recreational waters and thus represent a potential health risk to recreational users."* Thus neither the tunnel nor other similar measures can change this situation. However "*there appears to be evidence of an improvement in water quality as you move downstream from Kew to Putney*". Thus current CSO spills appear to have limited microbiological effect, but improvements at Mogden STW may well have been beneficial.

Bathing.

On 1st July 2012 the Port of London Authority enacted *"a new byelaw to control swimming in the busiest part of the Thames between Putney Bridge and Crossness by making it necessary to get the prior consent from the harbour master." "Here you encounter a fast running tide, bridges and eddies which can drag a person underwater in a trice. And there are also passenger vessels which* carry *over six million people a year and 1,000 tonne barges carrying freight."*

Putney to Crossness is almost all the length of the Tideway affected by CSOs.

There is a quote about a swimmer having to have "*the event carefully planned and managed with safety boats in attendance at all times."* From a discussion with the PLA I understand that, since July 2012, the PLA have only issued one licence for one swimmer to swim once from Putney to Vauxhall and then enter the water again way down in the estuary. Presumably the event could be managed to be several days after any significant CSO spill so water quality conditions would be improved.

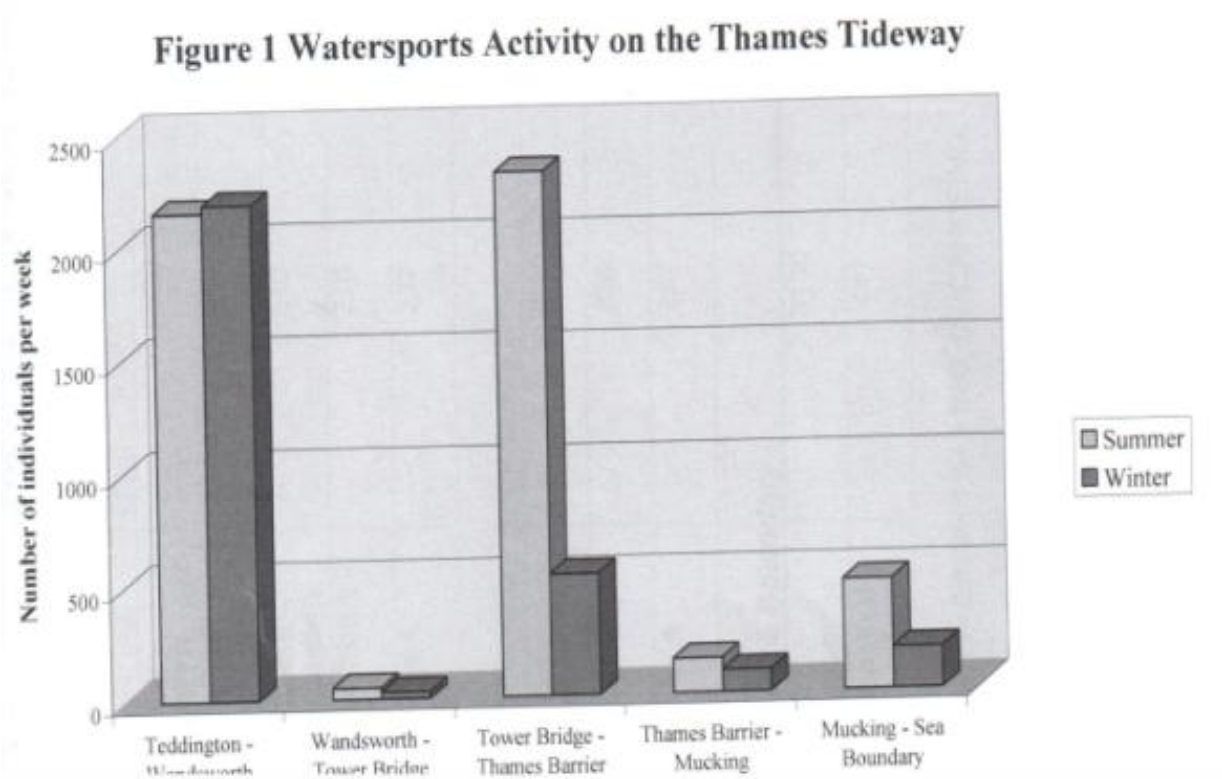
Water quality for bathing

In any case none of the Tideway is designated as a bathing water under the Bathing Water Directive and so there is no statutory water quality standard to be met. Thus the micro-biological standards are not directly relevant.

Identification of other recreation

The number of recreationalists was surveyed and the numbers reported in the document "Recreational Use of the Thames estuary."

The numbers found in each reach is shown on the histogram below.



Water quality standards

The Health Protection Agency (HPA) report The Thames Recreational Users study 2007, states on page 1 "*there is little evidence to link the presence of high levels of bacterial indicators of faecal pollution to the level of risk to human health."*

page 48 "*The 95 percentile of indicator organisms in the upper tideway permanently remain above the WHO microbiological standards for recreational water and this represents a potential health risk to recreational users*." Thus there is a background health risk in the Tideway irrespective of the CSOs.

However the "*WHO guidance is only aimed at bathers*" total immersion and risk of ingestion " *and as such is not necessarily indictors of risk to other recreational use such as rowers, sailing etc..."* HPA page 8.

Spill impact

"*There is evidence to suggest that the influence of secondary treated effluent from Mogden sewage treatment works is as great as that of the less frequent but common CSO discharges."* HPA 2007 page 54. Mogden STW upgrade was completed in March 2013.

Health Protection Agency assessment

The key information from a major study of health risks to recreational users in the upper part of the Thames (upstream from Putney Bridge) is summarised in the TW 2010 Needs report:

"*An assessment of health impacts upon recreational users of the River Thames was conducted and reported by the Health Protection Agency in 2007. This report, which quoted an EA estimate of between 3,000 and 5,000 recreational users of the tidal Thames... While there was evidence of an elevated health risk (gastric infection) to recreational users in the upper Tideway two to four days after a CSO spill event, the rate of gastric infection among recreational users was very low (12.8/1000/year) compared to the general population (190/1000/year). This may be due to the relative good health and fitness of recreational users, a greater awareness of hygiene and health and safety issues, and a developed immune response to infection from repeated exposure, which results in asymptomatic infection*."

The fact that gastric infection rates among recreational users in the upper Tideway are less than one tenth of the incidence level in the population as a whole, is a fair indication that the Thames health baseline, and the possible impact of the intervention, are not significant on a national scale in terms of the potential health impact.

Benefit of dealing with gastric events

It is recognised in the water industry that stated preference surveys are prone to overvaluation. The justification for using them is that there is usually no better alternative available. In this case there is a better alternative, and it is fully compatible with both the Advocate General's guidance and Treasury Guidance on Managing Risks to Public Health.

NERA did an analysis on the basis of the government guide on Managing Risks to the Public which discuses the Quality Adjusted Life Year(QALY) as a tool for cost effectiveness analysis of health impacts. NERA states that around £30,000 QALY appears to be increasingly accepted by government as a method of valuing health impacts. NERA did an analysis of the values of the potential health benefits based on the number of recreational users, annual risk of infection, average duration of illness expressed as % of a year, and value of quality of life adjusted life year.

"for example, *assuming that number of recreational users per year (N) is 5,000, the risk of infection during each year (R) is 18/1,000, the average duration of illness as a fraction of a year (D) is 3/365, and the value of a QALY (V) is £30,000, and assuming that the loss of quality of life during the period of illness is total, this would lead to an estimate of the annual cost of the health impact (=N*R*D*V) of £22,000. The corresponding discounted present value of such a stream of annual costs in perpetuity, if discounted the pure time preference rate for utility of 1.5 per cent specified in the Treasury Green book, is £1.5 million."* Page 29 of the NERA cost benefit analysis. Thus £1.5million is the amount it would be worth investing to deal with the gastric health risk problem.

The QALY method analyses the illnesses arising from gastric events which are short and uncomfortable rather than permanently disabling. There may be more serious pathogens present, and these would need to be explored in a full valuation, but it is not clear that they (or indeed the more routine forms of gastro-intestinal infection) can be eliminated altogether as users are also exposed to pathogens in treated but undisinfected effluent and through other infection pathways.

Even the £1.5m estimated QALY valuation assumed that relevant illness could be reduced to zero from the observed infection rate of 12.8 cases per 1000 person years, compared to 190/1000 person years in the population as a whole. A zero rate of infection seems improbable. There will at best be a small reduction in an already small risk.

Mogden Sewage treatment works improvements

Since then (April 2013) improvements have been made to Mogden STW including much increasing the flow to full treatment, improving the normal discharge quality, and reducing the storm overflows from about 110 spills a year to about 20 spills a year. Because now the more polluting first flush effect goes into the storm tanks, what now spills is "*heavily diluted storm water which is screened, settled in tanks and mixed with fully treated wastewater before it reaches the river*" TW Sewage Discharge Notifications. Thus the health risk impact of the remaining spills would be reduced from what was spilt prior to the upgrade. Thus the benefit of reducing the health effect would be less than previously assessed.

Spill notification

Thames Water now issue Sewage Discharge Notification to the rowing community and others as to when the Mogden STW and the Hammersmith Pumping Station system "*has in the last hour discharged untreated storm sewage*". Thus notification of a spill is already provided by Thames Water. This is welcome in helping river users to avoid such conditions should they consider this any risk.

Recreation in the London Docks

From the histogram above one can see that the other major area of recreational use is in the Tower Bridge to Thames Barrier reach. Looking at the details in the Recreational Use of the Thames Estuary report these are very largely dinghy sailors and water skiers in the London Docks. These are discrete non-tidal bodies of water where the only contact with the River Thames water is the abstraction of a small amount of water to top up the docks following loss from evaporation or leakage.

Assuming that the evaporation per year is about 600mm and that this occurs over a period of 200 days then the evaporation rate would be about 3mm/day. Allow a similar amount for seepage making a total of 6mm/day. Taking the areas of the Royal Docks as about 84ha, then the top up rate would be about 5Ml/d. A similar calculation for the West India Docks gives about 2Ml/d.

Whilst Thames Water is not responsible for the quality of the water in the docks, by their STW discharges and CSO spills they do influence its water quality. Should the water quality in the docks used for recreation not be sufficient, and the quality of the Tideway water be an issue, then it is suggested that water treatment could be provided to the top up water. These would have to cope with significant turbidity at times. One method that could be considered would be some form of moving bed sand filter to remove solids and disinfection using hypochlorite.

The cost of two small water treatment plants would be, I am advised, about £2million for the Royal Docks and about £1m for the West India Docks, a total of about £3 million. Such a system should be implementable within about two years.

Conclusions on recreational health

The TTSS objective was to substantially reduce the elevated health risk due to intermittent sewage discharges. The recreational users of the Tideway are primarily rowers in the Upper Tideway.

The EA assessed that 19 CSOs contribute to health risk. However this was subjective with no health evidence to support the assessment.

The Tideway is anyway not a Designated Bathing Water and thus does not have to meet Bathing Water Directive standards. In 2013 the PLA have effectively banned swimming in the Tideway.

The 2007 HPA study shows that rowers are ten times less likely to get gastric problems than the general population. Thus the vast majority of the recreationalists would already not be affected by elevated health risk as set in the TTSS objective and thus the Tideway would meet the TTSS objective.

The Quality Adjusted Life Year analysis done by NERA based on the2007 HPA study shows that, even if one were to be able to avoid all gastric events, it is not worthwhile spending more than £1.5million on health improvements in the upper Tideway.

The HPA study and the PLA announcement were done after the early EA assessments of the CSOs that contributed to adverse health. Thus the Environment Agency assessment should be reconsidered, taking on board the evidence from the HPA study, the NERA QALY analysis, the improvements at the Mogden, Beckton, and Crossness STWs and the Lee tunnel, and the recent PLA restriction on bathing.

Thus, considering the improvements already made to Mogden STW discharges, and the QALY analysis, it would not appear to be warranted spending more than £1.5m on any further measures.

7. Cost and need for further mitigation measures.

The objective of the Urban Waste Water Treatment Directive is "*to protect the environment from the adverse effects of ...waste water discharges."* From the three chapters above it would appear that, post the completion of the STW upgrades and the Lee tunnel, the TTSS objectives to meet the UWWTD would be met.

If thought appropriate to achieve even higher environmental standards, there are a series of measures that could be used to improve conditions further. Were the tunnel to be constructed, then these could be used as interim measures.

The cost is estimated/budgeted to be

Booms around CSOs	£ 2m
Workboat to collect boom debris	£ 1m
Oil and fine litter skimmers	£2m
Fixed diffuser system and monitoring	£ 12m
Docks water treatment system	£ 3m
Total	about £ 20 million.

These estimated costs do not include the costs of measures to reduce spill frequency. These costs estimates are at concept stage. Proper feasibility study and costing would be required to identify what is feasible, and with what benefit.

Potential fines

Having been found guilty in the ECJ for breaching the UWWTD, the UK is in danger of being fined by the European Commission. The mechanism for calculating the amount of fine is based on the seriousness of the infraction and the length of times during which it continued. We now know that the collecting system, even in its unimproved state, has caused no significant fish kills in a decade.

The commitment to the Tunnel can be reviewed and more widely beneficial alternatives can be considered without legal risk, but only if the Department takes a more objective view of benefits/impacts. I understand that the fines will be fixed at a level taking into account the Defra own estimate of impacts/benefits. There is therefore a double reason to get this right, and no case at all for further enhancing impacts/benefits

Disproportionate cost

The Thames tunnel is estimated to cost about £4.1bn. One question remains as to whether this cost is disproportionate.

The Advocate General, in his Opinion on the infraction proceedings para 62, states *"The disproportionate cost of some works, hence the lack of any need to undertake those works in practice, can be reliably assessed by taking into account also the* ***environmental effects of leaving those works unaccomplished****. It is clear that not carrying out some works, and tolerating inconsequence some discharge of untreated water into the environment, will be all the more acceptable the lesser the potential damage which the untreated water would cause."* My emboldenment

It is clearly arguable that, post the Lee tunnel completion, the TTSG objectives would appear to have been met, no identified elevated health risk days, fish sustainable, and few public complaints on litter, thus the environmental effects of leaving the tunnel not constructed would appear to be very low. In any case, If thought appropriate, the further measures could be implemented to reduce the remaining aesthetics effect by installing the booms and increasing the dissolved oxygen by providing in river bubbler systems as done in Paris for a total estimated cost of about £20m.

Cost benefit analysis

In November 2011 defra issued a Cost and Benefits of the Thames Tunnel report. This was based on the 2006 eftec Stated preference Survey and the Nera Cost Benefit Analysis with benefits updated to 2011 and further benefits added. This concluded with an assessment of benefits of some £3bn to £5bn. I considered this in my cost and benefits analysis report, dated March 2013. My assessment of the defra report and the base documents concluded that there were several places where the defra analysis was not robust, including a mathematical error which I assessed as about £0.5bn, and that the **benefit would be about £290m**. This compares with the construction cost of £4,100 m. My report was submitted to defra and the Environment Agency and **has not been challenged by either organisation.**

More recent information on GDP growth and other elements has resulted in my assessment of the benefit becoming £310m. However, now that it is recorded that only one fish has been killed by the Tideway CSOs in the last ten years, the benefit of the Tideway tunnel would be only £180m. See separate Cost and benefits analysis report dated 15th January 2013. Thus, on a cost benefit basis, the tunnel is not cost beneficial.

"The Climate Change act 2008 created a legal framework to cut greenhouse gas emissions and build the UK's ability to adapt to a changing climate. Water and sewerage companies are expected to reduce carbon emissions..." Drainage Strategy Framework Good practice guidance commissioned by the Environment Agency and Ofwat. May 2013 page 10. The Tideway tunnel will increase the pumping head by about an extra 50m for the about 16 Mm3/year, a considerably increased energy use, hence increased carbon emissions. I have been unable to identify where such an adverse effect has been taken account of. The possible alternative measures proposed by me in subsequent sections do not generally have any extra operational carbon emissions.

BTKNEEC

It does appear that the construction of the tunnel at £4.2bn would be vastly "excessive cost" and "*disproportionate cost*".

The European Court judgement states concerning BTKNEEC *"30.The Commission submits that that concept must be read in the context of Directive 91/271, of its aims and of its objectives, namely to protect the environment from the adverse effects of waste water discharges*." Since there do not appear to be any elevated health risk days and the QALY analysis shows it is not worth spending more that £1.5m, and the fish appear to be sustainable, and the litter complaints are "*relatively few"* it would appear that, post completion of the STW upgrades and Lee tunnel, the Tideway will be "*protected from the adverse effects of waste water discharges*."

The ECJ judgement states "*31. It* "the Commission " *submits that the concept of BTKNEEC allows Member States to chose between several solutions that promote compliance with both the provisions and the objective of the Directive 91/271, such as building new or increased storage facilities or diverting rainwater before it can enter the collecting system*."

To date about £1bn has been spent on upgrading the STW and constructing the Lee tunnel, a not insignificant sum. The question is whether it is necessary to spend yet more.

The Court considered *"para 90. Thus technical solutions to the problem of the collecting system for London exist and their costs cannot be regarded as disproportionate given that the United Kingdom has already taken the decision to implement them*."

It is true that in March 2007 the UK government instructed Thames Water to procede with the tunnel and that since then the Thames tunnel has been included in the National Policy Statement for Waste Water. However it is only the Secretary of State, acting on the recommendation of the Planning Directorate, who can finally decide and that has yet to take place. Thus this part of the ECJ judgement may be challengeable. In any case the costs of the tunnel are the costs of the tunnel, irrespective of any reasoning that surrounds them.

"67. The concept of BTKNEEC must be examined by weighing the best technology and the costs envisaged against the benefits that a more effective water collection or treatment system may provide. Within this framework, the costs incurred cannot be disproportionate to the benefits obtained."

*"68. In that context, account will have to be taken, as the United Kingdom submits, of the e**ffects of the discharges of untreated waste water on the environment** and in particular on the receiving waters. The consequences that those discharges have for the environment would thus enable examination as to whether or not the costs that must be incurred to carry out the works necessary in order for all urban waste water to be treated are proportionate to the benefit that that would yield for the environment."* My emboldenment.

After spending some 15 paragraphs musing on the meaning of BTKNEEC, and generally assuming it to apply widely to the interpretation of the Directive, the Advocate General's concludes with a two-part test:

"67. Accordingly, what I propose is a two-stage verification process, in relation both to collecting systems and to treatment plants. During the first stage, it must be established whether the discharges can be regarded as an exceptional event, or, more accurately, as an element in the operation of the collecting system or treatment plant which is not 'normal'. During the second stage, if the first stage has revealed that the events resulting in the discharge of untreated water into the environment were not exceptional, it must be established whether the BTKNEEC clause applies. During this stage, the burden of proof – which, during the first stage, is shared in the usual way between the Commission and the Member State – falls entirely upon the latter. It is for the Member State to prove that securing an improved level of collection or treatment of the water would be technologically impossible, or would involve costs that are wholly disproportionate as compared with the resultant benefits for the environment."

There is nothing in either of these conclusions which restricts the concept of proportionality or excessive cost so that it implies only "by way of exception", indeed the second part of the Advocate General's two part test, which the Court generally follows, expressly applies only where overflows are not exceptional. The Advocate General is also entirely sympathetic to guidance from the Commission providing general norms, always accepting this cannot amount to writing a specific numeric limit into the Directive, and that the impact of unchecked overflows on receiving waters and the cost of reducing that impact are in the end the test.

Thus, if the cost of the tunnel is excessive compared with the benefits, which in this case it does appear to be, then the BTKNEEC clause would conclude that some other measure, or combination of measures, should be adopted.

Spill frequency

Thus the remaining consideration is whether the Tideway has to also meet the provision in the Directive to only spill under unusual rainfall conditions. If that is so, then there is the question as to what is the allowable spill frequency.

"*We will end the so-called gold plating of EU rules, so that British business are not disadvantaged relative to their European competitors."* Coalition in its Our programme for Government 2010. The tunnel would spill about 4 times a year. Is that gold plating?

However the Advocate General's Opinion of the infraction proceedings, January 2012, states in para 48 "*On several occasions, however, both in the pre-litigation stage and before the Court, the Commission did indicate that, as a rule, exceeding* ***the limit of 20 overflows a year*** *would be a cause for concern, suggesting a possible failure to fulfil obligations. Despite all its limitations and without prejudice to the need for a case-by-case assessment,* ***a numerical criterion of that nature may be reasonable and acceptable as it had been determined by comparing the practices existing in the various Member States****."* Emboldenment added by me.

"50 The result is that, while, on the one hand, the United Kingdom cannot be criticised for having based a large part of its argument on the ***20-overflow rule, which is the only rule to have been set out by the Commission with some measure of clarity*** *during the pre-litigation procedure and, in particular, in its additional reasoned opinion...."* My emboldement.

The ECJ judgement, para 28, states that the Commission "*does not propose a strict 20 spill rule but points out that the more an overflow spills, ...the more likely it is that the overflow's operation is not in compliance with Directive 91/271."* Thus, since it would appear that, post the operation of the Lee tunnel the Tideway would meet the Directive environmental aims, it would seem that a spill frequency of about 20 spills a year, as has been proposed by the EC, would be appropriate for the Tideway.

However the objective of the UWWTD is "*to protect the environment from the adverse effects of the above mentioned waste water discharges."* It has been shown above that the effects of the current number of spills on the environment cause no significant effect. Thus it is quite possible that a higher number of spills could be allowed. Further the works currently under construction, including the STW upgrades and the Lee tunnel, will improve matters further. It would also be possible to construct booms around most of the CSO to retained litter until collected by floating equipment and to utilise the two existing litter collectors for the other CSOs. Thus it is quite possible that, should the correct evidence be presented, then the EC would accept the current situation.

However, that is speculation at present so I have had to assume that the aim of 20 spills a year as proposed by the EC would remain. The following sections consider how to reduce the spill frequency to 20 spills a year at least cost.

Drainage Strategy Framework

The Good practice guidance commissioned by the Environment Agency and Ofwat , May 2013 states on page 12 "*The framework promotes the full evaluation of alternatives to traditionally engineered sewerage solutions to test whether these offer lower whole life cost options or better responses to uncertainty. It is anticipated that drainage solutions in the future will be different from the ones we are used to."* The main TTSS studies were carried out in 2003/4 and reported on in 2005. At that time the only alternatives to reducing spill frequency which were considered were SuDs ,about which little was known, and a totally new foul drainage system which would have resulted in almost zero spills but at vast cost. In 2009 studies were done on a pilot SuDs system in the Putney area, but with no consideration even of infiltration into the underlying gravels and SuDs was rejected as the system could not achieve 10 spills a year. Since then it has been found that the sewer modelling was incorrect and the acceptable spill frequency has changed to up to 20. Further a number of techniques such as real time control/active system control have become available.

Thus the previous studies are out of date or inaccurate and are not a sufficiently robust basis for major expenditure. Thus, before major expenditure is involved, a study should be done to confirm, or otherwise, that the tunnel is still the most cost effective solution.

Combination of measures

I have not been able to find any significant study which has looked at a combination of all of the measures for the London CSOs.. My belief is that this is a requirement.

The defra River Basin Planning Guidance (RBPG) vol 2 August 2008 states in 9.4 "*As river basin planning principle makes clear the Environment Agency should consider the full range of measures which are available*."

In 9.5 the RBPG states "*The WFD requirement is to make judgements about* ***the most cost effective combination of measures,*** *so it is important that the Environment Agency considers the inter-relationship between measures."* My emboldening.

Whilst the PINS would not normally look at alternatives to schemes set out in an NPS, at the EFRA hearings in February 2011 on the draft NPS for wastewater, the government, in response to Q 205, said that "*the IPC will look very carefully ...at alternatives*." In response to Q209 the Minister replied "*the IPC will look at issues relating to this scheme and alternatives...."* Thus it would appear that government intended the PINS to also study alternatives.

8. Reducing flows into the combined sewers

"*Where a company may hsitorically have preferred to tackle sewer flooding or combined sewer overflow pollution by increasing its underground equipment to store more rainfall during storms, it might consider other options in future; such as working with customers to manage rainfall close to source, or preventing it from entering the sewer system...storm water retrofit techniques...enhancing incentives for customers to reduce surface water flowing to sewers... Water and sewerage companies should continue to review and develop other innovative solutions."* Drainage Strategy Framework, Good practice guidance commissioned by the Environment agency and Ofwat, May 2013 page 12.

Previously methods were studied as standalone, such as total separation which would acheive zero spills, but were found to be too expensive. The River Basin Planning Guidance 2008 9.5 states " *The WFD requirement is to make judgements about the most cost effective combination of measures, so it is important that the Enviironment Agency considers the inter-relationship between measures."*

In this section I look at a combination of measures such as the assumptions made by Thames Water on the flows in the existing sewer model, then look at the actual Thames Water water supply projections, and then look at ways that the flows into the sewers could be reduced even further. This can be done by reducing water use, the use of Sustainable Urban Drainage Systems(SuDS) and Blue Green Infrastructure, separaton of the foul and storm flows and also by diverting the sewer flows to other catchments. These meausres could be used as a combination where they are most cost effective in reaching the required spill frequency.

Comparison of modelled sewer spills with records of actual spills.
Thames Water sewer model was run for a large number of rainfall events, I believe 154, over a number of years. The output of the model was used to predict how often each CSO would spill and what volume would be spilt. This was then adjusted to provide frequencies and volumes in an

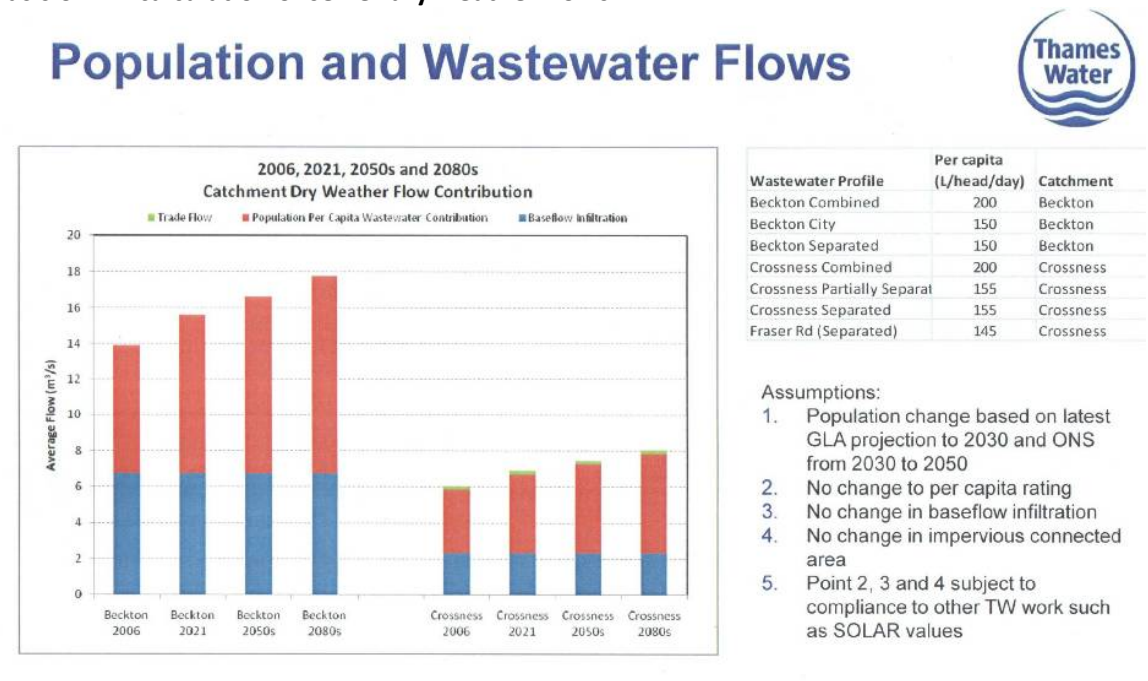
average year. This output for each CSO is shown in the Table in Appendix A. For instance Hammersmith pumping station was found to spill on average 50 times a year.

It was this model output which the Environment Agency used to assess which CSOs were causing unacceptable impact.

Thames Water now provide Sewage Discharge Notifications which are relayed to anglers and rowers and can be accessed through the Thames Anglers Conservancy. This gives information as to when Hammersmith Pumping Station spills. The period from 1st October 2012, to 24th October 2013 ie 12.6 months, then Hammersmith pumping Station spilt 27 times, ie 25 times a year on average.

This compares with the 50 times a year quoted in the TW CSO spill frequency analysis for Hammersmith. CEH, in their September 2013 Hydrological summary state that for the Thames catchment this period up to 1st October 2013 has 107% of average rainfall so it is wetter than normal. Thus one would have expected the number of spills during this period to have been above the average. This does seem to show evidence that the spill frequency in the TW model for Hammersmith of 50 times a year could be higher than reality. It would be appropriate to check the model outputs with the latest spill data.

Basis of TW calculation of sewer dry weather flows



Thames Water have used figures for dry weather flow (DWF) for 2011, 2021, and 2031.However the only basis I can find is on image 13 of the presentation given to me on 30th September 2011. This shows the Beckton dwf rising from about 13.9 m3/sec in 2006 to about 15.8m3/sec in 2021 and about 17.8 m3/sec in 2080s. Crossness shows a similar proportional increase. To the side the image states "*no change to per capita rating*." Further the image says *"No change in baseflow infiltration".* Infiltration is made up of both leakage and rainwater/groundwater infiltration.

This is an increase of some 14% by 2021 and 30% by 2080. This was reported to lead to a "*near continuous CSO overflow*" in the later years and is one of the reasons provided by the EA for the requirement for the full tunnel. It would appear that these sewer flows are the ones used in the TW sewer modelling. Judging by eye from the histogram the flows would appear to be

Beckton	Crossness
2006 13.9 m3/sec	5.9 m3/sec
2021 15.8 m3/sec	6.6 m3/sec
2030 15.95	6.8 m3/sec
2035 16.05	6.9m3/sec

That would be an increase by 2035 of Beckton about 2.15m3/sec and Crossness about 1.0m3/sec, 3.15m3/sec which I calculate as about 270 Ml/d.

Sewer and interceptor flows are driven by flows going into the sewers and this is due to household use, leakage, and groundwater infiltration. The last is likely to be driven by rainfall and to be largely similar on an annual basis. Thus sewer dry weather flow should correlate with water delivered to households and with leakage .

The area sewered to the Tideway interceptors is similar to, but somewhat smaller than that, supplied by Thames Water with water, so, judging by eye, a factor of about 85% of the water delivered ending up in the sewers would seem to be a reasonable assumption.

The Environment Agency have used the water into supply for the analysis so I will do the same. The projection of water to be supplied by Thames Water is given in the Thames Water Water Resources Management Plans (WRMP) 09 and dfWRMP14, table WRP5-FP. This shows water into water supply

2006/7	2180 Ml/d
2021/22	1943
2030	1917
2035	1952

Thus by 2035 there is a projected drop from 2006 of about 230Ml/d.

Thus the total reduction from that assumed by TW would be a total of the order of 500 Ml/d. This is about 20% of the flow in the sewer of about 2,000 Ml/d. Since the sewers are reported to becoming fairly full this could have a significant effect in some of the smaller spills now being able to be retained in sewer. Thus this correction should reduce the spill frequency significantly.

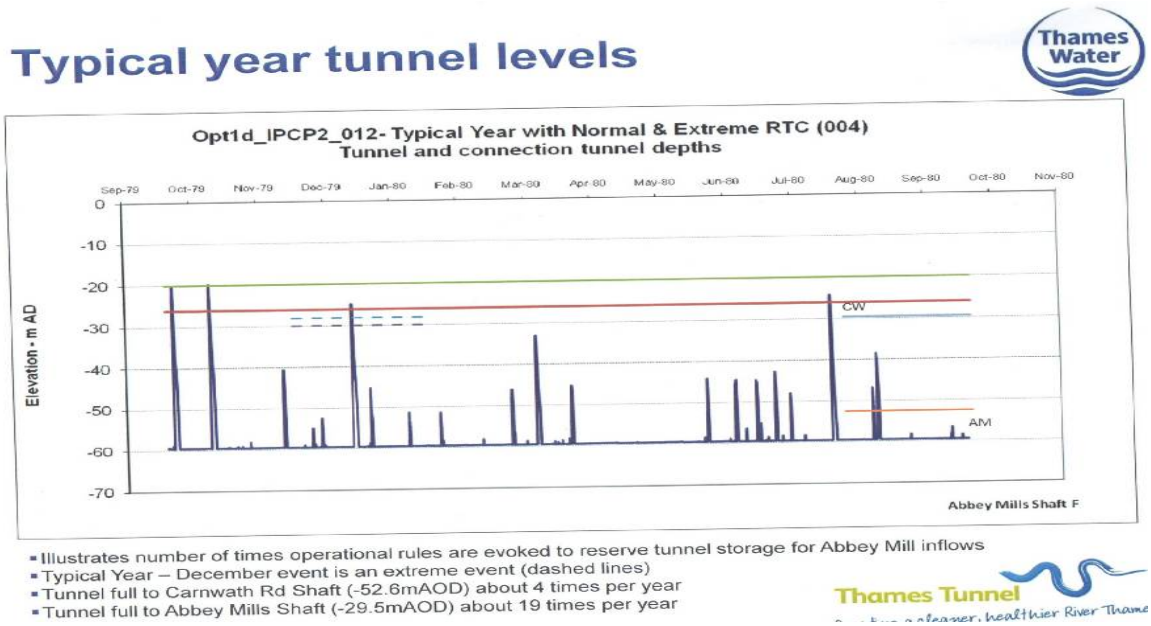
Therefore the water supplied, and hence reaching the sewers, is projected to go down during this period rather than up as in the TW sewer analyses and publicity material. As an illustration see the spill volume from the Falcon brook pumping station, see Appendix A, that due to the increasing population from 2006 to 2021 the spill volume increases from 709,000 to 779,000, a 10% increase. This should be a decrease due to less water being delivered to customers.

It is not possible to reliably split sewer infiltration between rainfall and leakage. An analysis of the inflow to Beckton STW does seem to indicate that, when TW reduced leakage, then the inflow to Beckton went down by a not dissimilar amount, see analysis in my Project Justification Report 2012.

Thus a reasonable assumption would seem to be that, by 2035, sewer dry weather flows as assumed by Thames Water would be nearly 20% more than projected dry weather flow. Thus, instead of spill volumes and frequency increasing as shown in the TW model results, spill frequency and volumes would actually decrease.

In the TW Engineering Design Statement 7.18 it says, (I cannot find the current quote so from memory), that changes in the dry weather flow would not significantly affect spills. That would be true for the tunnel where only large rainfall events would spill. However, in the case of spills from the existing sewer interceptors where there are many spills a year, many of these are small and a reduction of the sewer dry weather flow could have a significant effect on spill frequency. This is confirmed in the Resilience to change 7.23 page 13 "*but foul flow also affects discharge due to the combined nature of the sewerage system.*" This is illustrated by the diagram below where it can be

seen that of the 50 or so spills a year, about a third are of very low volume and, with revision of the dry weather flow in the interceptors, many of the small ones might not spill at all.



Thus, in my view, the current analysis of future spill frequency cannot be considered as robust and the sewer interceptor spill analysis should be re-run taking account of the conditions projected by TW in its WRMPs.

Reduce flow into the sewers further by reducing water use.

A further way to reduce sewer flows would be greater demand management. As an illustration the rdWRMP14 shows metering in 2020/25 to be 70% rising slowly thereafter to 75%. TW in its WRMP09 had set a limit of 80% on metering. In its Strategy discussion document TW says it will meter all homes by 2030. Increased metering, along with other demand management methods, would reduce water use and hence sewer dry weather flows further, and provide greater capacity to accept storm flows.

In additon, further demand management measures could be adopted, such as more non-household water audits. The benefit of doing this has been considered only for the water supply. Thus, including the reduction in sewage dry weather flow, would increase the available storm water capacity and hence the benefit of doing greater demand managment and make it economic to do more demand management measures. This should be considered.

Reduce flow in the sewers by reducing water main leakage and infiltration into the sewers.

All water main systems leak and some of the leakage is collected by the sewer and interceptor system. Reducing leakage further would also reduce sewer dry weather flow. This benefit should be considered.

Despite the aim in its Strategic Direction Statement to acheive water company average leakage, Thames Water still has the highest per capita leakage of any of the water companies. Thus there

would appear to be scope for reducing leakage further to reduce sewer inflow. When calculating the benefit of leakage reduction TW only take the benefits from the water supply element. They do not include the benefits of reduced sewer infiltration. Thus there would be scope to reduce leakage, and hence sewer inflow, further.

Sir Ian Byatt, the previous Director General of Ofwat has said in his Thames Tunnel: A Critique of a flawed Project " *A further contribution would be to reduce the considerable infiltration of ground water into the sewers. ...What seems to have happened in the intervening 24 years"* since privatisation " *is an accelerated deterioration in the smaller feeder sewer network that, coupled with continuing high urban leakage, is exacerbating infiltration into the sewerage system. .. I know of no evidence that Thames has investigated this or that sewer infiltraiton is seen as a problem. It would be perverse to reward Thames with a major increase in RCV as a consequence of its decision to improve its profitability by neglecting maintenance of the sewerage network."*

One of the interventions listed in the Welsh Water strategy is the relining of sewers to prevent groundwater ingress.Drainage strategy framework , May 2013 page39. Many of the London sewers are old, similarly to the London water supply pipes that, despite appreciable replacment, still have the highest leakage rate of any water company in England. Thus it would be reasonable to assume appreciable sewer infiltration. This appears to be supoprted by the Thames Water Population and Wastewater diagram a few pages earlier where the base year dry weather flow in the Beckton catchment appears to be about 40% infiltration (blue part of the histogram). Thus reduction of sewer infiltration may well be an appropriate measure in some areas.

I have been unable to identify where the potential and cost of this has been considered and reported by Thames Water. It should be considered appropriately.

Sustainable Urban Drainage Sytems and Blue Green infrastructure

One way to reduce storm runoff into the sewers is Sustainable Urban Drainage Systems (SuDs) and Blue Green infrastructure (BGI).

SuDs has the aim of holding back flood water and releasing it slowly. This can be done by "green" roofs planted with vegetation, permeable paving allowing water through to the soil below, often a gravel sub base layer or a artificial hollow structure, grassland depressions called swales that carry off water into ponds, and even garden water butts. Where the geology is appropriate, the storm water can be infiltrated into the ground.

"Our increasingly impermeable built landscape heightens the flood risk during heavy rainfall. Surface water run-off in urban areas overloads the combined sewers, causing the overflows to spill into watercourses.Suds alleviates the problem by mimicking the way rainfall drains away in nature. Measures include soakaways, balancing ponds, wetlands, and permeable drainage channels known as swales, all of which reduce the total rainwater volumes reaching the conventional surface water drains, combined sewers and rivers, and attenuate peak flows. ...permeable surfaces used for pavements, roads or car parks and even sedum roofs can be incorporateed into urban environments...Planning Policy Statement 25 (Development and Flood Risk) which states that local authorities should give priority to the use of Suds when deciding applications" Victoria Joy, legal director at Addleshaw Goddard. However this only applies to properties where a planning application has to be made, a limited number each year.

Some of these water storage areas could be in gravel or plastic box strutures designed to be under streets or car parks. Below is a typical plastic storage system.

Such techniques were looked at by TTSS but had not been sufficiently developed then and there was little experience of them at the time of the TTSS consideration in 2002. Thus the TTSS was not then able to recommend such an approach as being a viable option to meet the UWWTD.

Recent policy pronouncements

In the Application for Development Consent Planning Statement doc 7.01 Managing effects TW states "*7.4.23 One of the Government's key policy objectives (NPS para 2.2.3) is to reduce demand for wastewater infrastructure capacity by diverting surface water drainage away from the sewerage system using SuDS. The NPS recommends that "opportunities should be taken to lower flood risk by reducing the footprint of previousl-developed sites and using SuDS." (NPS para 4.4.22). If SuDS are provided, the NPS states that the development consent Order, or any associated development consent obligations, needs to make provision for their adoption and maintenance including any necessary access rights to property (NPS para 4.4.11)*."

The European Commission has promulgated in May 2013 its Communication on Green Infrastruture – Enhancing Europe's Natural Capital. COM(2013)249 final. This was issued after the NPSWW had been issued by the British Government. Thus the NPSWW would not have taken account of this Communication. "*Green infrastruture can contribute significantly to achieving many of the EU's key policy objectives...The European Commission adopted today a new strategy for encouraging the use of green infrastructure , and for ensuring that the enhancement of natural processes become a systematic part of spatial planning*."

The use of SuDs, green infrastructure and Integrated Water Resource Management (IWRM) is the way that many European and American cities are now going to overcome similar problems. Financial incentives drove up numbers of green roofs in Germany 19-fold in just 12 years. In Melbourne, Australia, a five-year scheme is establishing 10,000 "raingardens". The Augustenborg suburb of Malmo has been relieved of regular flooding by a network of green roofs, swales, ponds and mini-wetlands. Several cities in America, including Portland and Phildelphia, are establishing

similar natural infrastructure. BGI, with the planting of trees and other vegetation,would also improve the environment in London, should reduce summer temperatures, and should improve the health of the inhabitants. This is one of the major benefits of such a scheme in Phildelphia. Should not London do more than it is at present?

The Drainage Strategy Framework Good practice guidance commissioned by the Environment Agency and Ofwat May 2013 states on page 8 "*Water and sewerage companies are encouraged to invest in natural as well as built infrastruture to deliver their desired outcomes. The Natural choice demonstrated how this type of investment can deliver a wide range of positive social, environmental, and economic outcomes. Benefits can be determined using "payments for ecosystem services" methods. Water and sewerage companies are encuraged to consider these approaches where they can deliver cost beneficial outcomes for their customers. This is relavant to drainage planning because it encourages the use of retrofit sustainable drainage systems in place of more traditional sewer upsizing and storage."*

Page 30 *"It is becoming common place for North American cities to addess the issue of frequent combined sewer overflow (CSO) operation by using a combination of grey infrastructure (sewers) and green infrastrucuture. The wider health and ecological benefits of green infrastructure approaches and the reduced reliance on matriials and energy are attractive to utility planners and cities alike....Based on this New York has committed itself to an aggressive green infrastruture based runoff control strategy to provide long term redcutions in CSO spills."* Thus, with the general committment to a combination of such measures, the tunnel soution may well be outdated and it should be up to the tunnel proponents to show otherwise by a consideration of a combination of mesures including SuDs/BGI.

Thames Water in its Strategy Discussion Document page 17 states "*We will take steps to reduce the amount of rainwater that enters our sewers."* As a strategy in the short term (2015-2020) page 19 *"A major part of this long-term goal will involve working with the Environment Agency and local authorities to promote and install sustainable drainage systems."* Thus any measures or anlysis done within the catchment must assume that SuDs is promoted and installed in accordance with this strategy. However the modelling asociated with the DCO Application specifically ignores this benefit.

Geological suitability for infiltration

Parts of London are founded on impermeable London clay and associated head deposits. However the BGS geological maps 270 and 256 show much of the area between a line running approximately east west through Hyde Park and the river is Kempton Park gravel, with a similar situation on the south bank. Table 15 of the BGS memoire shows this as having a general thickness of 10-15m. There are also many other deposits of terrace gravel. Thus there should be scope for infiltration over about half the sewer catchment.

The Environment Agency report An assessment of evidence on Sustainable Drainage Systems and the Thames Tideway Standards October 2013 shows the BGS suitability of the subsurface for infiltration SuDS for each borough. This is split into 4 categories, Compatible for infiltration SuDS, Probably compatible for infiltration SuDS, Opportunities for bespoke infiltration SuDS and Very significant constraints indicated.

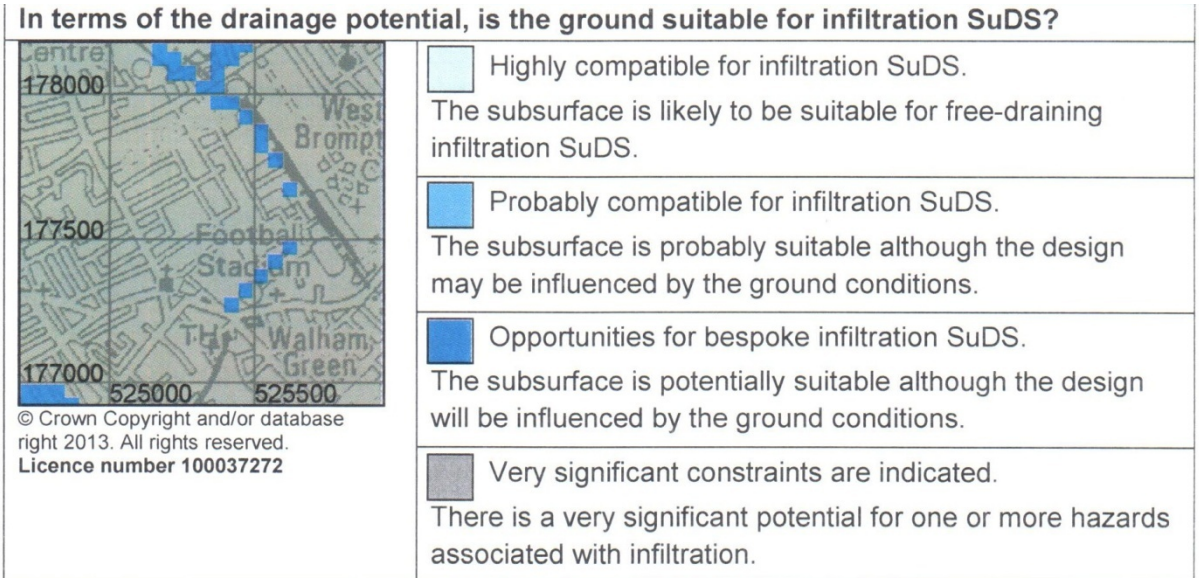
The Environment Agency report states in the Executive Summary "*The British Geological Survey (BGS) evidence highlights the limited scope for implementing wide-scale infiltration in the combined sewer network."* On page 13 this is referred to as "*key evidence*".

Bloomberg 2013 report Tunnel Vision page 19 provides the breakdown of the GLA area as 8%, 20% 39% and 33%. Whilst the sewer catchment area is somewhat smaller than the GLA area, there is no breakdown for the sewer catchment area and without such data one has to assume that, for this assessment, the GLA area represents sufficiently well the breakdown of categories in the sewer catchment area. "*In other words, infiltration SuDS could be developed, subject to some technical adjustments, across 67% of London's surface area. This conclusion is in contradiction with Thames Water's argument that SuDS cannot be implemented in London because it was built on clay.* " Bloomberg 2013.

It would seem appropriate to assume that "*Very significant constraints*" would generally not be suitable. The title "*Opportunities for bespoke infiltration on SuDS*" is defined as "*The subsurface is potentially suitable for infiltration SuDS, but the design will be highly influenced by the ground conditions.*"

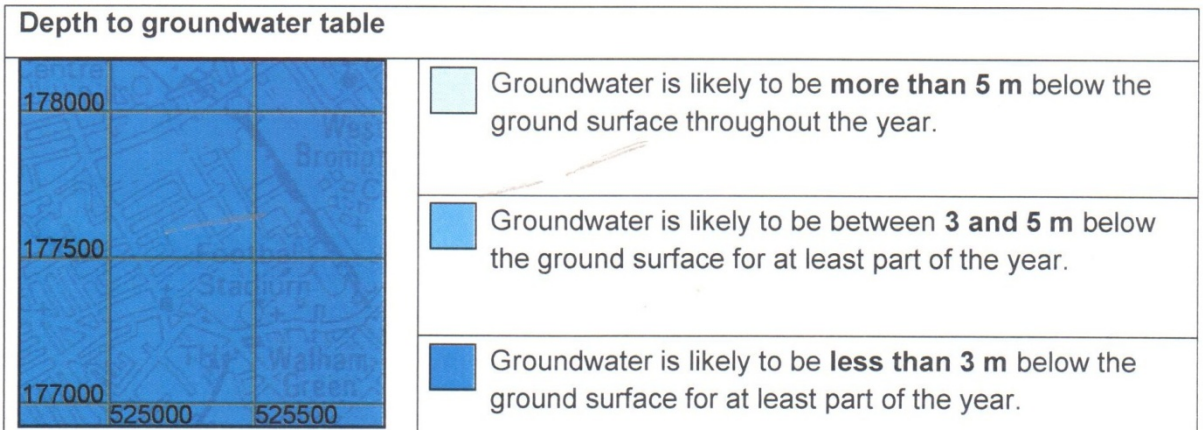
Example from Fulham

An important area for storm sewer flows is the area of Hammersmith and Fulham. Obtaining all the geological and infiltration information is expensive so I have chosen a representative area in Fulham. Much of this area is underlain by Kempton Park gravels which one would instinctively expect to be classified as appropriate for infiltration. However Table 4 of the EA assessment of Suds 2013, based on BGS data, states that the borough has 0% compatible for infiltration SuDS, 2% probably compatible for infiltration SuDS, and 64% Opportunities for bespoke infiltration SuDS. As an example I have obtained the conditions for an area of about 1km by 1km around Farm Lane in the area north east of Fulham Broadway. This is an area more than 2% of the borough. Almost all the area is marked as "*Very significant constraints",* see below.



The BGS report, Infiltration SuDS GeoReport for 99 Farm Lane, Fulham states that "*the superficial deposits are likely to be free-draining"*, likely as they are Kempton Park gravel. The permeability is "*likely to be high or very high*". The map shows that about 85% of the area is likely to have a superficial deposit thickness of greater than 3m. Another map shows in the entire area the "*water is likely to percolate through the unsaturated zone to the groundwater through the pore space in granular media".* However, for the whole area, the "*groundwater is likely to be less than 3m below*

the ground surface for at least part of the year." This is clearly the condition on which the BGS consider "*the design of infiltration systems would be highly influenced by the ground conditions".*



First many infiltration systems do not need the underlying strata to have a water table below 3m.

Secondly a borehole in the centre of the area, put down in December 2010 and reported on by RPS, a reputable infiltration and geotechnical consultancy, states "*The investigation identified …Kempton Park gravels to at least 3m depth (ie to the extent of the boreholes) across the site. Kempton Park Gravels were described as very sandy gravels with sand layers. No groundwater inflows were reported in the boreholes during drilling and subsequent monitoring of standpipes recorded dry conditions.*" 101 Farm Lane Fulham Flood Risk Assessment, page 7. The period January 2011 to August 2011 was somewhat drier than normal at 89% of long term average in the Thames catchment, but the difference of groundwater level in superficial aquifers in such circumstances would be expected to be close to normal. Thus the Kempton Park gravel at this place appears to have at least 3m of sandy gravel above the normal water table, and this should be very suitable for infiltration.

BGS geological map 270 shows Kempton Park gravel covers much, may be about 80%, of the rest of the borough, the rest being Langley silt. The cross section on page 75 of the BGS publication Geology of London shows that generally the thickness of the terrace gravel is about 6m, occasionally overlain by less than 1m of Langley silt. Thus even the areas shown on the BGS map as Langley Silt are likely to be underlain at shallow depth by several metres of terrace gravel. This area is remarkably flat. Whilst alluvial deposits do vary, much of the area marked as Kempton Park gravel and Langley silt should be suitable for infiltration.

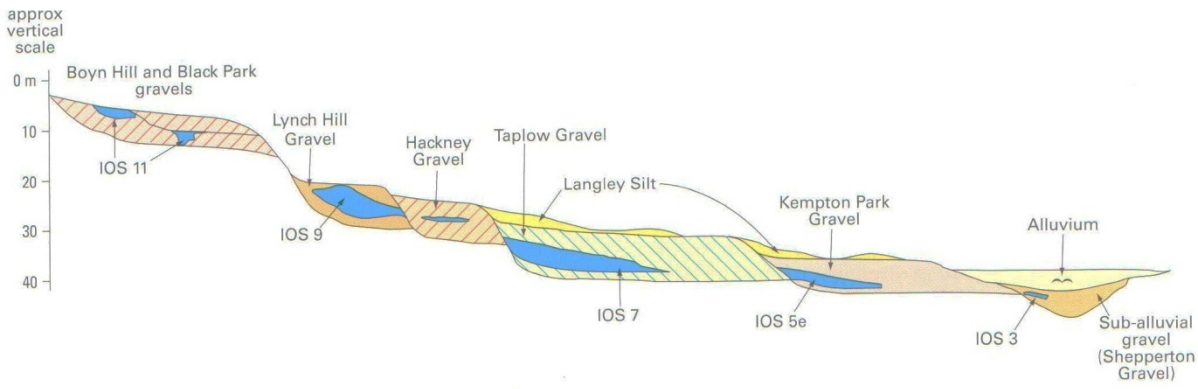


Figure 41 Schematic cross-section through the Thames River Terrace Deposits showing their relationship to interglacial deposits and their oxygen isotope stages (IOS) (after Bridgland, 1994).

Thus, on the basis of one area of about 1.5 sq km, the BGS geological map 270 which shows most of the area south of the east west line through Paddington to be underlain by terrace gravel, and the geological memoir, it would appear that the restrictions in the BGS assessment in this area do appear to be unnecessarily pessimistic, and it could be expected that in much of the area the so called "bespoke infiltration" would be relatively straight forward.

Thus, without being able to go into greater detail, it would be reasonable to assume that such areas underlain by gravels and classified as requiring bespoke design may well be suitable for infiltration, albeit with specially designed or bespoke measures in some places, and that the two other categories would generally be suitable. That would mean that about 67% of the sewer catchment area would be suitable for infiltration, with some areas subject to specially designed measures.

This seems at odds with the EA assessment of there being limited scope for implementing wide-scale infiltration.

It is also to be noted that, although in the Putney study area there are significant areas of Kempton Park, Boyne Hill and other terrace gravels,, see BGS map 270, the Pennine Water Group were instructed to assume that "*all of the SUDS units used in the study have had any infiltration capacity discounted."* The BGS geological map of this area shows a significant area of several metres of terrace gravel.

In addition, other techniques could be deployed where the subsurface is not optimal for infiltration SuDS. For instance, where water cannot infiltrate the ground, it can be stored temporarily in swales, subsurface gravel layers under roads, or constructed underground chambers. There are now strong plastic boxes specially designed for such requirements, see the photograph about 4 pages earlier.

Pilot areas in Putney in Appendix E to the 2010 Needs Report

The SuDS approach, by itself, was studied in Appendix E to the 2010 Needs report, for three pilot areas in Putney.

"The most comprehensive assessment of SuDS viability was undertaken by the Pennine Water Group in 2009 and was presented in the consultation of 2010 in Appendix E of the Thames Water Needs report." EA assessment report page 14.

The modelling was done by other consultants and incorporated into Appendix E. The output from the modelling is presented in the EA assessment report Table 2 on page 15. "*The modelling showed that when impermeable area was reduced by 50%, 10 spills remained in a typical year in the most successful SuDS implementation of the three trial catchments, Frogmore (Buckhold Road)."* Thus the EA has assumed that the modelling is correct, that the limit is 10 spills a year, and that SuDS fails to be an acceptable solution in the Putney area.

The Appendix to Lord Berkeley's letter to Lord de Mauley of 9th December 2013 states, "*Professor Richard Ashley who was responsible for carrying out the Putney SUDS Study discredits the Study because the underpinning modelling data for the study supplied by the Environment Agency and Thames Water incorrectly presumes that all the impermeable area drains to the West Putney Combined Sewage Overflow (CSO) whereas a very significant proportion discharges not to the CSO but directly to Beverly Brook. In view of the difference between modelled discharges (34,800m3) and empirical (20,100m3) the inferred error is in the region of 40%. This is also confirmed by a cursory view of the drainage plans for West Putney and by inspection of the discharge outfalls licensed by*

the Environment Agency to Thames Water, that exclude a large outfall in Richmond Park." Thames Water corrected the modelling for this and other errors and issued a revised model output in June 2011, see Appendix A. This also lowers the Frogmore Buckhold Rd existing spill frequency from 29 to 19 spills a year. This is shown in the table below.

Table 1 Three pilot study catchments-modelled spill frequency after EA Table 2.

Catchment	Existing system spill number Appendix E	Existing system spill number TW Model 2011	Appendix E 50% impermeable removed	Likely revision 50% impermeable removed
West Putney	59	26	52	About 20
Putney Bridge	33	33	16	stays at 16
Frogmore Buck Rd	29	19	10	less than 10

The Putney sewerage systems were then modelled on an assumption of a 50% reduction in impermeable area and the results, from Appendix E to the Needs Report, are shown in column 4. However, it is clear that two of the original numbers of spill frequency under the 50% scenario are no longer relevant. For instance, for West Putney the current spill numbers of 26 cannot increase to 52.

Thus Frogmore is already below 20 spills and even if it was found to be above the 20 spills, then a limited amount of SuDs would result in the spill frequency becoming below.

Putney Bridge, with the 50% SuDs reduces to 16 spills a year which would be below the EC 20 spills criterion.

West Putney, with the sewer network correction, is now at 26 spills a year. Lord Berkeley continues *"The software used by Professor Ashley's team was modelled to calculate the effects of disconnections and as a result it missed obvious, low cost, rerouting of surface water to discharges to Beverley brook such as the Roehampton Gate/Clarence Lane surface water drainage that is already separated but mixed with foul water at the Thames Water pumping station before pumping to West Putney CSO."* Thus rerouting this storm water along, if necessary, with limited SuDs or a detention tank, would reduce the West Putney spill frequency below the 20 spills a year criterion.

Thus all the three CSOs would be below the 20 spills a year spill frequency proposed by the European Commission and considered acceptable by the Advocate General.

The analysis in the Annex 1 to Appendex E focussed very much on spill volume reduction in extreme events. "*The December typical year and October 2000 events represent the most severe recorded rainfall events for the typical year and 154 event rainfall series respectively."*page 1. However this event has a return period of approximately one in four years. This is indeed an "unusual" event and one in which an overflow would not be in breach of the UWWTD. The analysis focused on spill volumes and makes little reference to the spill frequency

This Appendix E study was done under the direction of Prof Richard Ashley head of the Pennine Water group. However he has said in his email to me of 9th October 2013;

"1. TOR too narrow - only to reduce spill volumes and frequencies - no other benefits eg flooding, aesthetics and only RWH using barrels
2. study too high level - we could not investigate eg local infiltration measures - we were told these would not be viable - for the areas we were given to look at as supposedly being the most 'ideal' for SuDS". Note a significant area is shown in the BGS map and memoire as underlain by several metres of Kempton Park gravel
"3. time and resources did not allow individual SuDS to be defined and gross assumptions for 'blanket' applications had to be made and scaled up
4. no contact with councils, public or others allowed to test viability or look for synergies and mainstreaming (linking SuDS to other developments)
5. CH2M Hill did all the modelling so we had to presume they did it right
6. SuDS had to be considered as an 'all-or-nothing' option not a partial option as everyone else has done. Even then, significant partial benefits were shown in the modelling, with some overflows eliminated completely."

Referring to point 2,"*local infiltration measures deemed not viable*." Appendix E page 34 states *" The guidance available from the USA for retrofitting promotes the use of infiltration preferentially for retrofits and also for the control of water quantity. As it is unlikely that there is significant infiltration potential in the London Tideway Tunnels catchment this option has been discounted in the present study. As a consequence, all of the SuDS units used in the study have had any infiltration capacity discounted."*

The British Geological Survey (BGS) map of the area 270 shows much of the Putney study area underlain by impermeable London Clay and head, probably also impermeable. However about one third of the area is underlain by Kempton Park Gravel, Taplow Gravel, Boyn Hill Gravel, or Black Park Gravel. Thus this aspect of the study will have under estimated the benefit acheivable by infiltration. Thus such a study could well warrant doing again, correcting the sewer model, considering all methods of spill reduction, and focussing more on the frequency of spill events.

The EA report An assessment of evidence on Sustainable Drainage Sytems and the Thames Tideway Standards October 2013 states that Appendix E "*suggested that 37% was a more realistic estimate of what is practically acheivable."* That is indeed what is said in Appendix E. However that was assuming that no infiltration was available. In reality a significant area in the Putney sewer catchment is underlain by gravels and, had these been included, then the effect would have been larger. Thus this statement by the EA, whilst it is copied from Appendix E , is not robust.

Consideration with reduction due to SuDS (50% less impermeable area)

The spill frequency with 50% impermeable removal, as calculated by the Appendix E Annex 1 model on page 48, is shown in column 3. This shows a dramatic reduction in spill volumes and some reduction in spill frequency.

However there would still be CSOs that are shown in the table as spilling post construction works more frequently than 20 times a year on average, the number proposed by the European Commission in the infraction procedings.

The EA has suggested that the limit of impermeable removal might be as low as the 37% assessed at Putney. However that assesssment took no account of infiltration. With the potential of up to 67% infiltration area then the 50% should be acheivable, albeit would need careful study.

The EA report An assessment of evidence on Sustainable drainage Systems and the Thames Tideway Standards October 2013 states in the Executive Summary about Appendix E "*The report found that*

the level of service provided by even the highest likely level of SuDS intervention did not match that of the proposed tunnel option.Typical year spills, after interventionns, is approximately 4 spills per year for the tunnel option." True but so what? The 4 spills a year achieved by the tunnel has no relevance to the EC proposed up to 20 spills a year.

The Environment Agency report An assessment of evidence on Sustainable Drainage Systems and the Thames Tideway Standards October 2013, says in its Executive Summary "*However SuDS measures alone cannot reduce spills from the Combined Sewer Overflows (CSOs) sufficiently to meet required standards, and therefore fail to meet the requirements of the UWWTD*." No account is taken of the weaknesses of the Appendix E analysis, of the potential for infiltration in much of the sewer catchment area, or of the potential benefit of the other measures which could be used. Thus the EA report conclusion is not robust and needs to be redone using a full combination of measures.

Further, the TW Resilience to Change 7.23 page 16 states " *For the purposes of comparison, and the potential for a maximum impact of change on the project, the same level of impervious area has been assumed in the evaluation."* Thus, despite government policy to encourage SuDs,TW have assumed that no further suDs will take place in the two sewer catchment areas. This does seem both biased and wrong.

My assessment cannot predict final CSO spill frequency. However I believe it does show that further analysis of where SuDs, associated where appropriate with infiltration, and how this could be implemented, would be appropriate.

Implementing of Suds and BGI

It must be recognised that SuDS and BGI would require to be implemented by a number of different authorities and householders. For instance householders/housebuilders would need to put in green roofs, rainwater butts and soakaways in new or renovated properties. However redevelopment of London is only about 2% of properties a year so after 10 years only about 20% would be expected to be revised. However I am informed by Roland Gimore email 14/2/14 that many of the side roads need repair and the provision of permeable surfaces with storage underneath could provide storage relatively cheaply. Disruption would be localised,dispersed, and for short periods of time.

Unlike the tunnel solution, where the benefit would come only once the tunnel is operational in about 10 years time, benefit does occur from the beginning of a SuDs programme. The speed at which the programme is implemented is a matter for others but the most cost effective approach found in Philadelphia, is to develop a 20-25 year programme which integrates these works with others, thus minimising costs. Thus such an approach would make a continuing reduction in storm spills which would also be able to mitigate any increase in storm runoff resulting from climate change.

Regarding timescalae and effect the EA in its An assessment of evidence on Sustainable Drainage Systems nad the Thames Tideway Standards , October 2013 staes on page 14 "*Evidence is limited for understanding the timescale for the extensive implementation of SuDS in london. Estimates vary for different scenarios proposed. Timescales include 10% of core urban areas in ten years through redevelopment only and 20-30 years to provide a reduction of 90% in the number of discharge events."* Thus a conservative interpretation might be a 60% reductionm in spill frequency at the end of 20 years. That would be sufficient to reduce 50 spills a year to 20 spills a year in 20 years, ie 2034. In which case using SuDS only the tunnel would be needed only from 2024, its date for completion, and 2034 when it becasme redundant. The reality would be that its need would taper to zero by

then. Thus by this analysis by the EA the tunnel would be a 120 year asset but would not be need after the first 10 years of its life.This must cast serious doubt about its viability.

The costs of SuDS and BDI measure are not included in the estimated costs of the Combined Interim Measures as their costs are not known and would increase progressively and be spread over a longer period.

Appendix E states on page 3 "*It is expected that the passing of the Flood and Water Managment Act 2010 could address some of these major impediments for new developments and areas undergoing redevelopment. The Act, however, does not deal specifically with retrofitting altered stormwater managment measures and how these would be dealt with still remains to be seen."* A change in the legislation could make implementation of Suds and BGI both easier and quicker.

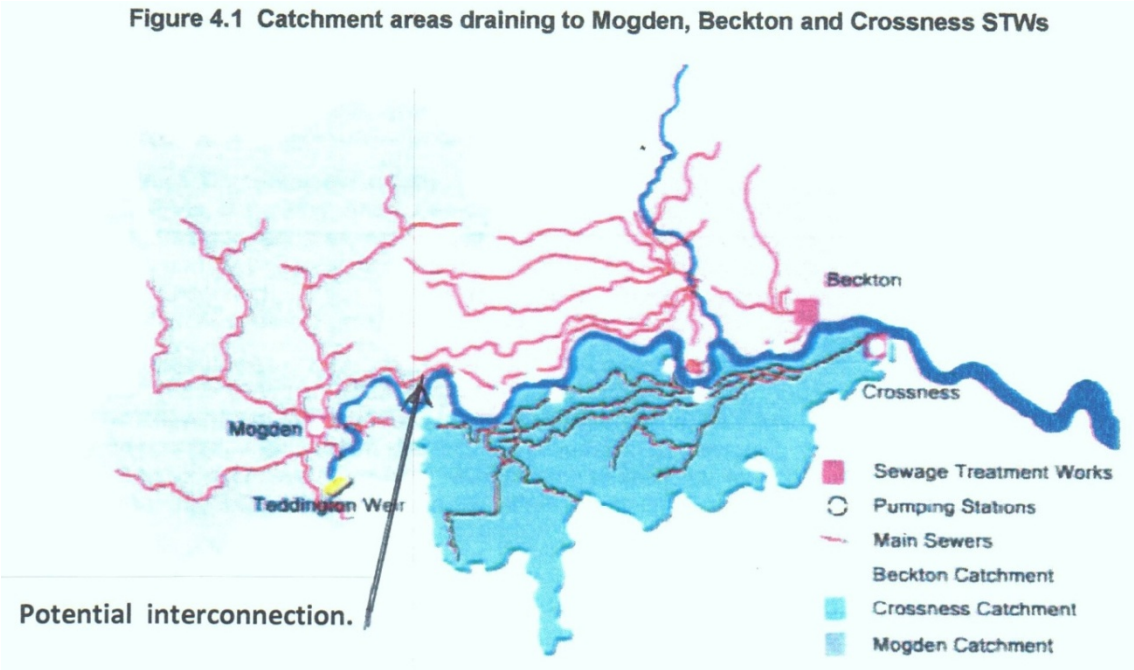
Example in London Parks

NCE online reportd on 26th March 2014 " *The £3.7M Dulwich and Belair Parks sustainable drainage system project was passed by Southwark Council. It included a new wetland area in Belair Park and more trees and shrubs in Dulwich Park to soak up rainwater. Underground tanks will also be installed in the parks providing storage for rainwater which will be gradually released into the sewer system."* This is an illustration of what could be done.

Reduce flow into the interceptor sewer system by diverting storm flows to other catchments.

Another way to reduce the spill volume is to reduce the catchment flowing to the interceptors and the Tideway CSOs. I have identified three options.

Figure 4.1 Catchment areas draining to Mogden, Beckton and Crossness STWs



Divert to the Mogden STW catchment

The plan of the sewerage network above shows a Mogden main sewer coming almost as far as Hammersmith. Connecting this sewer to the Hammersmith sewers and passing the flow to Mogden STW could reduce the flows in the Beckton interceptors. However I have been told by Thames Water that the sewer connecting Chiswick to Mogden STW may become fully loaded during large storm conditions. However this may not occur during smaller events or with real time control, thus might

be able to reduce the number of spills to the Tideway. This would need study. There may also be other similar connections that can be made. Such arrangements ought to be investigated.

Divert to the Hogsmill STW catchment.

One way for augmenting water resources considered in the dWRMP09 is to divert some of the flow going from the Wandle valley sewer to Crossness STW, to flow to the Hogsmill STW works upstream of central London. It was called Hogsmill B with a 20 Ml/d (1/4 cumec) diversion. This would both increase the flow over Teddington Weir, and thus could be used to augment the water resources for London, as well as reducing the dry weather flow in the southern interceptors by about ¼ m3/sec and reducing the CSO spill volumes from them. This dual benefit should be looked at and taken account of in the various cost benefit analyses in both the water supply dWRMPs and the sewer system analyses.

Connect to the existing Thames / Lee raw water tunnel.

There is a tunnel under the Beckton sewer catchment that connects the Hampton intake upstream of Teddington Weir to the Lee Valley reservoirs, see plan below. It is normally used for conveying raw water abstracted from the River Thames to the Lee Valley reservoirs. The Institution of Civil Engineer paper by Cuthbert and Wood on The Thames-Lee Tunnel Water Main 1962 states its capacity as 120 mgd, about 500 Ml/d or 6m3/sec. However the Cascade LTOA report quotes the abstraction licence as direct from the river to the tunnel with a capacity of 682 Ml/d, a substantial amount. The ICE paper states that there are access shafts at about one mile spacing.

Were it possible to divert storm water into this tunnel, then it would reduce the flow to the sewer interceptors. A separate storm water system would need to be identified, and possibly developed,

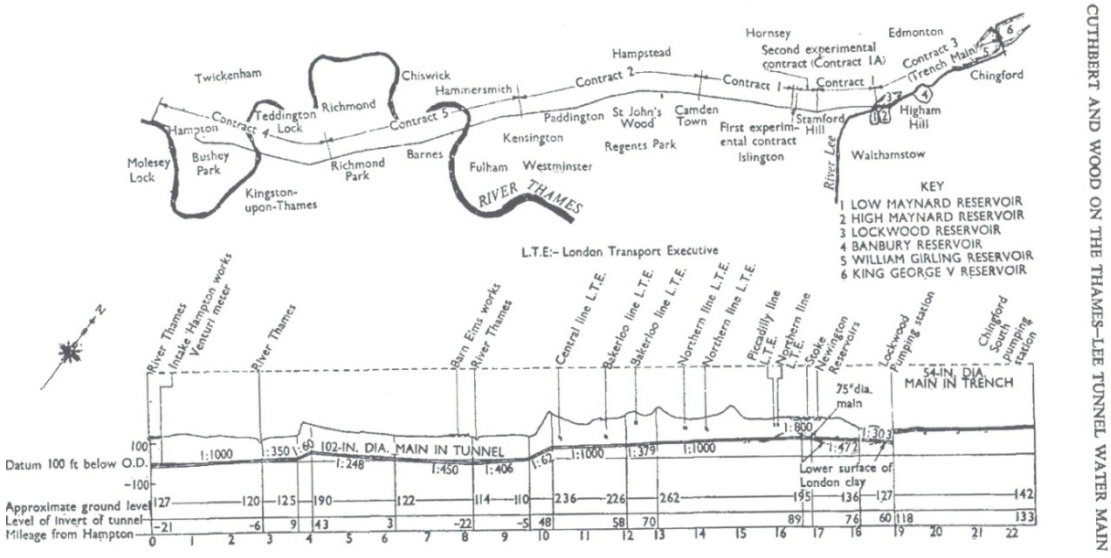


FIG. 1 (above)—PLAN OF THAMES–LEE TUNNEL MAIN (below) LONGITUDINAL SECTION

and connected. Places that could be considered might be based on Holland Park, Kensington Gardens, and Hampstead Heath. Thames Water are developing a storm water protection system for the Counters Creek area in West Kensington and Fulham. It is noticeable that their new storm relief sewer goes over the top of the Thames Lee tunnel, near the mid point of the new storm relief sewer. It is not clear where the nearest connection shaft would be but would not it be sensible to consider connecting the storm flows in the Counters Creek area into the Thames Water Thames to Lee tunnel. I can find no record where this has been considered.

It is likely that inlet screening would be necessary. Delivery would be to the Lee Valley reservoirs where considerable dilution and some natural treatment would occur. Coppermills water treatment works provides advanced water treatment.

Such a scheme could also collect runoff during a dry spell and provide some increase in water resources. I believe such a system has not yet been considered but should be.

Correct records of spill frequency

Hammersmith is an important Pumping Station. It is shown in the Appendix E table as spilling 50 times a year at present and to only reduce to 43 times a year with 50% reduction in impermeable area.

However the spill frequency shown in the Sewage Discharge Notifications as shown earlier in this chapter, is that the spill frequency during 2012/3, when CEH quoted catchment rainfall as 107% of the long term average , is 25 times in a year.

Further the spill volumes for the years 2001 to 2008 show generally a spill volume of about 2 Mm3/year. However for 2008 the spill volume was 386,000m3. The CEH monthly rainfall statistics for 2008 are a catchment rainfall of 116%, indicating a wetter than normal year. TW have not provided a reason for this and i can only presume that the puming station was operated in a different mode during this year, reducing both spill volume and spill frequency.

Thus it is important that accurate records are provided for all CSOs against which to verify the sewer model.

Provision of new drainage

The TW leaflet "Why does London need the Thames Tideway Tunnel ?" September 2012 states on page 18 that "*Separate systems for rainwater and foul sewage are now required for all new development."* The current consultation on the Guidance to Schedule 3 of the Flood and Water Management Act 2010 states, page 26 "*to ensure that there is no runoff to the receiving waterbody from small rainfall events, interception mechanisms are required to capture and retain the first 5mm."*

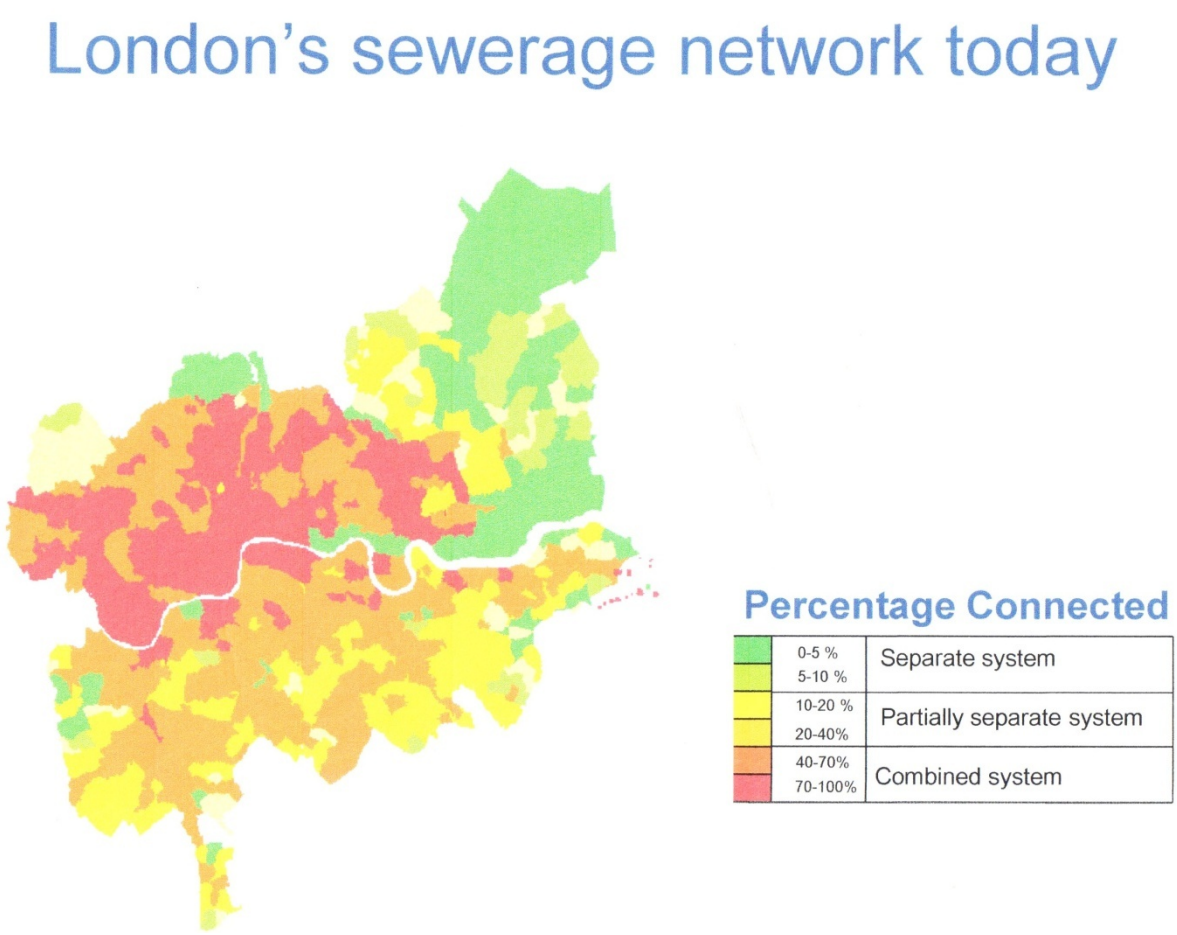
Thus there is already a significant separate drainage system in many parts of London and this will increase in the future. However in many places there is not a suitable storm water trunk drain discharging to a water course, so quite often such separate systems finish up being connected into a combined sewer. The important aspect is to ensure that, wherever economical, now, or in the future, the separate storm water systems discharge to water courses and not to the combined sewerage systems.

Separation of foul and storm sewers.

The TTSS considered separating out the combined sewer system of all of London into foul water pipes and storm water pipes. This was found to be very expensive, as well as resulting in digging up every street in London with the disruption that that would entail. Thus, as a single solution it was rejected.

However, there are places where separate storm water pipes exist and there are places where new storm water systems could be installed economically.

The percentage of properties served by combined sewer systems is shown on the plan below.



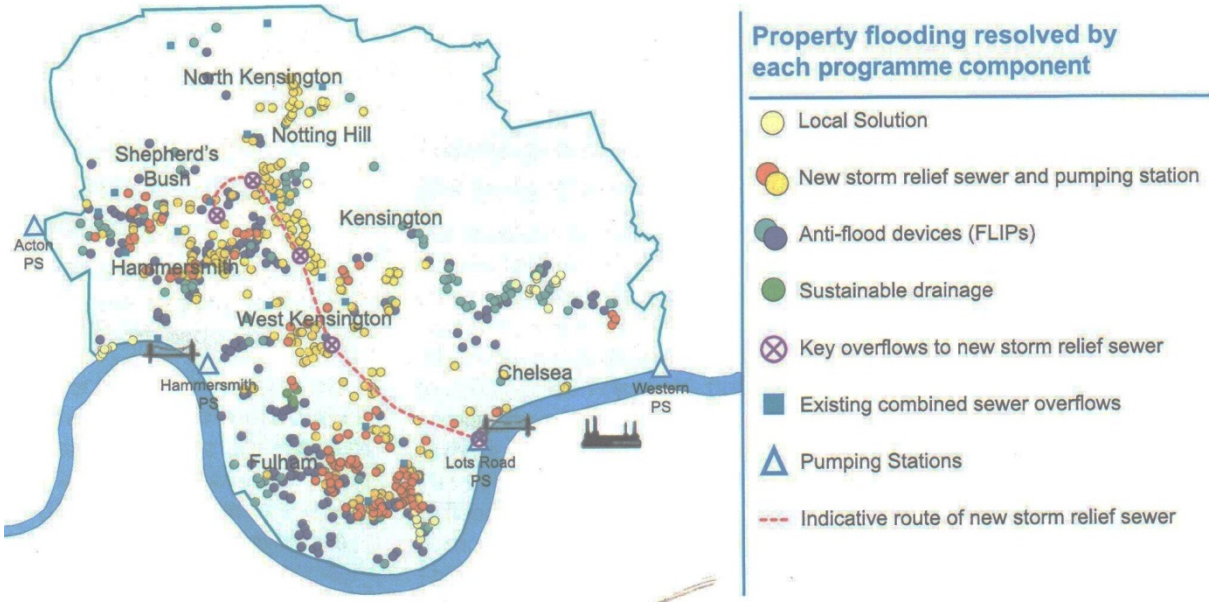
Thus the plan shows that there are many areas where there are extensive separate sewerage systems. There has been some misunderstanding of the nature of London's sewerage system throughout the history of this scheme, with comments being made at times that there are no surface water sewers in London. This is incorrect and has probably lead to some incorrect assessments being made about the viability and the cost of alternatives.

In 2012 TW issued a leaflet "Why does London need the Thames Tideway Tunnel?" On page 18 this quotes the cost of separating the combined systems in **Putney Bridge** as £27m. Thus it would seem that there may be a number of places where sewer separation may be economic.

I understand that at the PINS hearings Thames Water have said that "*all road runoff needs to be taken to treatment because it may contain metals.*" This is not the case generally in the country or, judging by the plan above, even in London. The Additional Reasoned Opinion dated 27/11/2008 in para 6 states "*By contrast* " to a combined system "*where the system is designed to collect urban waste waters and rainwater run off separately, then this collection and retention until treatment obligation only applies to that part handling the urban waste waters."* Thus storm runoff does not need treatment.

Counters Creek

One major drainage alteration is that proposed for Counters Creek in Fulham. Here the combined sewer system results in a significant amount of local flooding. Thames Water have a plan to provide measures and a new storm relief sewer.



My understanding is that the new storm relief sewer will be a combined foul and storm water sewer. Were the new storm sewer to be for storm water only and most of the storm drains be diverted into it, then the storm water could be discharged direct to the Tideway near the Lots Road pumping station. In addition the combined sewer flows would be much reduced thus reducing the flow in the low level interceptor. This in turn would result in the spill frequency and spill volumes of the Hammersmith, Lots Road, and Western Pumping Stations reducing, possibly becoming within the limits of allowable spill frequency.

Since the flow reduction would be in the northern low level interceptor, the reduction in interceptor flow would also reduce the spill frequency further downstream, albeit to a much lesser extent.

Connection of storm flows from properties direct to the Tideway.

It is interesting that much of the length along the banks of the Tideway are over 70% combined sewer system. However here it should be relatively cheap to connect the storm water systems to the Tideway. Such an approach was done by the London Docklands Development Corporation. There are quite a few existing developments that could probably be retrofitted with separate systems such as Chelsea Harbour, and Queens Walk, from Tower Bridge back to Westminster Bridge on the South Bank taking in the Concert halls, the Oxo Tower, and the Mayors office.

In the TW Resilience to change 7.23 page 14 it states *"Fig 5.2 ...shows that the majority of central London wards, north and south of the river, is predicted to experience the greatest increase in population, that is the area closest to the river and therefore the area most likely to contribute to CSO discharges."* This seems to me a rather negative way of thinking. If it is the areas nearest to the river that are being redeveloped to provide more housing then this should be the area where the new storm sewers should be connected direct to the river, thus reducing CSO spills in an economical way.

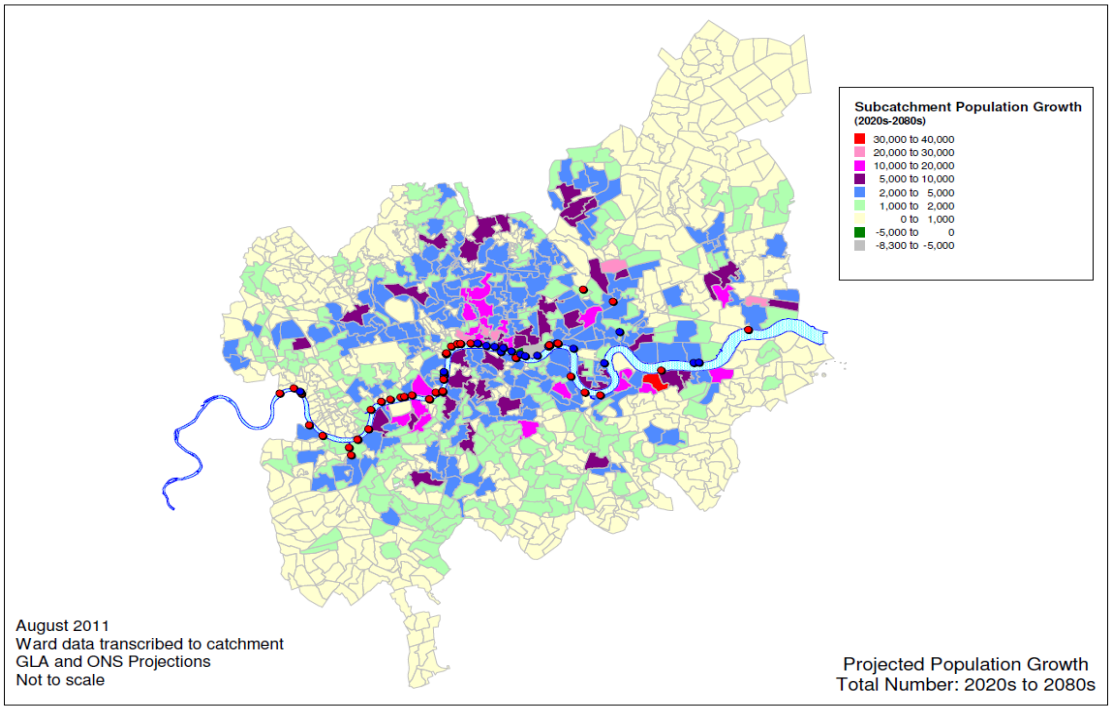


Figure 5.2 Changes in population predicted between 2020s and 2080s.

For instance new re-development sites like Chelsea Barracks and Battersea Power Station offer opportunities. These, and similar developments, would provide quite a significant area, and hence significant reduction in CSO spills. They should also be implementable in a relatively short period. Once the connection to the existing surface water outfalls were established or new ones made, there would be the opportunity to extend the area as new development takes place nearby but further from the river.

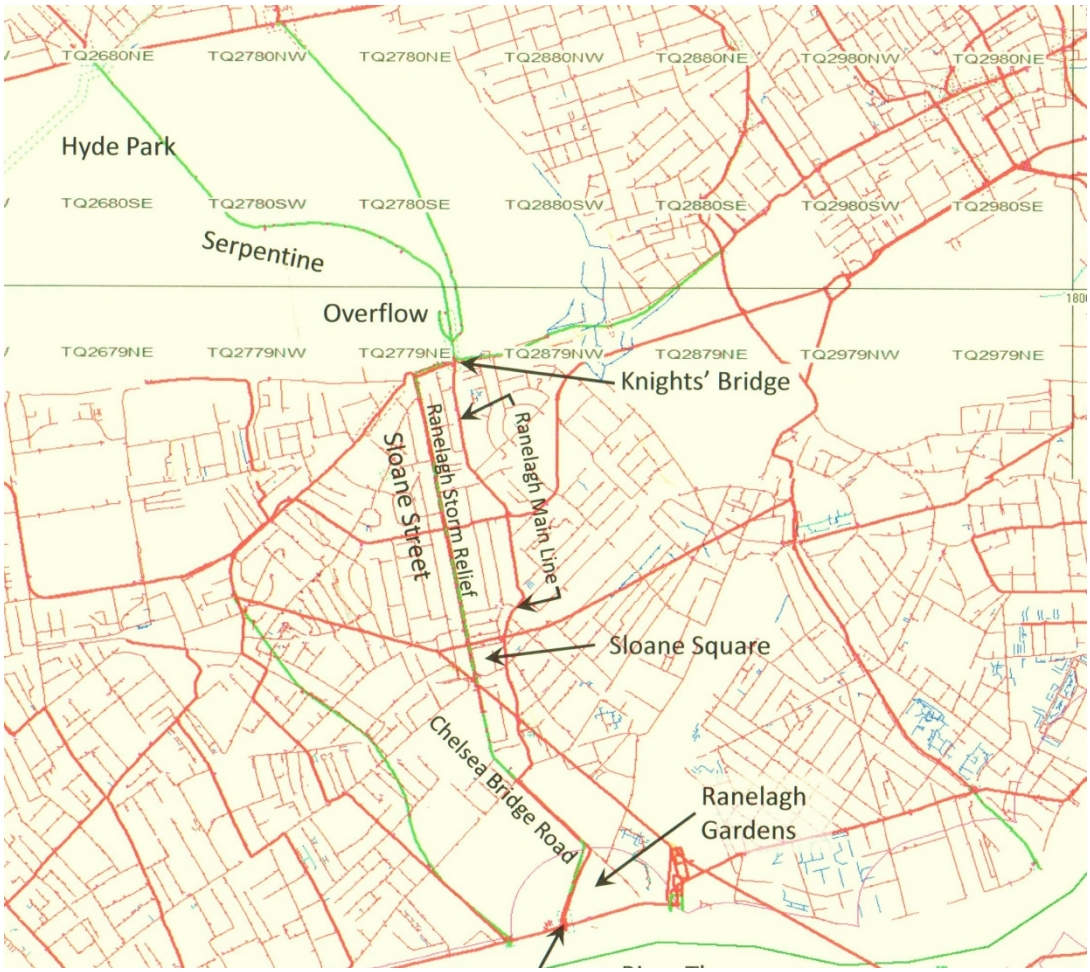
Combined sewer separation

From the plan on a previous page it can be seen that there are a number of areas, those coloured yellow, where the system is largely separate already. For instance much of the south of south London has only 10% to 20% combined. It is not clear to me whether all of these are connected to the high level interceptors or some to a local river. However for areas connected to the interceptors, consideration could be given to disconnecting the remaining foul connections, sometimes a slow and difficulty task, and then connecting the storm water sewers direct to a local river or the Tideway, thus reducing the combined sewer flows into the interceptors and hence CSO spills.

An instance of where separation of combined sewers proved appropriate is the city of Spokane which spent about $50m to separate the storm and foul systems and eliminated about 85% of the volume of the combined sewer overflows.

Ranelagh CSO

Without knowing all the information about the sewerage system, it is not possible to identify where sewer separation might be possible and thus reduce CSO spills. However one instance might be the Ranelagh sewer where the CSO spill frequency is 27 /year. The plan below shows the sewer and storm water system. The combined sewer runs down to the east of Sloane Street, and the storm relief sewer down Sloane Street. This system also takes the outflow from the Serpentine and another drain that crosses Hyde Park. One possibility might be to convert the storm relief to take only storm water including the Serpentine and discharge direct to the tideway. This would require a significant amount of new connection but it would reduce the CSO spill frequency and the load on the lower interceptor.



There may well also be other areas where it would be economical to separate the combined sewer into foul and storm water. For the TTSS this was only looked at on a total London basis. It ought to be looked at now on the basis of what could be done economically as part of a combined measures approach. For instance such an approach was adopted in Acton but never completed. Would it be economical now to do so? Whilst the areas where this is appropriate may be limited, that does not mean they should not be studied and the potential benefit established as part of a combination of measures.

Foul Sewers within storm drains.

I have been provided with information that in Jersey they separated some of the combined drainage systems by putting a new sewer pipe within the previous combined drain and thus separating the

foul and storm. In that way an 820mm dia foul main was run on saddles within a 2.72m pipe/culvert that then became a storm drain only. Such an arrangement could be suitable for some places in London.

Summary

The pilot study in the Putney area resulted in the CSO spills greater than 10 spills a year. These were considered to be excessive, thus SuDS was rejected for the Putney area. Later modelling corrected the sewer model and the revised spills should be less than the EC proposed spill frequency of up to 20 spills a year. However this has not been understood by the Environment Agency who continue to use the incorrect spill frequency. Thus SuDs should not have been rejected.

Thames Water, in its analysis of interceptor spills, assumed an appreciable increase in sewer flows, some 2.6 m3/sec, some 13% of the current 20 m3/sec by 2021. Sewer flows are based on water delivered to customers and infiltration, predominantly that coming from water main leakage. However instead of going up, the TW WRMPs show water delivered and leakage going down by 2024 by some 170 Ml/d, some 2m3/sec, about 10%. Thus TW models would have over-estimated the dry weather flows in the interceptors by some 23%, thus significantly over-estimating the spill volumes and frequency.

The EA considers the scope for infiltration as limited whereas, with special design methods in some areas, it should be useable in about 67% of the sewer catchment.

There are also ways of reducing the flows into the sewers such as diverting sewer flow to other catchments and implementing SuDs and BGI.

The areas close to the river are almost entirely combined sewer systems. Separating out the drainage of existing and new developments close to the river should be straight forward and should be economical and reduce sewer spill frequencies. In addition the re-design of the Counters Creek proposals should much reduce the spill frequency of Hammersmith, Lots Road and Western pumping stations.

There may also be some scope to reduce spill frequency further by separating the sewers in other areas.

No study has yet been done on the extent that such measures could change the spill frequencies. It should be done.

9. Suggested measures in the sewer system

Introduction

In London there is a system of trunk sewers going down the historic “valleys” and interceptors going largely horizontally to carry away flow to the east. The levels of the interconnecting structures are fixed ands many were constructed as much as a century ago. London development has changed much since then so the levels may no longer be optimum. Further they are fixed and therefore they are not able to adapt to the different conditions of summer thunderstorms. Thus there is likely to be appreciable scope for passing more flow along the interceptors and less storm flow down and into the river. For instance, if more sewer storm flow in the Notting Hill or Hampstead area could be retained in the upper interceptors, then there would be less flow in the Low level sewer and hence less CSO storm spill. The sewer system is shown in the figure below.

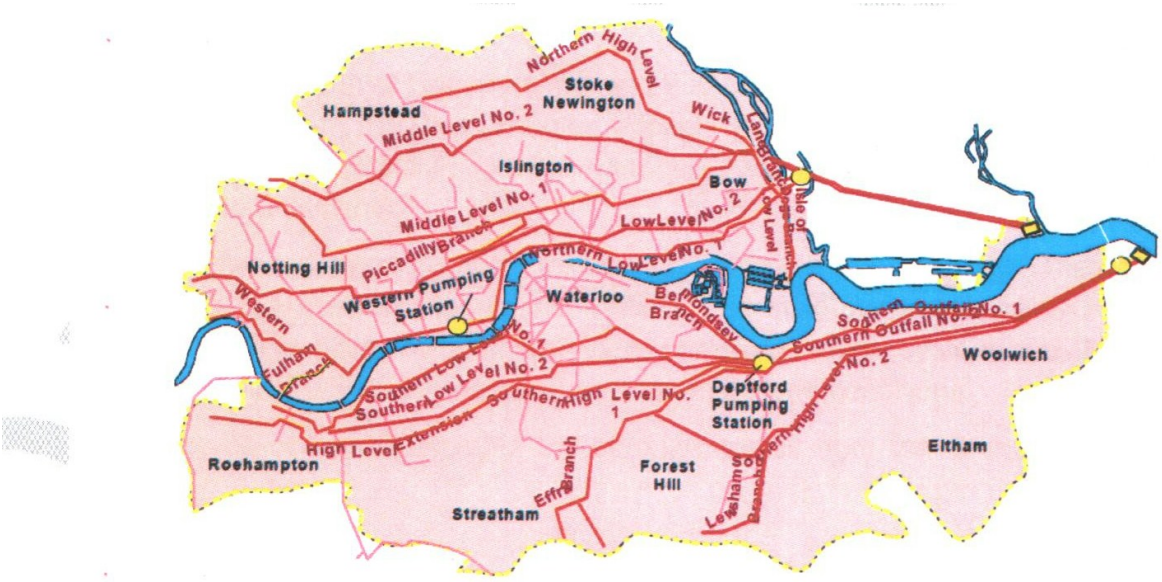


Figure 1.4: The Beckton Sewer Catchment

Remove restrictions in the sewer network.

Restrictions in a sewer network can result in more flow being discharged to the local river than necessary.

Appendix B to the Needs report 2010 describes the situation in a number of other cities , mostly European. On page 37 it describes that "*80 flow restrictions were eliminated*" in Hamburg. It is likely that there are also restrictions in the London system. It is not clear who has looked at this in London, what was the outcome, how many remain, and what benefit would be obtained in reducing CSO spills by eliminating them.

The London sewer network is almost entirely concrete and brick with fixed sizes. This was developed over a a long period so what was considered optimum many years ago, maybe as much as a century, may well not be optimum today. The TW sewer model is now much better and more accurate than at the time of the TTSS study in 2004. It could be used to analyse for such restrictions.

As an example I understand that there are a few restrictions already known in the London sewer system. For instance I understand that the connection between the Fleet sewer and the lowest interceptor sewer is only about 3 foot across and that this restricts flow in the Fleet sewer from flowing into the low level interceptor, irrespective of whether there is spare capacity in the interceptor. This results in a larger spill from the Fleet CSO than necessary. Whilst enlarging the connection may not be easy, because it lies directly below the Blackfriars Bridge road interchange, this illustrates one action that could be taken to reduce spill volumes.

Whilst the restrictions along the lowest interceptor sewer may have been studied as part of the Tideway Tunnel project, there may well be restricitons in higher parts of the sewer network that could be changed beneficially, thus reducing flows in the low level interceptors and hence CSO spills. Thus it is proposed that the sewer network be studied to identify the restrictions and whether they could be altered to provide benefit to the system and reduce CSO overflows.

Detention tanks and storage

Detention tanks can be used to store storm runoff and then release it slowly after the event has passed. This was looked at by TTSS as a standalone measure but rejected as it was thought that there would be insufficient space available in much of London for the large quantities of storage needed for a standalone detention system.

Acton CSO

There was work done some years ago of disconnecting part of the Acton catchment into storm and foul sewers. However this was never completed. Acton Storm relief is shown in the 2011 Table of Performance as spilling 29 times a year. Thames Water have reported in 6.1.11 of their response the Examining Authority APP63 "*The exceptions are Acton Storm Relief CSO, due to ongoing increases in storm tank capacity from recent capital works to improve the facilities to clean-out the tanks after storm events...*" Thus the spill frequency of the Acton CSO has now reduced and the table of spills in the Pind documents shows this as 17 spills a year, within the limit proposed by the EC.

Belair and Dulwich Parks.

NCE online of 26th March states that as part of a £3.7m sustainable drainage project "*Underground tanks will also be installed in the parks providing storage for rainwater which willl gradually be released into the sewer system.*"

Spill frequency when flows are small.

However detention tanks could be especially suitable where the spill volumes are low. One rough initial measure of detention volume is the annual volume divided by the spill time to give an average spill rate and also the total spill volume divided by the number of spills to give an average spill size. Using the information in the Table of Performance, gives the following information.

	Av spill rate	average spill volume	Spills/year
West Putney	305m3/hr	1,300m3	28
Putney Bridge	640m3/hr	2,100m3	33
Frogmore Bell l	149m3/hr	670m3	27
Savoy St	180m3/hr	470m3	18

The Putney Bridge and Savoy St outfall areas are congested so it may, or may not, be possible for them to incorporate relatively small volumes of storage in the right place.

The volumes required to reduce the spill frequency sufficiently may not be large. Thus for these CSOs it would be worthwhile identifying what size of detention tank could be provided and whether that would be able to reduce the spill frequency sufficiently to meet the criteria.

Storage facilities

There may well be other CSOs where detention tanks may be worthwhile.

For instance there are reservoirs on Hampsted Heath which are said to result in flows to the Fleet Sewer. There is a proposal to raise the dams by several metres.The questions are do these reseroivrs

control flow into the combined sewers? Can their flow be diverted to a water course ? Can the reservoirs be adapted or operated in a way that reduces storm flow and CSO spill ?

There may be other places where stoarge could be provided. For instance the sewer map in the section on sewer spearation shows a combined sewer crossing Green Park and a storm dran crossng Hyde Park to the east of The Serpentine. Whilst these are Royal Parks and obtaining development permission is not easy, Hyde Park does have a large water ring main control shaft and an underground car park, both added to it in the last 50 years.

I understand that Thames Water may already have acquired land at the tunnel construction shaft sites which could alternatively be used for storage of interceptor storm flows.

Thus all potential locations need considering.

Real time control and active system control.

The Bloomberg October white paper Tunnel vision page 20 states *"in the case of sewer overflows, utilities can use control systems to store and move wastewater in real-time during heavy rain events and to adapt to the unique features of each event, therby decreasing the number of overflows.To that effect, dynamic mathematical models and simulators are used to develop a program for a specfic sewer system to guide automatic control systems when a wet weather event is approaching. The most advanced systems use radar-based rainfall measurement* " as is avialable in UK, see the diagram on the next page " *and forecasting tools to anticipate where exactly in the city the sewer system is expected to be under pressure and adjust accordingly.*

In a numaber of projects, utilities have managed to lower their sewer infrastructure investment needs using these technologies. For instance, Paris eliminated the need for $800m in sewer infrasturture investement by adopting smart monitoring and control devices at the beginning of the 2000s. Other cities have achieved savings using these technologies including Louisville, Quebec, Copenhagen, Montreal, Barcelona, Milwaukee and South Bend. "

Experience elsewhere

In Quebec real time control alone reduced spill frequency from 45 spills to 26 spills, a near halving. Bloomberg's Table 7 showed that real time control has reduced CSO project costs by 27% in Paris up to 95% in South Bend.

It is reported in the Needs case Appendix B that in Barcelona storm events are managed using real time control (RTC) and detention tanks. Page 6 also lists RTC as also being implemeted in Lisbon, Marseilles, Vienna. Many cities have also built detention tanks to assist RTC and minimise CSO spill.

I have also been told that, in the town of Boulogne Billancourt, RTC is expected to reduce the CSO discharge volume into the Seine by 80%, and hence spill frequency. The email Gilmore/Binnie 28th October 2013 states "*Confronted with the problem of overflows from its combined sewer system into the River Seine during rainfall, the department of the Hauts de Seine (which covers some thirty urban districts on the west side of Paris) has decided to implement the real time control of its sewer system. The preliminary studies, based on a MOUSE computer model of the sewer system, showed that the real time control of the sewer network under study has a high potential benefit, since it would allow an 80% reduction of the volumes of waste water discharged into the Seine annually in the study zone. Following on from these encouraging results, the installation of a complete real time control system was set in hand.The system, at present undergoing testing and evaluation, consists*

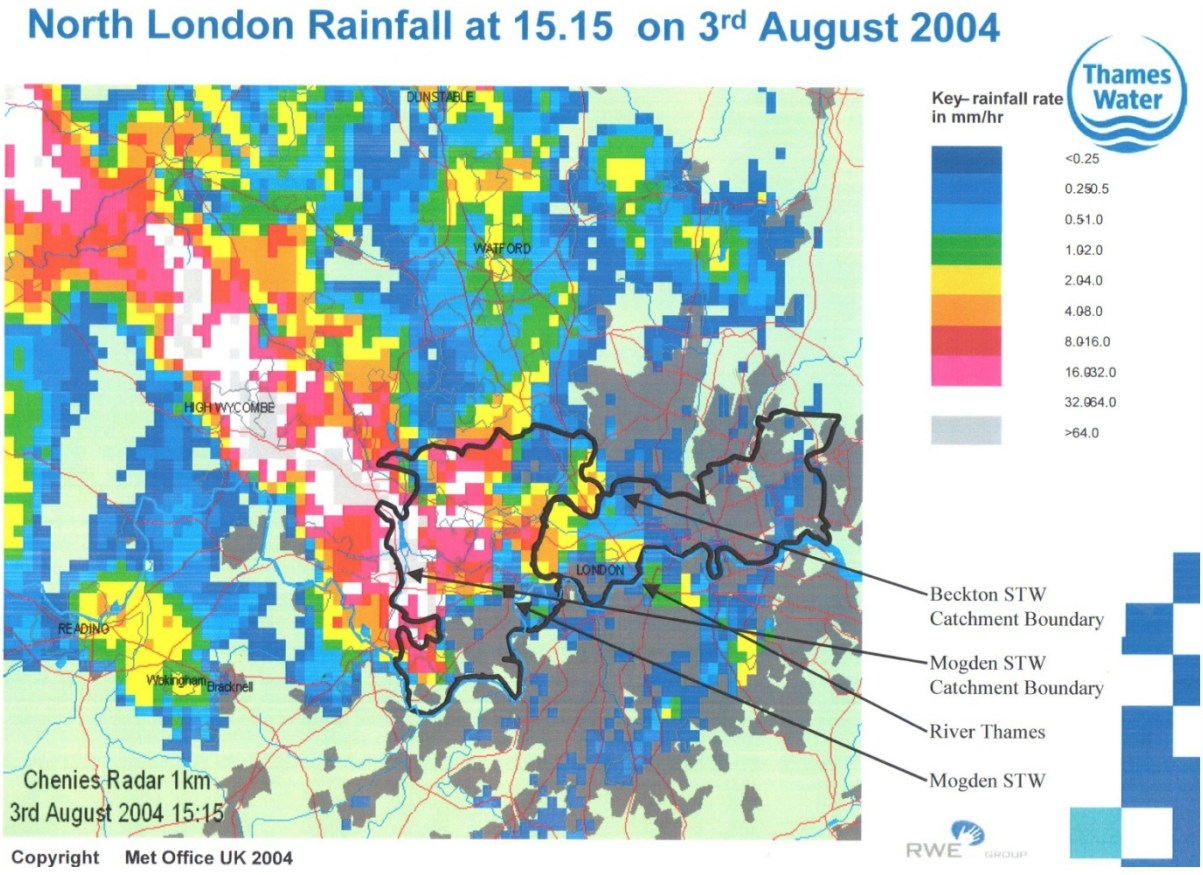
principally of a MOUSE ON LINE real time model and a system for forecasting rainfall by means of radar images."

Thus real time control, occasionally assisted by detention tanks, has been shown to have major benefits.

London

In London there are many interconnections between the sewers and the interceptors see previous image. At present these interconnections operate with a fixed weir. However the levels of the weirs were constructed many years ago, some may be 150 years ago. London, and hence its sewer flows, has changed considerably since then and the fixed weir settings may no longer be optimum.

Of importance, many of the most polluting storms are localised summer thunderstorms when the river flows are lowest. Thus conditions will vary appreciably from one storm to another. Thus there may be spare capacity in an interceptor because the rain has not fallen in the part of the catchment draining to it. Thus, in the illustration below, some rain fell in the west of the Beckton catchment but none in the eastern part, thus there would have been spare capacity in the eastern parts of the interceptors.



These measures would require moveable weirs with actuating motors.

The Thames Water Strategy discussion document of about 2012 states on page 19 "*Our strategy also includes the increased use of innovative, real-time control and monitoring systems. We have already*

begun installing this technology, which will help us to manage our network more actively and take swifter action to avoid operational problems."

However my understanding is that the action focuses on water supply pipes the model does not include real time control througout the sewer interceptor system. Further,the model results which the Environment Agency uses to reject SuDS as not giving sufficient benefit, was run before this strategy and the EA makes no mention of RTC or associated detention tanks.

UKWIR reports on Active System Control

UKWIR, of which Thames Water is a member, has produced two research reports 13/SW/01/4 and 13/SW/01/5. Whilst these include real time control, UKWIR has broadend the scope to active system control of sewerage systems. Thus the latter is entitled "The use of Active System Control When Designing Sewerage Schemes-A Guide." The writeup states "*The project considered the current usage of ASC in the UK where it was felt that insufficient consideration of the use of ASC was being made , and also investigated its application elsewhere in the world."*

The Guide states "*Measurement of the hydraulic state of a sewer and the tools necessary to take action to activate equipment in the sewer already exist and are widely used. ASC should be an automatic consideration when considering measures for addressing a problem*." Such as consideration of high CSO spill frequency.

"*Catchments larger than 350 ha*" as in London "*have been shown to have a flood response from spatial rainfall which is different to uniform rainfall. Research (HR Wallingford 2009) in this area is very limited, but analysis of radar rainfall over London carried out by Thames Water (unpublished) indicated that extremely high intensity ranfall"* as in a summer thunderstorm which might affect river water quality " *is constrained to a very small area with storm depths being reduced by half over distances of one to two kilometers. This indicates that there is potential for managing the floodiing by diffusion through a highly inter-connected system, especially in relatively flat areas with inter-connected sewers.*" as occurs in much of London. Thus RTC/ASC would be particularly good at reducing the critical summer thunderstorm spills which can affect water quality in the Tideway.

"*The conclusions of the project confirmed the limited awareness and use of ASC for sewerage scheme and a risk-averse attitude to considering its use. However it was understood that there were many potential benefits to using ASC more widely The research hs resulted in a Guide to assist the water industry in considering the use of ASC systems where a number of operational and performance benefits can be gained by using active system control* ."

Supporting statements by the Envionment Agency and ofwat.

In UKWIR 13/SW/01/5 there are supporting statements by the Environment Agency and Ofwat.

"*The Environment Agency supports the use of Active Control Systems and requires it to be considered as part of the options appraisal stage of all schemes....**The Environment Agency wants to work closely with industry on the use of ASC for sewerage systems to avoid regulatory barriers, maximise cost effective investment and promote innovation."***

"Ofwat has the view that it is important to look at different ways of enhancing the service companies provide to customers.This Guide, along with the drainage Strategy Framework, will enable companies to maximise the operation of their drainage networks....It is hoped that this Guide will encourage companies to look at alternative ways of optimising their neworks and reducing sewer flooding."

Thus both the Environment Agency and ofwat support real time control/Active system control and the EA requires it to be considered. But for the tunnel it has not beenconsidered as an alternative to the tunnel.

Conclusions

Technology now includes rainfall radar, water level sensors, sewer models and control systems such as moveable gats and moveable weirs to provide active real time control. The rainfall over the London catchments is seldom uniform, thus, during storm events, some storm sewers will be loaded more than others. The London sewer and interceptor network has many interconnections. Thus there would seem to be scope for ASC/RTC to actively manage sewer flows, and reduce spills to the Tideway. Such active control systems have been used with success in other countries including Quebec where spills of 45/year were reduced to 26/year.

The rainfall and sewer model should be run to see what benefit could be obtained from RTC/ASC, with detention tanks where appropriate. Were such measures found to be sufficiently beneficial in reducing CSO spill they should be implementeable within a relatively short time scale.

Increase the pumping rate.

The combined sewer overflows at the east end of the system are driven largely by the capacity of the interceptor sewers and the pump out rate into the sewage treatment works. The Crossness dry weather flow is about 6 m3/sec, see TW diagram in Chapter 8. The current Crossness pump out rate is I believe about 9 m3/sec. In the Crossness STW upgrading, costing £145m, this capacity is being increased to 13.68 m3/sec, see TW booklet on the Crossness STW upgrade. In turn this will reduced the Greenwich CSO spill frequency from 51 spills/year to 28 spills/year, see the Table of Performance in Appendix A. There is no consideration of whether this pumping rate is optimum and it may be possible to increase the pump out rate further and reduce the Greenwich CSO spill frequency further. This might need another storm detention tank at Crossness.

My understanding is that the pumps at Greenwich pump into the low level interceptor that arrives at Crossness STW. Thus could one increase the pumping capacity at Greenwich pumping station to take up some of the increased capacity of the Crossness pumps? Logically that should bepossible, and thus reduce the spill frequency at Greenwich further. This may, or may not, be able to increase the peak flow rate in the interceptor but it might enable the interceptor peak flow rate to be maintained for longer, thus reducing spill at Greenwich.

This factor does not appear to have been considered for the upgraded Beckton works and the lee tunnel. The Water projects on line document on beckton says the uprated Beckton STW will, in 2014, be able to "*handle 60% more sewage during storms and periods of heavy rainfall*" . However the North East CSO, the first major one upstream, will, once the Lee tunnel is operational see the Table of Performance in appendix A, have the same spill frequency at 31 spills/year. This seems surprising. The shafts and pumps at Beckton STW are sized to take the flow from both tunnels. To get much increase in interceptorflow may well require Active System control of the control weirs on the upper interceptors and the CSOs. The EA requires active System Control to be considered. However the potential benefit from this and the increased capacity appears to have been ignored. Thus the benefit of the Lee tunnel and its pumps on the upstream CSO spill frequency should be reconsidered.

It may also be possible to reduce spills at some of the CSOs by increasing pumping capacity at the current pumping stations, probably linked to real time control of the subsequent CSOs. These possibilities need considering.

Conclusion

There appear to be a number of ways that CSO spill frequency can be improved, including

Removing restrictions in the sewer network

Detention tanks and storage

Real Time Control/Active System control

Increasing the capacity of pumping stations.

10 Resilience to future conditions.

General

One has also to judge how much change there will be in future conditions and how any scheme put forward might be able to cope with them.

TW state in Resilience to Change 7.23 5.3.4 that they have made a number of assumptions about resilience, ie the conditions at some particular date in the future.

Design year

Thames Water in its analysis of the future has used 2050 and 2080. "*6.2.10 The data presented in table 6.1 also indicates a deceleration of change between the 2050s and the 2080s time periods in terms of number of rainfall events and this is also true for monthly rainfall totals....It is therefore concluded that running both time periods through the catchment and water quality models was not warranted and that the 2080s time period projections would suffice to indicate the impacts of change upon the project."*

To design a scheme for 2080 conditions is not necessarily economic. Thus the design date should be the date of completion of the tunnel, assumed to be 2023 or the end date of the Water Framework directive, 2027. For a scheme based on the measures proposed by me, a sensible design date would appear to be 2020 when the measures listed in my report could be implemented and then another date in the future say 2030. If the measures proposed by me could meet these two conditions, then it would be sensible to continue to bring in SuDs, or other ways of reducing spills knowing that there would be time to bring in other measures should that prove necessary. Further, technology is improving, for instance RTC was not even considered by TTSS ten years ago, so new methods of reducing spill frequency may well become available by then.

Thus, it is bad economics to build a scheme to meet the conditions which are assumed to occur some 65 years in the future.

Sewer catchment areas.

"no change to impervious areas through SuDs". Since it is government policy for SuDs to be implemented then this is unreasonably pessimistic.

This presumably also assumes no infiltration benefit. Considering that it would appear that significant areas would be suitable for infiltration this again seems unreasonably pessimistic.

Waste water rates

"*significant population growth with no reduction of wastewater rates* " This implies a constant per capita consumption as set out in my Chapter 8. Again, it has been shown in chapter 8 that, although population increases from 2006, then up to 2035 sewer dry weather flow is very likely to decrease. Thus such an assumption is unreasonable and is likely to significantly over-estimate spill frequency from the CSOs.

"*are all appropriate assumptions to diagnose the potential future water quality issues emanating from climate change and population growth*. *They represent conservative assumptions that trend towards showing the higher range of potential impacts*. *These conservative assumptions about catchment characteristics mean that the projected impacts are if anything somewhat high.* " Thus even Thames Water admit that the assumptions result in a higher spill frequency than will actually occur.

Future rainfall

"6.2.1 The most extensive work on climate change impacts was focused on precipitation over the Beckton and Crossness catchments: the main factor that affects the number of CSO events and volume is rainfall."

Two points arise.

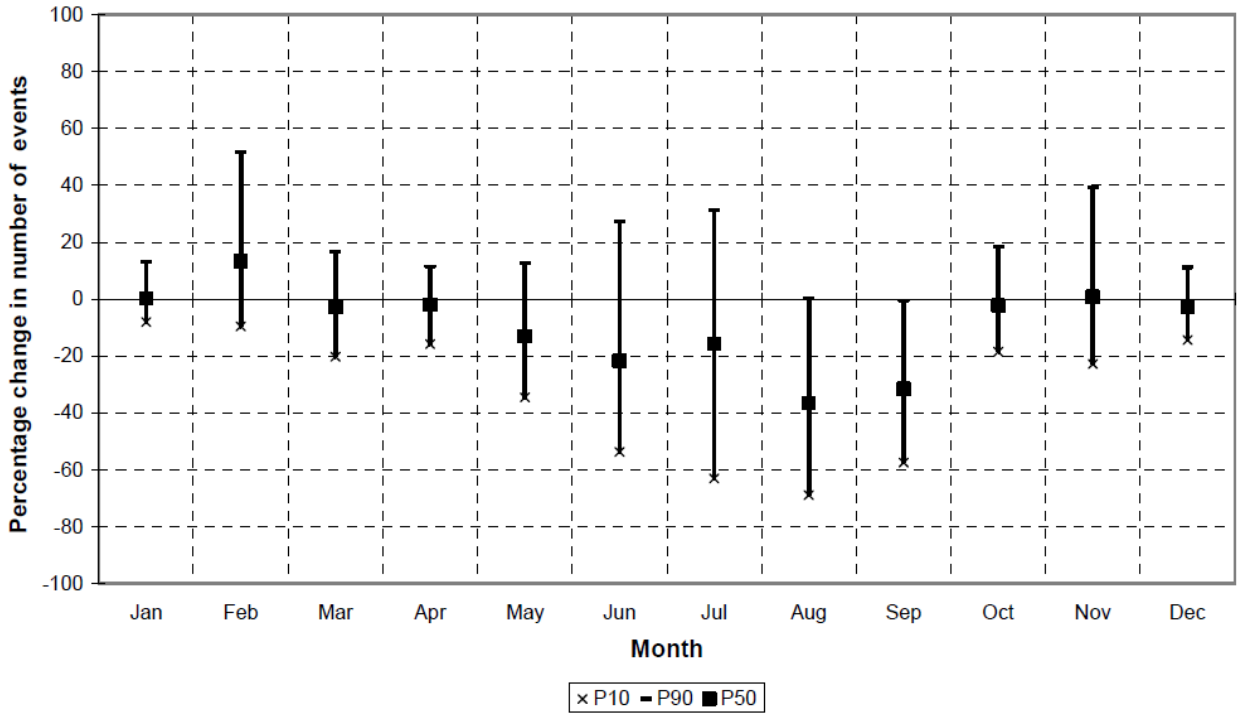
"6.2.1 Specifically HR Wallingford produced modified rainfall data sets for the typical year (for CSO performance evaluation) and modified CTP event series (for water quality evaluations). The monthly changes for these two datasets are different because the CTP set is based on larger rainfall events above the monthly threshold, whereas the typical years set is based on all events." The reason why two sets of rainfall sets are required for the two analyses is not clear and this needs proper explanation before it could be accepted as robust.

"6.2.9 there is a wide range of uncertainty in projections." Indeed, and therefore caution in reliance on the results.

"6.2.10 It was concluded that running both time periods through the catchment and water quality models was not warranted and that the 2080s time period projections would suffice to indicate the impacts of change upon the project." Whilst this might appear appropriate currently, it is a long time to the 2080s and such analyses so far ahead has to be treated with caution.

Future spill frequency

"6.3.2 Figure 6.1 shows the change in the monthly event numbers predicted with medium emission scenario."



From this it can be seen that all months are the same or less except for February. Thus it is highly likely that, with constant sewer flows, the spill frequency would diminish. On the assumption that all months have a similar number of rainfall events, judging from 6.3 a reasonable first assumption, then the number of rainfall events, and hence CSO spills, would reduce by about 10%. Thus a CSO spilling 30 times a year would naturally reduce by 3 spills a year. However the CSO system is complex so to find the actual number would require running the sewer model.

Flow of the river Thames

The impact of spills on the river will be affected by the freshwater flow as this will affect the salinity and the length of time an event takes to leave the Tideway. "*6.6.6 Using the projected 20 per cent decrease in river flows is believed a conservative approach, as this projects lower freshwater inflow to the tidal Thames and therefore could exacerbate the effect of CSO discharges*."

Indeed summer flows may go down but, with increased winter rainfall, winter flows may stay the same or even increase. As an example total event rainfall depth increase in November, December, January , February, March, and April. Thus a blanket 20% decrease in river flow is not likely to be a reasonable assumption.

Further some documentation shows 55% of the river flow of the Thames basin being abstracted for use. Thus, whereas the much higher winter river flows will be changed relatively little by abstraction, the smaller summer flows will be changed significantly more by abstraction. Thus such a blanket analysis would not be appropriate.

Further, it is not the flows reaching the lower River Thames that matter but the flows reaching the Tideway. Thames Water abstract large quantities of water upstream of Teddington Weir to provide a water supply to London. This is controlled by the Lower Thames Operating Agreement. This sets minimum flows over Teddington Weir, for instance 600Ml/d, and these would predominate during a dry summer. Thus, although the 20% reduction in river flow in summer might seem a reasonable assessment, if the river is already at the minimum LTOA flow over Teddington Weir, then there

would be no change. Thus the 20% river flow reduction is not conservative at all, rather the reverse, and needs reconsidering. It is quite possible that dry weather summer river flows would change very little.

STW effluent conditions

Since the water quality analyses were undertaken earlier than 2013, it would appear reasonable to presume that the final STW effluent quality used in the analysis would have been that before the upgrading of the sewage treatment works. This is supported by the statement "*6.7.2. Similarly the quality and quantity of final effluent discharges from the five STWs will have an impact on river water quality*."

Indeed, the improvements to the Beckton and Crossness STW are intended to remove the chronic dissolved oxygen conditions in the middle/lower Tideway.

However 6.7.3 states "*All analysis is with the 50th percentile change, medium emissions*, "fine" *and assumes no change to the catchment, collection system, works capacities and operations of the system."* This does not appear to take account of the increase in sewage treatment works capacity or improvement of the effluent quality. The Mogden STW upgrade was completed in 2013 and I believe the Beckton STW and Crossness STW upgrades are due to be operational in 2014. Thus, If the TW assumption is that the STW upgrades are not included in the analysis, then that would clearly not be a true reflection of future conditions.

Future temperature

"6.6.5. The principal conclusions from this analysis are: unlike the rainfall analysis there is significant difference between the 2050s and the 2080s tidal Thames temperature scenarios; and the changes throughout the year are fairly constant with around 1.5 to 2.0C for the 2050s and 2.5 to 3.0C for the 2080s." For the assessment of the dissolved oxygen content in the Tideway the summer temperature increase is the most critical. The numbers that I was given by Thames Water on 30th September 2011 for the temperature increase were:

Results of calculated monthly uplift values for River Thames temperature (°C) in the 2050s and 2080s for Medium emissions p50

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2050	**M**	**p50**	2.1	2.0	1.5	1.6	1.6	1.6	1.5	1.3	2.0	2.2	2.2	2.1
2080	**M**	**p50**	2.8	3.0	2.2	2.3	2.3	2.2	2.4	2.1	2.9	3.0	3.0	3.0

It can be seen that in the 2080s the summer temperature , May 2.2 to August 2.1, falls significantly below the lower bound mentioned by Thames Water in the Application of 2.5C. I believe this would have a significant effect on the dissolved oxygen content of the Tideway and would affect the results. Thus confirmation is needed as to what summer temperature increases were actually used and, if different, then the standard ones used in the next analysis..

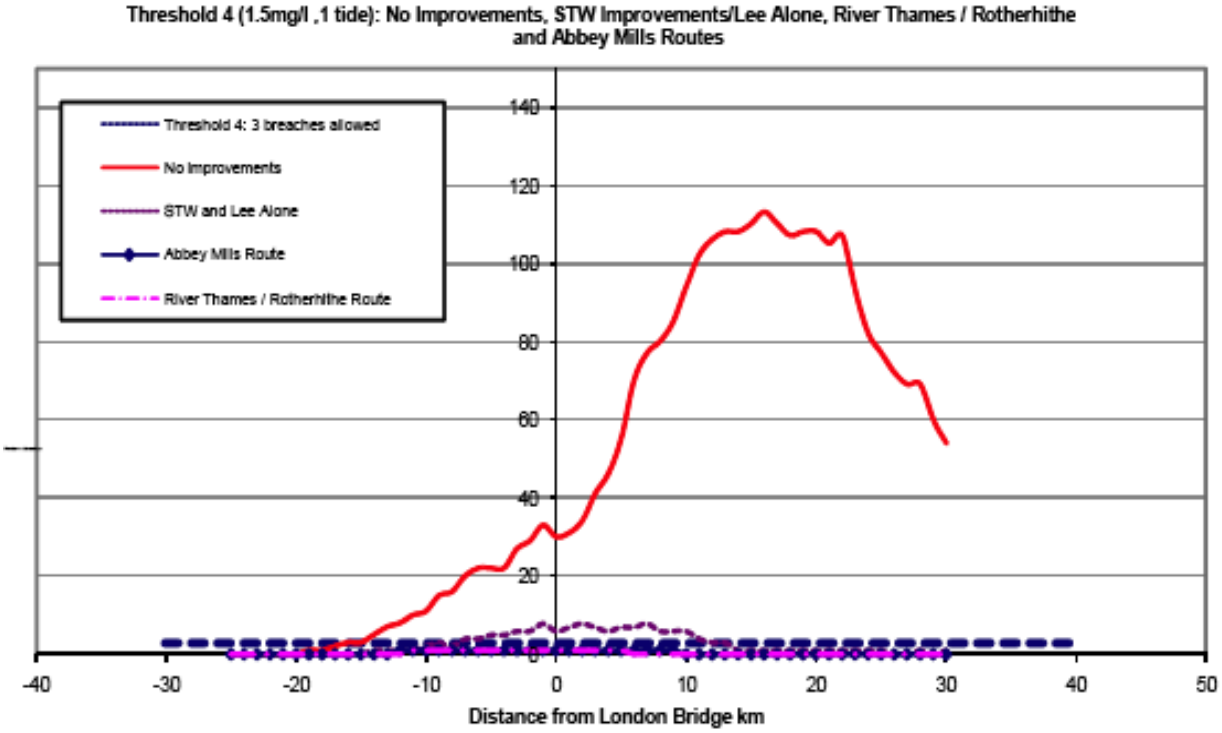
Water quality modelling for future climate.

Resilience to change *"6.7.7 the increase in the threshold exceedance seen in Table 6.4 is therefore driven by the increase in river temperatures and reduction in "fresh" water inflow at Teddington; neither of which can be controlled by the project."*

The water quality modelling for future climate is challenged because it does not appear to make allowance for the implementation of SuDs or other such measures, the future dry weather flow in the sewers taking account of revised pcc, the benefit of improved STW discharges, the LTOA restricting reduction of summer freshwater flows into the Tideway, and appears to assume too high an increase in summer water temperature.

"6.7.8 If the project was not constructed, the exceedance would be far higher, with reversion back to current conditions when most CTP events fail all standards (hence the problem needs solving today). Increased temperatures would simply make the river even more susceptible to CSO discharges."

The 2010 Needs case modelling shows at threshold 4



This illustrates the situation for threshold 4. The red line is the current number of failures/fish kills and the mauve line the situation with STW upgrades and the Lee tunnel. This is over a 34 year period. The actual current situation is that during the last 10 years, there have only been 3 recorded fish kills. For the 34 year period this would amount to 10 fish kills. This is considerably less than the 110 odd shown by the model. Thus the standards and the model do not represent the current situation and must be reconsidered. Just by the STW upgrades and the Lee tunnel, the situation would be considerably improved, with the latest modelling, 7 failures in 2020 modelled conditions with increased dry weather flow, against the target 4. Were the 2020 dry weather flow conditions adjusted for reducing water supplied rather than the assumption of increased dry weather flow then it is possible that the failure conditions would meet the theoretical dissolved oxygen standards.

In any case a combination of measures are proposed to reduce the number of spills to the 20 spills a year target proposed by the European Commission.

It would be important to correct the various factors and do the study, projecting into the future and considering the items that Thames Water have identified as changing the situation, but correcting the factors where appropriate. There would appear to be a reasonable expectation that the fish kills would remain within the allowed criterion.

11. Proposed studies

Need to study combinations of measures

From the chapters above it would appear that, post the Lee tunnel completion, the Tideway would meet the environmental requirements set out in the TTSS, or, in the case of health, expenditure beyond about £2m would not be justified. This would need formally confirming.

However it would still be appropriate to ensure the interceptors did not spill except under unusual rainfall conditions, proposed by the European Commission as up to 20 spills a year.

The defra River Basin Planning Guidance Vol 2 August 2008 states 9.4 As river basin planning principle makes clear the Environment Agency should consider the full range of measures which are available." "9.5 *The WFD requirement is to make judgements about* ***the most cost-effective combination of measures, so it is important that the Environment Agency considers the inter-relationship between measures."*** My emboldenment. Thus the requirement now is to consider not just a single solution but also combinations of measures.

The defra November 2011 A strategic and economic case for the Thames Tunnel report lists on page 8 the measures previously considered as "*screening of discharges, local storage and treatment and a shorter tunnel in west London." "Converting the current combined system into a new separate drainage system, Sustainable drainage systems, and a tunnel based system."* All the alternatives were considered and costed as if they were standalone solutions, in the case of the separate drainage system to achieve near zero CSO spills.

The TW 2010 Appendix E looked at SuDS only, without including infiltration let alone other measures. Similarly, the EA SuDS assessment report is just a consideration of a single alternative, SuDs, without even considering infiltration.

Thus I have been unable to find any study that has looked at how a combination of measures could reduce spill frequency sufficiently at an economical cost.

Regarding spill frequency, I recommend that a **combination of measures** including correcting sewer dry weather flows, SuDS, BGI, infiltration, diversions of sewer flows, removal of obstructions, real time control, detention tanks, sewer separation and other such measures, be studied with the aim of reducing spill frequency to that suggested by the European Commission.

Application to the entire LTT model

From page 48 of Annex 1 to Appendix E an analysis was done of the spill frequency of the CSOs. The results are shown as Table 3 in the EA assessment report. It would appear that this was done on the basis of no infiltration allowance, the earlier sewer model which did not show the correct spills for certain of the CSOs, and rising sewer dry weather flows rather than falling ones as shown elsewhere

to be appropriate. Thus that analysis would predict higher spill frequencies than would actually happen.

Comparison between the Appendix E model and the 2011 modelling

I have shown in the Table below a comparison of spill frequencies.

The output from the model used in the Appendix E is shown in the first column. The output from the corrected 2011 TW model is shown in column 2. Thus several of the spill frequencies have changed appreciably. For instance

West Putney has been analysed in an earlier section of this note and a solution identified which would separate a storm water pipe from the combined sewer system and this should reduce the spill sufficiently below the 20 spill level.

Abbey Mills will be connected to the Lee tunnel about 2015 and is not expected by TW to spill at all after then.

The Holloway CSO is shown in the Appendix E modelling as currrently spilling 49 times a year. The later modelling shows Holloway CSO spilling only 8 times a year under current conditions. I understand from TW Application for Planning consent APP63 page 11 that there is a temporary weir which retains CSO spills. This might be a case for RTC. RTC might well be of benefit in using sewers to the maximum amount and reducing spills elsewhere.

Savoy street is shown in Appendix E as currently spilling 47 times. However the later 2011 modelling, see Appendix A to this report, shows it only spilling 18 times a year under present conditions.

The Greenwich Pumping Station reduces from 45 spills a year to 28 spills a year, a considerable reduction and approaching the 20 spills a year without the corrections of the reducing sewer dry weather flows or SuDS measures.

Thus the Table in Appendix E and the EA assessment do appear to overestimate the spill frequencies for a number of the CSO that are shown to spill in excess of the limit.

The table below sets out for each CSO the 2009 spill frequency in Appendix E, the revised spill frequency found in the June 2011 Table of Performance, where appropriate the spill frequency with 50% SuDs, and then my initial suggestion as to how the spill frequency might be reduced to below the EC proposed 20 spills/year. Obviously this is an initial subjective suggestion and anyway not the only way that could be used so the full combination of measures would need to be considered.

Table 2 Analysis of the LTT system.

CSO name	No of events existing Appendix E	Number of events 2011 model	Number of events 50% less	Revised	Comments
West Putney	59	26		About 20	sep/Det/SuDs
Hammersmith	57	50		Les than 25?	Counters Creek
Abbey Mills	55	56		2015 0	Lee tunnel
Holloway	49	9		OK	RTC
Savoy Street	47	18		OK	
Greenwich	45	28			RTC/Sep
Falcon Brook	43	40			RTC/sep/Suds
Acton	40	17		OK	
Lots rd	39	38			Counters Creek
Western	39	37			Counters Creek
Deptford	38	36			RTC/sep
Frogmore Bel L	36	26	21		Det tank/SuDs/Sep
Heathwall	35	34	22		RTC/sep/suds
Putney Bridge	33	33			Det/suds (16)
North East SR	31	31			RTC/SuDs (18)
Brixton	30	28			RTC /sep
Frogmore B Rd	28	19			OK
Earl	28	26			RTC/sep
Ranelagh	27	26			Sep/det/RTC
Fleet main	20	23			Remove obstruction/RTC

The remainder would spill less than 20 spills a year. (n) are with 50% SuDs reduction

Comparisons to identify most economical measures

It is clear that most measures will be economical in some areas and not in others. Welsh water have developed a thematic map to show the potential for storm water removal. A similar map could be used for London showing where certain measures are economic and where not. In that way it should be possible to identify the most economical method of achieving the required spill frequency of up to 20 spills a year.

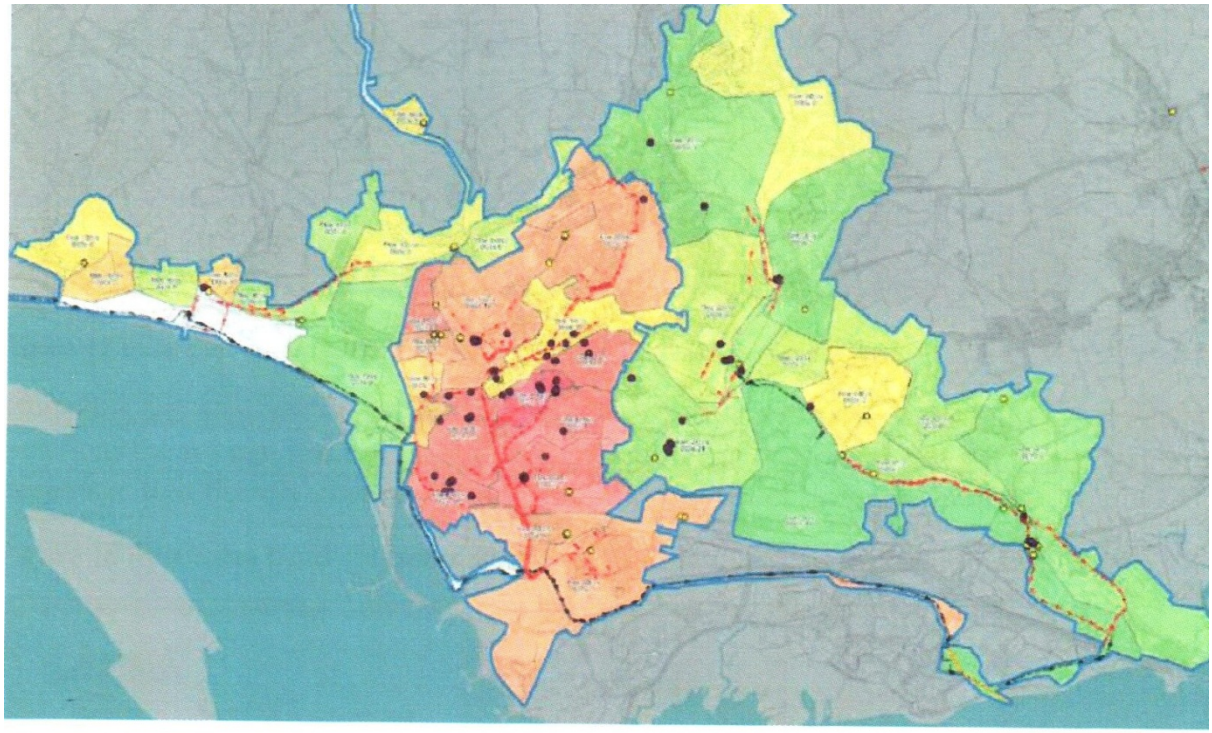


Figure 16 Thematic map showing areas of maximum potential for storm water removal

Customers interests

Ofwat's response to the Thames water's recent IDOK application says "*We do not consider it to be in the best interests of current or future customers to allow costs that are not justified or that we think may not be efficiently incurred.*" Indeed. But how can the costs of the Thames Tunnel be justified if the choice is based on studies mostly done years previously when technology was less developed, which did not include the study of widespread use of several new techniques such as Active System Control, and a number of other techniques, and when no combination of all these measures to identify the most economical solution has been done? In my view such a study must be done now to confirm, or otherwise, the justification for the tunnel.

Consultation with European Commission

If, as may well be the case, a combination of measures were found to meet the objectives and to be appropriate and economical, they should be discussed with the European Commission.

Independence and positiveness of study

As has been shown by ofwat, water companies have a bias towards large capital schemes as, in that way, they are allowed to charge their customers more and increase profit for their shareholders, called capex bias. Thus, in my opinion, such study work would need to be carried out independently of the water company, in this case Thames Water, albeit probably using the TW sewer models. It should also be undertaken with a positive approach as to how to achieve the objectives, rather than "why not" as with some of the previous studies.

12. Summary and conclusions.

Central London has a **combined sewer system** which, in 2000, had 57 overflows which spilled into the Thames up to 50 times a year causing aesthetic, environmental and health effects.

The Tideway was required to meet the **Urban Waste Water Treatment Directive** by 2000. The aim of the Directive is to protect the environment from the adverse effects of waste water discharges.

The **Thames Tideway Strategy Steering Group** studied the Tideway from 2000 to 2005. There are no specific numeric standards in the UWWTD so the TTSS came up with three objectives specifically focussed on the Tideway covering aesthetics, environment and health. Based on the information available then, the TTSS proposed that, to meet these objectives, three sewage treatment works be upgraded and a storage/conveyance tunnel be constructed from Hammersmith to Beckton STW at a cost of £1.7bn for the tunnel. The total cost of the tunnels has now risen to a total of about £4.8bn.

The **current works of upgrades** to the Tideway sewage treatment works and the Lee tunnel, will reduce the volume of spill from the current about 39 Mm3/year to about 18 Mm3/year, much reduce the number of dissolved oxygen failures, and has much reduced the spills from Mogden STW which was primarily responsible for the fish kills in 2004 and 2011 in the Kew/Chiswick area.

The TTSS **aesthetic objective** is to limit the pollution caused to the point where it ceases to have a significant adverse impact. The EA assessment classified 36 CSOs as unsatisfactory. However the assessment is subjective and has no aesthetics data to support it. The criterion for classifying CSOs as unsatisfactory is "*historic justified public complaints*". The EA reported that there were "*few formal complaints"* from the public about adverse aesthetics impact. Since then two litter collector barges are working. In addition Mogden STW discharges have dramatically reduced and the Lee tunnel will more than halve the remaining discharges. Thus post Lee tunnel, about 2015, it would appear that the objectives will be met.

If appropriate, discharge of sewage debris in the river could be reduced yet further by installing **booms** around most of the CSO outlets covering some ¾ of the spill volume. The retained debris can be collected. The existing skimmers and new oil skimmers could be used in the river to collect that which escapes or where booms cannot be fitted.

The TTSS **ecological objective** is to have a sustainable fish population. Fish are considered the most sensitive ecological species and dissolved oxygen (DO) standards have been set, based on fish trials. The current works of the improvements to the sewage treatment works, and the Lee tunnel, go a long way towards reaching the DO standards. Evidence from the 28th May 2013 spill at Mogden STW indicates that the upper Tideway now meets the dissolved oxygen criterion. The most sensitive species in the fish suite are salmon who are now deemed as unsustainable in the short, medium and long term. The EA has provided a schedule of fish kills in the Tideway for the last ten years. Instead of the 24 failures/ fish kills as projected by the 2013 dissolved oxygen model, only 3 have been recorded by the EA. This casts doubt on how reliable the models are at predicting fish kill conditions. Further the Tideway CSO spills only resulted in the recorded death of one fish. The model for the projection of dissolved oxygen conditions in the future is not robust. Thus, post the Lee tunnel, operational in 2015, it would appear that the objective of a sustainable fish population would be met.

The existing mobile bubbler boats would be flexible to reach where the monitoring system showed they were required to cope with any issues from the Tideway CSOs. If further dissolved oxygen improvement were required, a fine grained **diffuser system** using compressed air or oxygen would be able to raise the dissolved oxygen levels further and provide fish refuges as has been done in the River Seine downstream of Paris and presumably approved by the EC.

The Tideway is used by rowers for **recreation**. The TTSS recreation objective is to substantially reduce the number of elevated health risk days. The Tideway is not a designated bathing water and

is not subject to the Bathing Water Directive. For navigation reasons, the PLA has recently banned bathing in the Tideway except with a special licence. The HPA carried out an analysis of the illness of rowers in the upper Tideway. This showed that the rowers were ten times less likely to get gastric problems than the general public. Standard Quality Adjusted Life Year (QALY) analysis shows that it would only be worthwhile **spending a maximum of £1.5million** to deal with their gastric problems.

Since then improvements to **Mogden STW** where spills have reduced from an average of about 110 a year to about 20 much smaller ones will have much improved water quality in the Mogden/Hammersmith stretch of the Tideway where there are many rowers. A warning system has been provided to warn rowers and others in the Upper Tideway when CSO spills occur.

Thus it would appear that, when the Lee tunnel is completed about 2015, the **current works** will meet the three TTSS objectives set to meet the UWWTD objective to protect from adverse effects.

If thought appropriate, **further mitigation measures,** including booms around most of the higher spilling CSOs, in river aeration, oil skimmers, and treatment of the top up water to the docks could be used to improve conditions further in the next two to three years at a cost of about £20m.

The Advocate General's guidance following the infraction proceedings was that "*The **disproportionate cost of the works**, hence the lack of any need to undertake those works in practice, can be more reliably assed **by taking into account also the environmental effects of leaving these works unaccomplished.**"* Leaving the tunnel unconstructed would appear to mean the environmental effects would still be satisfactory.

Defra **Cost Benefit Assessment** 2011 study claimed a benefit for the Thames tunnel of some £4bn to £5bn. My then unchallenged assessment of the report and supporting documents was that the benefit should be £290m.My recent update shows this as £310m but assuming fish are sustainable, as shown above, then the benefit would reduce to £180m. Thus it is clear that, post the Lee tunnel completion, the tunnel would not meet any normal cost benefit assessment criteria and would be excessive cost and disproportionate cost.

The European Commission has taken the United Kingdom to **European Court** as it considered that the collecting systems spilled more often than "*unusual conditions*" as set out in Annex 1(A) of the Directive 97/271 (UWWTD). The Court ruled in October 2012 that this was so, and that the UK had not established disproportionate (excessive) cost as it had decided to implement the tunnel, and thus that the United Kingdom had failed to fulfil its obligations under the directive. However the Court did not rule that the tunnel be adopted, merely that an appropriate solution be adopted.

The Environment Agency appears to assume that 4 or 10 spills a year would be the limit. During the infraction proceedings the European Commission proposed, and the Advocate General agreed, that a **spill frequency of up to 20 spills a year would be acceptable**. Thus the EA assumption should be changed. The upgraded Mogden STW has already spilled 20 times in 10 months, a spill frequency of about 20 spills a year, with no adverse impact on fish, as confirmed by the EA. Thus the EA does appear already to have approved a spill frequency of about 20 spills a year in the upper Tideway.

TW assumed in its sewer model analysis that **sewer flows would increase** with increasing population and constant per capita demand. The increase from the base date of the calculations of 2006 to 2035 , based on the histogram provided, is some 270 Ml/d. However the TW WRMPs show that water supplied is projected to decrease by some 100Ml/d. This is a reduction of nearly 20% on the sewer dry weather flow assumed by TW, thus reducing the spill frequency , not increasing it.

At the time of the TTSS, 2003, there was limited information about **sustainable urban drainage systems** and there was very limited experience of how well they worked. Thus the TTSS was unable to recommend them as a viable solution to meet a European Directive.

A pilot study of **Sustainable Drainage System** (SuDS) was carried out in the **Putney** area and Appendix E to the Needs report showed that spills would be 10 /year or more. SuDS in the Putney area were therefore rejected. However the sewer model was subsequently corrected by Thames Water. The analysis has not been redone. However it would appear that the spill frequency with SuDS would be meet the EC 20 spills a year criterion. Thus the spill frequency with SuDS would be within the EC limit. Further, although there are significant areas of terrace gravel in the Putney area, the study team were instructed by TW that "*infiltration was deemed not viable*". Thus, with infiltration, the spill frequency would be lower still.

The EA assessment of SuDS says that the scope for **infiltration** in the sewer catchment is limited. The Bloomberg report, based on the BGS data, states that 67% of the area could be developed for infiltration, subject to some technical adjustments and bespoke measures. The Farm Lane area of Fulham is claimed by the EA to only have 5% suitable for SuDS but is shown by BGS to be have high permeability but to suffer from groundwater level less than 3m below the surface. However SuDS can be done with less than 3m of terrace gravel. Further, geotechnical investigation in Farm Lane, Fulham, has shown no water table within 3m of the surface from December 2010 to August 2011. Thus there would seem likely to be reasonable expectation that infiltration, albeit with special measures in some areas, would be possible within about 2/3rd of the sewerage area.

The **TW 2010 model** was run for London with 50% impermeable area eliminated. This showed excessive spill frequency. However the model was based on increasing sewer flows and assumed no infiltration and is therefore pessimistic and should be run again using appropriate conditions.

Anyway flow in the sewer interceptors could be reduced by reducing the amount of **water entering the sewers** by connecting part of the sewerage system to another STW, Mogden or Hogsmill, or to the existing Thames/Lee water transfer tunnel.

The implementation of widespread **SuDs and BGI** would also increasingly reduce storm flows from entering the sewers.

Whereas total separation of the sewer system would be uneconomic and very disruptive, there appears to be significant scope for **separation** of the sewers, particularly of developments along the Tideway and other local rivers, as well as areas where the sewers are already largely separate.

Remaining spills from the sewers into the Tideway could be reduced further by **removing restrictions** in the sewer system, increasing pumping capacity at the STWs, and implementing **real time controls /active system controls** and **detention** tanks. The Environment Agency requires active system control to be considered for all schemes but it hasn't been.

The WFD requirement is to make judgements about the most cost-effective **combination of measures**. Whilst a number of studies have been done by TW about how well individual measures would work and how much they would cost, I have been unable to identify any study about how a combination of measures would work and how much that would cost.

The Commission has since stressed in its Policy Communication the importance of **Green Infrastructure**. It would be open for the UK government to discuss such an approach for London with the Commission

Defra Cost benefit assessment November 2011 study claimed a benefit in the upper half of some £3bn to £5bn. My then unchallenged assessment of the report was that the benfit should be about £290m. However, with only one fish killed from the Tideway CSOs and fish sustainable post the Lee tunnel, the benefit reduces to £180m.

Considering the high cost of the tunnel at £4.1bn in 2011 prices, and the increase in customer bills throughout the Thames valley of about £80/household/year, then the alternatives of SuDS, infiltration, real time control, detention tanks, sewer separation, and other associated measures, along with corrected model data, should be **studied** to check if a **combination of such measures** could meet the required spill frequency. This should be done independently and positively.

To check **resilience** TW have projected conditions in the Tideway to 2080, increasing sewer dry weather flow and water temperature, reducing river flow, changing rainfall and ignoring SuDs. The extent of some of these is challenged and, for a combination of measures, some of these should be reconsidered.

If found to be appropriate, such an approach should be discussed with the **European Commission** with a view to being implemented. This could result in a major reduction in expenditure at a time of difficult economic circumstances, along with reduced future customer bills in the Thames Valley.

Professor Chris Binnie, MA, DIC, Hon D Eng, FREng, FICE, FCIWEM.

31st March 2014.

Appendix A modelling of the river conditions and Table of performance.

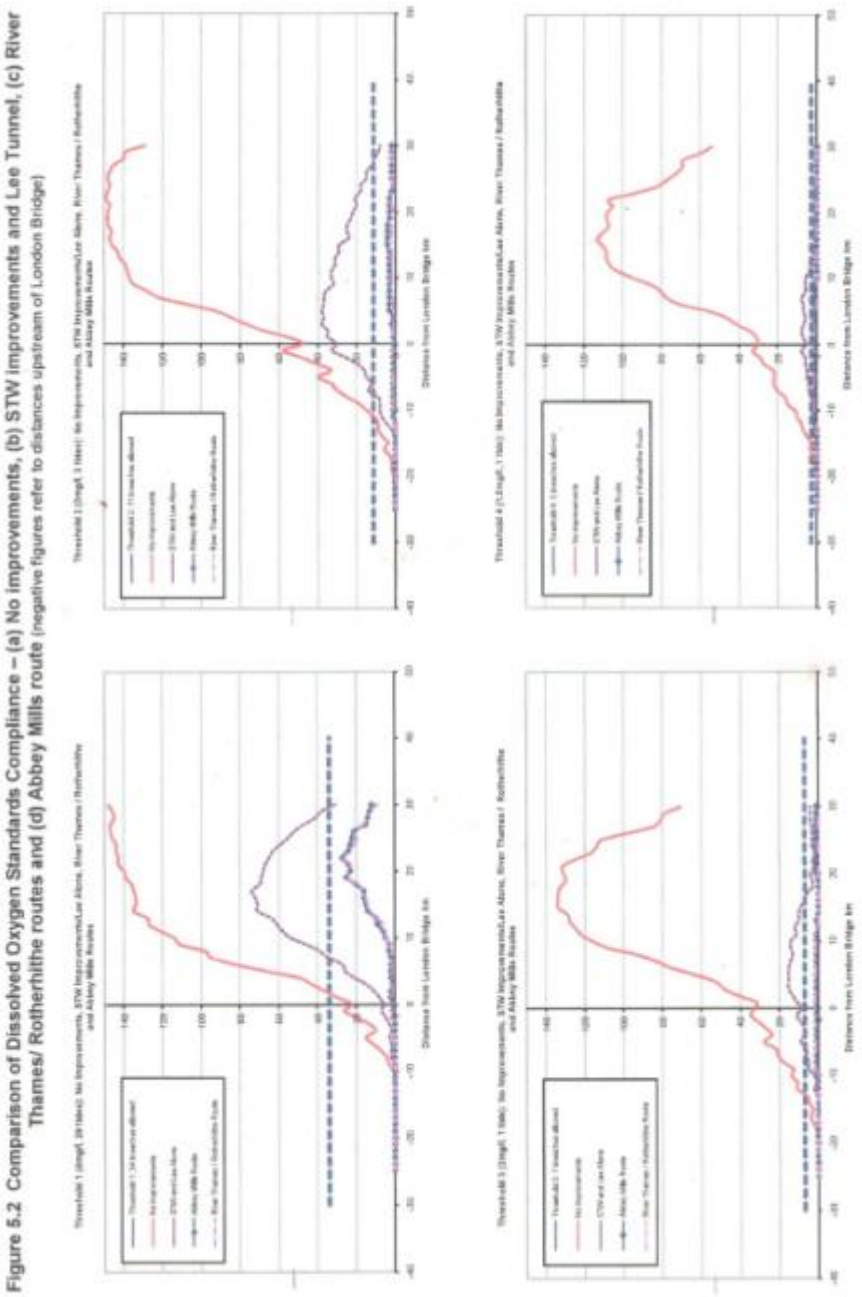


Figure 5.2 Comparison of Dissolved Oxygen Standards Compliance – (a) No improvements, (b) STW improvements and Lee Tunnel, (c) River Thames/ Rotherhithe routes and (d) Abbey Mills route (negative figures refer to distances upstream of London Bridge)

Table of performance

LTT ID	EA Cat	CSO Name	Existing System & Existing STW 2006 (June 2011)			STW Improvements and Lee Tunnel 2021 (June 2011)			Recommended Phase 2 Consultation Scheme 2021 (June 2011)		
			Total Volume (m^3) [a.]	No. of Spills [a.]	Spill Duration (hrs) [a.]	Total Volume (m^3) [a.]	No. of Spills [a.]	Spill Duration (hrs) [a.]	Total Volume (m^3) [a.]	No. of Spills [a.]	Spill Duration (hrs) [a.]
CS01X	Cat 1	Acton Storm Relief	312,000	29	152	325,800	30	163	0	0	0
CS02X	Cat 2	Stamford Brook Storm Relief	500	2	2	500	2	2	400	2	2
CS05X	Cat 1	West Putney Storm Relief	34,300	26	113	36,400	28	119	1,500	1	4
CS37X	Cat 3	LL1 Brook Green	0	0	0	0	0	0	0	0	0
CS03X	Cat 2	North West Storm Relief	2,800	1	1	4,100	1	1	700	1	1
CS04X	Cat 1	Hammersmith Pumping Stn	2,208,000	50	648	2,362,100	51	690	103,600	1-3	16
CS06X	Cat 1	Putney Bridge	68,100	33	107	70,800	33	111	1,600	1	3
		Upstream Putney Bridge Total / Maximum [b.]	**2,626,000**	**50**	**1,023**	**2,800,000**	**51**	**1,086**	**108,000**	**3**	**26**
CS07A	Cat 1	Frogmore SR - Bell Lane	17,300	26	124	18,100	27	130	500	1	4
CS07B	Cat 1	Frogmore SR - Buckhold Road	85,600	19	68	88,600	21	72	1,500	1	3
CS08A	Cat 1	Jews Row - Wandle Valley SR	300	1	2	2,900	1	3	0	0	0
CS08B	Cat 3	Jews Row - Falcon Brook SR	7,400	2	7	7,500	2	7	7,500	2	7
CS09X	Cat 1	Falcon Brook Pumping Stn	708,900	40	263	779,300	42	291	56,200	4	26
CS10X	Cat 1	Lots Rd Pumping Stn	1,135,000	38	348	1,283,000	42	410	91,000	4	31
CS11X	Cat 2	Church Street	0	0	0	0	0	0	0	0	0
CS12X	Cat 2	Queen Street	0	0	0	0	0	0	0	0	0
CS13A	Cat 2	Smith Street Main Line	1,400	4	8	1,500	4	8	1,500	4	8
CS13B	Cat 2	Smith Street Relief	0	0	0	0	0	0	0	0	0
CS14X	Cat 1	Ranelagh	283,000	26	142	305,700	27	153	18,300	2	10
CS15X	Cat 1	Western Pumping Stn	2,046,200	37	200	2,323,900	41	228	244,300	4	24
CS17X	Cat 1	South West Storm Relief	227,900	12	38	238,400	13	40	3,900	1	3
CS16X	Cat 1	Heathwall Pumping Stn	654,900	34	200	748,300	38	246	62,500	4	26
CS18X	Cat 2	Kings Scholars Pond Storm Relief	1,400	2	4	1,800	3	5	500	1	2
CS19X	Cat 1	Clapham Storm Relief	12,700	5	12	14,400	6	15	7,900	1	5
CS20X	Cat 1	Brixton Storm Relief	264,600	28	131	278,600	29	137	5,700	1	4
CS21X	Cat 2	Grosvenor Ditch	2,600	3	7	3,000	4	9	500	1	3
CS39X	Cat 3	Horseferry	3,400	3	7	3,800	3	7	300	1	2
CS40X	Cat 3	Wood Street	0	0	0	0	0	0	0	0	0
CS22X	Cat 1	Regent Street	22,200	4	12	25,700	8	19	0	0	0
CS23X	Cat 1	Northumberland Street	71,500	13	34	88,400	14	43	300	1	2
CS24X	Cat 2	Savoy Street	8,400	18	47	8,500	18	47	1,400	4	7
CS25X	Cat 2	Norfolk Street	0	0	0	0	0	0	0	0	0
CS26X	Cat 2	Essex Street	2,100	3	6	2,300	3	6	0	0	0
CS27X	Cat 1	Fleet Main	521,100	20	73	571,200	23	83	36,800	4	14
CS42X	Cat 3	Pauls Pier	0	0	0	0	0	0	0	0	0
CS55X	Cat 4	London Bridge	8,300	7	14	8,900	7	14	4,300	5	10
		Downstream Putney Bridge to London Bridge Total / Maximum [b.]	**6,086,000**	**40**	**1,745**	**6,784,000**	**42**	**1,975**	**546,000**	**5**	**191**
CS28X	Cat 1	Shad Thames Pumping Stn	91,900	15	70	100,400	15	69	71,300	4	14
CS43X	Cat 3	Battle Bridge	0	0	0	0	0	0	0	0	0
CS44X	Cat 3	Beer Lane	0	0	0	0	0	0	0	0	0
CS45X	Cat 3	Iron Gate	200	1	2	200	1	2	300	1	2
CS46X	Cat 3	Nightingale Lane	0	0	0	0	0	0	0	0	0
CS49X	Cat 3	Cole Stairs	0	0	0	0	0	0	0	0	0
CS50X	Cat 3	Bell Wharf	0	0	0	0	0	0	0	0	0
CS29X	Cat 1	North East Storm Relief	782,400	31	288	847,400	31	303	84,300	4	32
CS51X	Cat 3	Ratcliffe	0	0	0	0	0	0	0	0	0
CS31X	Cat 1	Earl Pumping Stn	539,000	26	184	593,900	30	207	50,500	4	26
CS30X	Cat 1	Holloway Storm Relief	7,800	8	18	8,400	9	23	7,000	2	9
CS52X	Cat 3	Blackwall Sewer	0	0	0	0	0	0	0	0	0
CS36X	Cat 2	Wick Lane	0	0	0	0	0	0	0	0	0
CS32X	Cat 1	Deptford Storm Relief	1,471,500	36	252	1,976,000	39	343	161,300	4	29
CS33X	Cat 1	Greenwich Pumping Stn	8,322,500	51	672	3,940,100	28	240	571,500	4	35
		Downstream London Bridge to Greenwich Total / Maximum [b.]	**11,215,000**	**51**	**1,484**	**7,466,000**	**39**	**1,187**	**946,000**	**4**	**147**
CS56X	Cat 4	Isle of dogs Pumping Stn (Foul only)	12,900	6	9	13,100	6	10	13,10	6	10
CS35X	Cat 1	Abbey Mills Pumping Station from STATION P	15,319,000	56	873	0	0	0	0	0	0
CS35X	Cat 1	Abbey Mills Pumping Station from STATION A	4,099,800	45	403	0	0	0	0	0	0
CS37X	Cat 4	Canning Town Pumping Stn	0	0	0	0	0	0	0	0	0
CS34X	Cat 1	Charlton Storm Relief	600	2	3	900	2	3	900	2	3
CS53X	Cat 3	Henley Road	0	0	0	0	0	0	0	0	0
		Downstream Greenwich to Henley Road Total / Maximum [b.]	**19,432,000**	**56**	**1,288**	**14,000**	**6**	**13**	**14,00**	**6**	**13**
		Crossness STW Storm Tanks	308,300	5	27	50,200	3	8	50,60	3	9
		Tideway CSO				609,100	3	19	698,300	3	22
		Total / Maximum [b.] to the River (CSO + Tunnel Overflow)	**39,667,000**	**56**	**5,567**	**17,723,000**	**51**	**4,288**	**2,363,000**	**6**	**408**
Sewarage Treatment Works [c.]		Beckton Catchment	444,610,000		8784	508,290,000		8784	508,240,000		8784
		Tunnel Pump Out	n/a		n/a	6,201,000		791	22,128,000		1551
		Beckton STW (Catchment + Tunnel Pump Out)	444,610,000		8784	514,490,000		8784	530,370,000		8784
		Crossness STW	200,560,000		8784	230,940,000		8784	230,280,000		8784

Notes

a. All CSO spills less than 100m3 have been removed. Volume, number and duration of spills have been adjusted accordingly.

b. For Volume and Duration, the sum of all CSO spills in the reach is reported. For Number of Spills, the maximum number of spills in the reach is reported.

c. Typical Year Model simulation is only for 270 days. The table includes infilling the remaining days with average daily DWF for Beckton and Crossness STW.

Appendix C Further in river control of sewage debris

General system

Should it still be deemed appropriate to reduce the aesthetic effect further, then, where practical, booms could be fitted around the CSOs and further oil skimmers provided to pick up slicks not otherwise collected by the litter collectors.

Typical CSO discharging

CSO discharges at Vauxhall Bridge

Booms

In various places elsewhere a floating boom has been used to concentrate the floating litter/debris which is then collected and disposed of. One such installation is at Cardiff Harbour, see the last page of Apendix C. It may be possible to provide similar booms at the Thames CSOs, thus concentrating the floating sewage litter so it can be retained when a spill occurs and not escape into the river.

I have been in touch with Bolina Booms who supply such booms. The booms would need to both float at high tide and to retain the collected debris when part of them are sitting on the foreshore during low tide. The proposed arrangement consists of vertical piles in the form of a trapezium with the long side the shore and the short side in the river and parallel with the river flow. The booms would be flush faced Bolina environmental booms fitted with alternate kite floats to keep the boom stable and upright when dried out at low water. The boom would be kept in position by four piles at each point of the trapezium/rectangle with floating collars around them to move with the tide. Concern has been expressed as to whether the booms could cope with the 5m tidal range in the Tideway. However, Bolina Booms believe that, with the collar system shown below, this should not be a problem

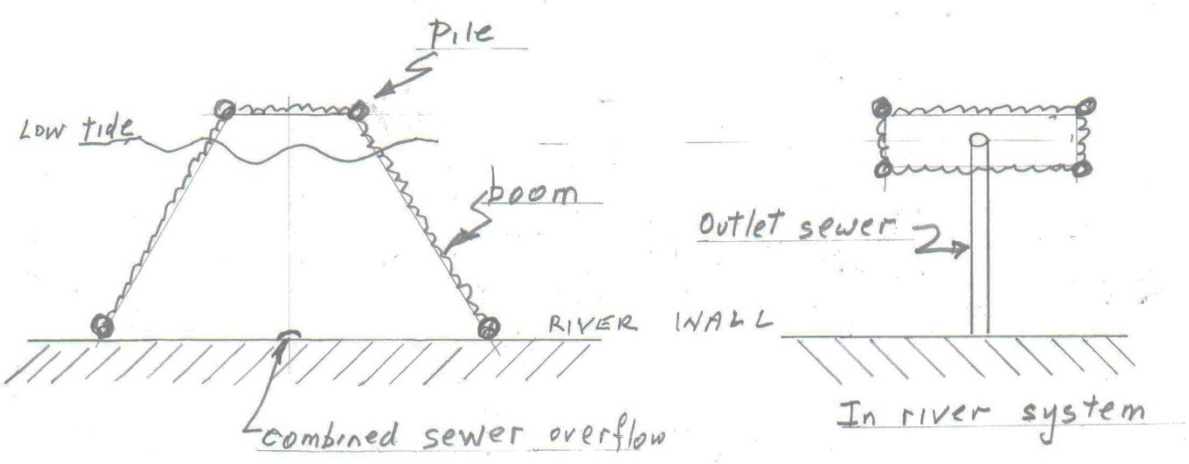
Picture of a typical boom installation

The debris within the booms would need to be collected. It is proposed that this be done by a floating craft. This could be by having a trash trap at the outlet of the boom which is then lifted up by a mechanical grab with fine mesh. For the finer debris a fish pump could be used to suck up the surface water in a similar way to that used for moving fish from one tank to another.

Thames Water, in its response to the Examining Authority document APP63 states in *"4.1.13 A local boom could also be installed at the outlet of Shad Thames pumping Station CSO under the boardwalk where the discharge occurs to capture discharges, if accesible."*

Picture of a variable water level boom.

Below is a sketch of the iitial boom arrangment when the CSO is in the river wall and also when the CSO is out in the river.



Location of boomed CSOs

In 2004 the Environment Agency considered 36 CSOs as unsatisfactory. However there have been a number of changes since then. Because of these changes a number of CSOs in the Table of Performanace, see Appendix A, now have zero discharge. These are Abbey Mills, Wick Lane, Church

St, Queen St, and Norfolk St. However I have based the boom proposals on the EA list but left out those with vey low spill volume or where booms may not be practical.

Constructing a boom system costs money and anyway a CSO with a low spill volume would not be worthwhile booming. In the TTSS the EA had taken 1,000 m3/year as the limit below which adverse impact would not occur. Arbitarily I have taken a limit of 3,000m3/year set out in the EA mdel as an economic cut off point point. This would remove a number on the EA category 2 list of CSOs that do not operate frequently but which the EA deems have an adverse environmental impact viz Stamford Brook, Smith St, KSP, Grosvenor ditch, Essex St,and Charlton from the list of those to be boomed. The only two schemes left in category 2 are NW Relief 4,100m3/year and Savoy St, 8,500m3/year. From the Admiralaty chart the outlet from the NW Relief looks to be in the river. Holloway is a CSO spilling about 8,000m3/year into the Tideway well downstream of Tower Bridge so the river is large and should be able to absorb the impact. The two Jews Road CSOs have a combined discharge of 10,000m3/year with a spill duration of 7 hours/year. Thus it is unlikely to warrant premanent booming them but rather using one of the floating skimmers.

An outlet on the bed of the river makes booming more problematical with the high tidal currrents in the Thames. From the Admiralty Chart it would appear that Hammersmith, Heathwall, SW Relief, Lots Rd, Clapham, and Brixton have outlets on the bed of the river at or near low water and any boom might obstruct navigation to/from adjacent wharves or bridges. For the time being I have assumed that these could not be boomed.However it might be possible to alter the outlet in a way that enabled them to be boomed and this should be considered.

From the Admiralty chart it would also appear that Acton, Falcon bridge, and Greenwich also have outlet near low water. However it would appear that a boom here is unlikely to obstruct navigation. The question then is how quickly will the floatables rise to the surface. I have no information on this. I have had, therefore, to make a broad assumption. I have allowed for a rectangle 5m by 25m with the long side parrellel with the tidal flow.

Frogmore CSO discharge is into the River Wandle. I have allowed for an angled boom across the Wandle with a length of 50m.

Tideway indicative boom layout

Site name	CSO	Vol/year	Spill time	Against wall	Distance to chart	Min width m	In river
	no	k m3	hrs/year		datum m	bridges/river	dimensions
Acton	1	300	163				5m x 25m
W.Putney	5	35	119	Y	30m		
Putney bridge	6	70	111	Y	30m	40	
Frogmore	7	100	130	River Wandle		50	
Falcon Br P/S	9	780	291				5m x 25m
Ranalegh	14	300	153	Y	60m		
Western P/S	15	2,300	228	Y	30m		
Regent St	22	25	19	Y	zero		
Northmbrlnd	23	80	47	Y	zero		
Fleet (B bridge	27	570	83	Y	10m		50m
NE Relief	29	800	300	Y	40m		

Deptford	32	1,900	343	Y	40m	
Greenwich	33	4,000	240			5m x 25m
Shad P/S	28	100	69		50m	
Earl P/S	31	600	207		40m	
Total		11,960				

CSOs unlikely to be viable		2,300		
Hammersmith	4		690	
Heathwall	16	700	240	
Brixton	20	270	137	
Clapham	19	14	15	
Lots rd	10	1,200	410	Pier
	Total	4,484		

That would result in 15 CSO discharges into the Thames and Frogmore into the Wandle being boomed. The result is that, based on the TW Table of Performance, about 75% of the overflow that is classified by the EA as having an adverse environmental impact would be boomed, thus much restricting the amount of sewage debris that would enter the free flowing Thames. Should the EA wish to have the small category 2 CSOs boomed as well, this could be studied.

Approval

Approval from the PLA and the Environment Agency would be needed for the planning, implementation, and technical aspects of these measures. However those that I believe would obstruct or hinder navigation have not been included in these proposals which should mean easier discussions with the PLA.

Cost

Bolina booms have quoted a budget price of £1,246,000 for the supply, assembly and installing of the above instalations including piles and piling and including Lot's Road which has subsequently appeared to be a restriction on navigation.

They have made this offer subject to good acccess to set up pontoons into the Thames near the site and that each site is accessible by river from one to another. They have also excluded the cost of licences to work in the river or the provision of Health & Safety files. They have also made the quote subject to site survey for possible extras including wall seals, engineering design, ground investigation, UXO surveys, permits and permissions, planning aplications and licences plus possible delays due to inopportune weather or tidal conditions. Making a broad brush allowance of £3/4m for these elements and some contingencies would bring the boom cost to £2m.

The layout of the discharge at Mogden STW is unknown by me. Spills there will still occur on rare occassions, see the event of 28th May 2013. Subject to the site layout, it might be possible at low cost to provide booms there to collect any floating debris, thereby reducing even further the potential impact on Tideway rowing and sailing boats and other features.

Retained sewage litter collection.

There are various methods of taking the sewage debris from within the boom. One method is a Trash Trap. This collects the trash in a metal mesh container which can be lifted out by a barge and boom arm and emptied into the hole of the collector vessel.

General Description

The 'Trash Trap' is constructed in galvanized steel with a metal mesh basket. The basket incorporates small holes to allow the movement of water to continue whilst collecting the floating debris. Typically 1t capacity but can be made to different sizes depending on application

The Trash Trap is a useful complimentary tool to OPEC's boom range.

In general booms can only be used as a temporary measure to act as a containment barrier against floating debris.

Another method if the retained sewage debris is small is to use a fish handling vacuum pump as supplied by Afak Techniek BV of Holland. This is normally used to move fish from one tank to another but should be suitable for collecting floating debris and water into a nearby barge.

Such systems would be operated from a powered work boat with a lifting arm and a cargo bay and a screened water discharge system, probably during the upper part of the tidal cycle to provide floating access to the boom structures.

I have no knowledge about the cost of such a powered work boat but assume that about £1m would be a reasonable budget.

In-river litter collection

Thames Water have two litter skimmers. With the Lee tunnel and the STW upgrades removing more than half the spill volume, and the potential addition of booms controlling some 80% of the remaining overflow, it is likely that no extra litter skimmers would be needed. Thus the craft would continue to operate but now concentrating in the areas where booms may not be able to be installed, likely to be Hammersmith, Lots Rd, and Heathwall.

There are also oils which can form a film on boats. This could be car oil, cooking oil, or sewage derived. I understand that there are skimmers developed to collect oil and similar, so they should be provided. Provisionally I have assumed that four such oil skimmers would be required. However their effectivness should be established and, if need be, more provided.

Fig 3.1 – Typical Oil Skimmer

Implementation period

Such a scheme of booms and skimmers should be implementable within about two to three years.

Cost

The current two litter collectors cost £2m each so I have assumed that the smaller oil skimmers would cost a similar total amount, say £2m.

Appendix E Environment Agency record of fish kills in the Tideway 2003-2013

Classification	EA comments	Notification Identifier
Category 3 - Water	Storm discharge, no reported fish kill	197529
Category 2 - Water	Category 2 pollution incident due to poor water quality from storm sewage discharges. Eels reported dead by eel fishermen but no dead fish or invertebrates were seen following incident attendance. Fish kill suspected but no	234023
Category 2 - Water	Category 2 pollution incident due to storm sewage discharges. Several carp reported dead but not verified by EA attendance	317681
Category 1 - Water	Category 1 incident, fish kill in tideway due to storm discharges and poor effluent quality. Unknown number of eels recorded killed in fishermens nets	329236
Category 3 - Water	Storm discharge, no reported fish kill	400805
Category 2 - Water	Category 2 pollution incident reported due to large volume of oil spilled at Chiswick marina. 2 dead fish reported, unknown species.	405308
Category 3 - Water	Storm discharge, no reported fish kill	427028
Category 3 - Water	Storm discharge, no reported fish kill	435975
Category 3 - Water	this is an incident of dead eels in keepnets - not typical fishkill	436584
Category 3 - Water	Storm discharge, no reported fish kill	509263
Category 3 - Water	Storm discharge, no reported fish kill	510007
Category 1 - Water	Category 1 incident, fish kill in Bow Creek due to sewage discharge from Abbey Mills. Reported 500 bream, 50 eel, and other 100 other fish killed	533804
Category 3 - Water	Storm discharge, no reported fish kill	537138
Category 3 - Water	Storm discharge, no reported fish kill - significant impact on DO	608672
Category 3 - Water	Storm discharge, no reported fish kill - significant impact on DO	611822
Category 3 - Water	Storm discharge, no reported fish kill - significant impact on DO	681789
Category 1 - Water	Category 1 incident, eels reported dead in nets by fishermen. Unknown number reported, fish kill due to storm sewage discharges	696005
Category 3 - Water	Storm discharge, no reported fish kill - significant impact on DO	706550
Category 3 - Water	Storm discharge, no reported fish kill	776289
Category 3 - Water	Storm discharge, no reported fish kill	813791

Category 3 - Water	100 dead fish approx, due to algal activity Royal Albert Dock, site attended by EA	821848
Category 3 - Water	200 dead roach and around 30 dead carp, Woolwich docks, due to thermocline inversion, site attended by EA	831498
Category 3 - Water	Storm discharge, no reported fish kill	888629
Category 3 - Water	Storm discharge, no reported fish kill	896103
Category 3 - Water	Storm discharge, no reported fish kill	897660
Category 3 - Water	Storm discharge, no reported fish kill	903808
Category 3 - Water	Storm discharge, no reported fish kill	904556
Category 3 - Water	Storm discharge, no reported fish kill	904929
Category 3 - Water	Storm discharge, no reported fish kill	910218
Category 3 - Water	Storm discharge, no reported fish kill	917091
Category 3 - Water	Storm discharge, no reported fish kill	921758
Category 3 - Water	Storm discharge, no reported fish kill	990918
Category 3 - Water	Storm discharge, no reported fish kill	997515
Category 3 - Water	Storm discharge, no reported fish kill	998172
Category 3 - Water	Storm discharge, no reported fish kill	998817
Category 3 - Water	Storm discharge, no reported fish kill	1009926
Category 3 - Water	Storm discharge, no reported fish kill	1012268
Category 3 - Water	Storm discharge, no reported fish kill	1014129
Category 3 - Water	Storm discharge, no reported fish kill	1022782
Category 3 - Water	Storm discharge, no reported fish kill	1030834
Category 3 - Water	Storm discharge, no reported fish kill	1040033
Category 3 - Water	Storm sewage pollution in Chelsea, 1 dead fish reported, site attended by EA	1095027
Category 3 - Water	Storm discharge, no reported fish kill	1138741
Category 3 - Water	Storm discharge, no reported fish kill	1143955
Category 3 - Water	Storm discharge, no reported fish kill	1159247

Notification Date	EA Water Management Region	EA Water Management Area	Location
21/10/2003	Thames Region	South East - Thames	Upper Tideway. Isleworth.
03/05/2004	Thames Region	South East - Thames	Erith Marshes
04/06/2005	Thames Region	South East - Thames	Old Deer Park
24/06/2005	Thames Region	South East - Thames	Abbey Mills and Tideway
21/05/2006	Thames Region	South East - Thames	Old Deer Park
08/06/2006	Thames Region	South East - Thames	Chiswick Bridge
13/08/2006	Thames Region	South East - Thames	Old Deer Park
14/09/2006	Thames Region	South East - Thames	Creekmouth - Tideway
18/09/2006	Thames Region	South East - Thames	Coldharbour
29/06/2007	Thames Region	South East - Thames	Chelsea Bridge
02/07/2007	Thames Region	South East - Thames	Old Deer Park
24/09/2007	Thames Region	South East - Thames	Bow Creek
09/10/2007	Thames Region	South East - Thames	Old Deer Park
29/07/2008	Thames Region	South East - Thames	Old Deer Park
07/08/2008	Thames Region	South East - Thames	Jenningtree Point
26/05/2009	Thames Region	South East - Thames	Old Deer Park
07/07/2009	Thames Region	South East - Thames	Old Deer Park
12/08/2009	Thames Region	South East - Thames	Albert Bridge
02/05/2010	Thames Region	South East - Thames	Old Deer Park
16/08/2010	Thames Region	South East - Thames	Old Deer Park

12/09/2010	Thames Region	South East - Thames	Gallions Reach
17/10/2010	Thames Region	South East - Thames	North Woolwich
26/05/2011	South East Region	North East Thames	Old Deer Park
22/06/2011	South East Region	North East Thames	Old Deer Park
28/06/2011	South East Region	North East Thames	Old Deer Park
17/07/2011	South East Region	North East Thames	Chelsea Bridge
19/07/2011	South East Region	Kent & South London	Old Deer Park
21/07/2011	South East Region	North East Thames	Chelsea Bridge
04/08/2011	South East Region	North East Thames	Old Deer Park
25/08/2011	South East Region	Kent & South London	Bugsby's Reach
11/09/2011	South East Region	North East Thames	Old Deer Park
15/05/2012	South East Region	Kent & South London	Barking Reach
03/06/2012	South East Region	Kent & South London	Chelsea Bridge
06/06/2012	South East Region	Kent & South London	Old Deer Park
07/06/2012	South East Region	Kent & South London	Halfway Reach
06/07/2012	South East Region	North East Thames	Creekmouth
10/07/2012	South East Region	Kent & South London	Old Deer Park
15/07/2012	South East Region	Kent & South London	Old Deer Park
06/08/2012	South East Region	Kent & South London	Old Deer Park
25/08/2012	South East Region	Kent & South London	Chelsea Bridge
23/09/2012	South East Region	North East Thames	Hammersmith Bridge
17/03/2013	South East Region	North East Thames	Battersea Reach
25/07/2013	South East Region	Kent & South London	Barking Reach
05/08/2013	South East Region	Kent & South London	Barking Reach
13/09/2013	South East Region	North East Thames	Hammersmith Bridge