Thames Tideway

Review of Tideway spills and their environmental impact.

with addendum 1

By

Professor Chris Binnie

MA, DIC, HonsDEng, FREng, FICE, FCIWEM

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Chrisbinnie@btopenworld.com

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Executive summary

Introduction

1 The sewerage system of central London combines foul and storm water in one pipe with combined sewer overflows into the Tideway during storms. This has resulted in excessive storm discharge and adverse environmental conditions. The European Urban Waste Water Treatment Directive (UWWTD) has the objective "*to protect the environment from the adverse effects of water discharges."* A programme of work including upgrading of the sewage treatment works and the construction of the Lee tunnel is nearing completion at a cost of about £1.2bn. The construction of the Thames tunnel at a cost of £4.2bn will start in about a year. Information has been received recently of the benefit that has been achieved so far. This Review considers whether the benefit of the current works is sufficient to meet the UWWTD, whether the Thames tunnel is still required or whether other measures are likely to b sufficient. This report was issued to Defra in December 2014 and this updated version includes their response and consideration of the issues raised.

Dissolved oxygen/ ecology

2 The Environment Agency (EA) state that, since the upgrade of Mogden STW in March 2013, despite many untreated storm spills, they are not aware of any instances when spills have caused significant adverse environmental impact on the river water quality. Thus the EA considers the Mogden spills comply with the UWWTD. Thus the E A has concluded that, provided there is no significant adverse environmental impact from spills, then any overflow is satisfactory and the UWWTD is met. "*The EA will consider the effect of discharges, rather than frequency."*

3 Since fish are the most sensitive ecological indicator, trials were carried out to determine the dissolved oxygen (DO) standards required in the Tideway so fish could be sustainable and the ecology satisfactory.

4 Thames Water set up a sewer model and a river water quality model. This showed that only the Thames tunnel would be sufficient to meet the required dissolved oxygen standards. However Thames Water identify many potential errors in the data and state that "*it is unlikely that it will ever be possible to acquire sufficiently comprehensive data.*" to produce robust output. Comparison with the dissolved oxygen readings, and the fish kill records show the model appreciably overestimates the fish kills and the sags in dissolved oxygen content of the Tideway.

5 The EA record of fish kills in the Tideway shows 3 fish kills over the last 10 years, with only one, of one fish, caused by overflow from the CSOs to be connected to the Tideway tunnel. The Tideway Fish Risk Model for the AMP4 condition and for the 2020 situation, once corrected for obvious errors, shows the Tideway fish to be sustainable.

6 To meet its requirement to monitor dissolved oxygen content in the Tideway the EA has established 9 Automatic Quality Monitoring Stations (AQMS). They have provided 7 years of records of the 3 main AQMSs. Lord de Mauley queried the applicability of the readings and their assessment but they are similar to the assessment by the EA for Mogden. The EA state that they are "*a better indicator of how often each DO standard is breached*". Analysis of the dissolved oxygen records of the Chiswick and Cadogan(Chelsea) AQMSs shows that the upper Tideway has met the dissolved oxygen standards since 2009. Once the Beckton and Crossness STW upgrades were completed in early 2014 the Erith AQMS has also met all the dissolved oxygen standards. Once the Lee tunnel is operational in late 2015, halving the spill volume, then the water quality in the lower Tideway will improve further.

7 The AQMS readings at Chiswick and Cadogan show that the upper Tideway now meets the Water Framework Directive dissolved oxygen good ecological status. It is probable that, once the Lee tunnel is operational in late 2015, the full Tideway will meet good ecological status for dissolved oxygen..

8 Thus, post the Lee tunnel and the STW upgrades, it would appear that, similarly to the current Mogden STW, storm discharges from the Tideway CSOs would not cause significant adverse impact on the ecological quality of the river, and, in line with the Environment Agency statement about Mogden, the Tideway ecology should be regarded as satisfactory under the terms of the UWWTD.

Health of recreationists

9 The Tideway is not a bathing water under the Bathing Water Directive. For navigational reasons the PLA have banned bathing downstream of Putney except with a special licence and guard boats.

10 The 2004 E A assessment used a theoretical matrix of location and volume of discharge to assess the impact of CSOs on health but provided no data on health impact to support its assumptions. It concluded that 19 CSOs were unsatisfactory for health reasons

11 The EA 2006 recreational users study found that most recreationalists were some 5,000 rowers, largely in the Chiswick-Putney area. The Health Protection Agency (HPA) found that their gastric illness was less than one tenth that of the general population. Using the Quality Adjusted Life Year analysis, as used by NICE, NERA found that the benefit of curing all gastric events would be £1 1/2m. Defra suggest that it would be "*somewhat in excess*", maybe £2m? Thus it would not be worthwhile spending more than this amount to deal with health aspects. Thus the health aspect of the CSO spills is not significant.

Aesthetics

12 The TTSS aesthetic objective is to limit pollution so it ceases to have a significant adverse effect. The HPA state the "*floating matter disseminates relatively quickly*" and Jacob Babties expect *"little aesthetic change due to the Tideway Strategy Options*" which includes the tunnel.

13 The 1997 Defra guidance criterion for unsatisfactory overflows is that they should have "a *history of justified public complaints*". For the 2004 assessment the EA identified only 3 CSOs as meeting this criterion. Instead the EA assessed CSOs on a largely theoretical and unsubstantiated basis, with no field data provided to support the assumptions. They then classified 33 CSOs as unsatisfactory for aesthetics reasons.

14 Since 2007 Thames Water has operated two litter collector boats which they say "*are a real success story enabling them to collect quantities of sewage litter*".

15 The EA carried out a similar assessment in 2011, but with no consideration of the benefit of the floating litter collectors, and this confirmed the same 33 CSOs as unsatisfactory. In 2012 the EA confirmed there were "*relatively few CSOs that have a history of justified public complaints"*. Thus there are few CSOs that should be classified as unsatisfactory for aesthetics reasons.

16 Should further measures be required to achieve no significant adverse aesthetics effect, then floating booms could be placed around most of the CSOs and the retained debris collected for treatment and disposal at a capital cost estimate of about £2m and achieved within about 1-2 years. Such a system appears to conform with the UWWTD to collect and

treat. Such a boom litter collection system is already in operation elsewhere in London. Floating booms were proposed by me some two years ago. Despite its low cost, the authorities have not carried forward the idea of floating booms. Thus one could conclude that, since the cost is not significant in comparison to the tunnel and could provide about 8 years control of most of the sewer debris prior to tunnel commissioning, the authorities have concluded that their benefit is less than their cost of about £2m. Therefore there is not a significant adverse aesthetics impact.

Overall impact

17 Thus, now the STW upgrades are operational, the conclusion is that the Tideway now meets the requirement for "*no significant adverse environmental impact*" from the CSOs and thus the objective of the UWWTD. The completion of the Lee tunnel in late 2015 and, if thought appropriate floating booms, will improve conditions further.

Cost Benefit analysis

18 In 2003 the TTSS carried out a willingness to pay (wtp) study based on a show card that stated there were 4 to 8 fish kills and 120 elevated health risk days per year, and assessed the benefits Thames Water customers would pay for the tunnel as some £5bn, substantially in excess of the then £1.7bn estimated cost of the tunnel. In 2006 a similar study used a show card with 1 or 2 fish kills per year and found the benefits varied from £1.5bn for Thames Water customers and about £4bn for all householders in England.

19 The project was then split with some benefit applied to the improvement of the STWs and some for the Lee tunnel which, between them, would about halve the volume of spill into the Tideway. The cost of the Tunnel was then re-estimated at some £4.1bn at 2011 costs base. In 2011 Defra then issued a Cost benefit report, revising a number of key assumptions and estimating the benefit as between £3bn and £5bn. I have reviewed the Defra report. Putting in the NERA health benefit of £1.5m, assuming the DO and thus fish benefit as sustainable, keeping the benefit area as the TW area of those that would actually pay, correcting the economic growth since 2006 to what has actually happened, correcting the benefit split between the Thames tunnel and the other works, and including the construction and operation dis-benefits, resulted in a benefit of about £500m. This is a small proportion of the current cost estimate and would not normally receive funding.

Best Technical Knowledge Not Entailing Excessive Cost

20 Defra have stated "*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."* Since the STW upgrades and the Lee tunnel, cost about £1.2bn, appear to fulfil the objective of protecting the environment from the adverse effects of water discharges, it is concluded that no further measures are required until climate change effects become significant in a few decades time. Were it required to reduce the spill frequency then there are measures, see 24 below, that could do that, almost certainly to whatever spill would be frequency required.

Spill frequency

21 Defra state that the CSO spill frequency is 50 to 60 spills/year. As shown in this report, the base case with the STWs upgrade, Lee tunnel connecting Abbey Mills to Beckton STW, and the 2013 DCO modelling, then the spill frequency is up to about 40 spills/year.

22 In the UWWTD, spills are allowed during unusually heavy rainfall. There is no definition of this but the European Commission (EC) has stated that it "*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 the EC appear prepared to consider more than 20 spills/year provided there is no significant environmental impact on the receiving water.

23 The TW sewer modelling assumes that, post 2006, sewer dry weather flows increase with increasing population and thus that there is less spare capacity in the sewers and thus there will, in future, be more frequent storm rainfall spills. However Defra have approved the TW WRMPs that show that, despite increasing population, more metering, more efficient water using appliances and demand management will result in the water into supply reducing and not returning to the 2006 level until later in the century. Thus the current sewer model almost certainly over-estimates spill frequency.

24 Ways of reducing spill frequency include removal of restrictions in the sewer system, separation of foul and storm flows into separate pipes, especially in areas close to the Tideway, or another water course, local detention tanks, real time control/active system control (RTC), sustainable drainage systems such as green roofs, swales and pervious pavements, and infiltration into the terrace gravels which underlie much of the combined sewer catchment. For instance Bloomberg report RTC reduced spills in Quebec from 45 to 26/year.

25 These measures could be used in combination where each is most economical. Whilst it is a Defra requirement that, in the RBMPs, a combination of measures be studied, this has never been done fully or properly. It should be.

26 I believe that a combination of measures could reduce the spill frequency from the current about 40 spills/ year to an acceptable level at a much smaller cost than the tunnel.

Future

27 Over the next decades, the increasing population and climate change will worsen the situation but this would take place over many decades. Thus more measures, particularly SuDS, could be taken, to ensure that the no significant adverse environmental impact status remains.

28 I recommend that, before Thames Water places large and expensive construction contracts, the post STW upgrade records of dissolved oxygen be analysed, the water quality model be calibrated against these records, the spill frequency of the CSO be reassessed, and whether other measures could reduce the spill frequency to an acceptable level. A decision could then be taken as to whether the Thames tunnel is actually needed to achieve no significant adverse environmental impact and meet the requirements of the UWWTD. If so this could save the country, and in particular Thames Water customers, a substantial amount.

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1 Introduction

Central London has a sewer system that combines both foul drainage and storm drainage in one sewer. When a storm occurs the flow can become greater than the carrying capacity of the sewers and the storm water, mixed with limited foul water, spills into the Tideway through 57 combined sewer overflows (CSO). The objective of the Urban Waste Water Treatment Directive (UWWTD) is to protect the environment from the adverse effects of such discharges with implementation before 2001.

Between 2000 and 2005 I chaired the Thames Tideway Strategy Steering Group (TTSSG) which was told by the Environment Agency that the upper Tideway suffered from regular fish kills resulting from frequent and damaging discharges from Mogden STW, the middle tideway suffered from the CSO discharges, and the lower tideway had chronic low dissolved oxygen conditions. It concluded that the first could only be solved by upgrading the Mogden STW, the latter by improvements to the effluent quality from the downstream sewage treatment works (STW), and, for the CSOs through central London, it recommended the Thames tunnel at £1.7bn

Subsequently the European Commission (EC) took the UK government to the European Court of Justice (ECJ) for not meeting the UWWTD and the UK was found to be in breach of the Directive as at 2001, before the sewage treatment works improvements were in place. The UK offered no defence of disproportionate or excessive cost in these proceedings. The Court assumed the Tunnel must be value for money because the UK had decided to build it.

Since then over £1bn has been spent in improving the Tideway water quality. This includes improving the treated effluent quality and reducing the storm spill frequencies and storm spill volumes of the three main STWs, Mogden, Beckton, and Crosssness and these are now operational.

In addition the Lee tunnel, which will take the spills from Abbey Mills pumping station direct to Beckton STW, is nearing completion and is expected to be operational about late 2015. This will reduce the spill volume, currently about 39 Mm3/year, to about 18 Mm3/year. This about halving of the annual spill volume into the Tideway will be a substantial further benefit and will soon improve conditions in the middle/ lower Tideway significantly.

In September 2014 the Secretaries of State. Defra and DCLG, approved the Development Consent Order that grants planning permission for the Thames Tideway's construction to collect and convey combined storm overflows for treatment at Beckton sewage treatment works (STW) and reduce the CSO spill frequency to an average of about 4 spills a year. This was estimated to cost £4.2bn, at 2011 prices. The examination in public by the Planning Inspectorate that preceded this decision did not assess need, cost or benefits on the grounds that, in respect of a national infrastructure project, they were precluded from doing so. Concern has been expressed as to whether such expenditure is warranted.

This review considers the latest data available. The Minister Lord de Mauley has written twice to Lord Berkeley in 2014. This review takes account of all the points raised and responds to them. I am grateful to the Environment Agency (EA) for the meetings, discussions, data, and correspondence. In particular this review considers the Tideway water quality data which is also assessed in more detail in Appendix A. This review incorporates Lord de Mauley's letter of 13th January 2015 and Lord Berkeley's comprehensive rebuttal of 19th January, attached in Appendix G.
The prime consideration of this review is whether, now the STW upgrades are operational, the CSOs still result in significant adverse impact of the Tideway and still breach the UWWTD.

2 Urban Waste Water Treatment Directive

Objective
The objective of the UWWTD is "*to protect the environment from the adverse effects of... water discharges.*" The Directive says that that spills should only be allowed under certain conditions such as "*unusually heavy rainfall*". Unusual is not defined.

Spill frequency guidelines

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, where the environmental impact is satisfactory, as required by the Directive, a spill frequency above 20 spills a year could still be acceptable.

Lord de Mauley in his letter of 24th February to Lord Berkeley stated "...*and paragraph 61 "the Court does not have jurisdiction to define numerically obligations laid down by that directive*". He continued "*The Commission has not subsequently proposed or adopted any guidelines on spill limits...*"

The Examining Authority's main report on the Tideway Tunnel development consent hearing, 15.16 states "*The European Commission does not specify the number of CSO discharges that it would regard as acceptable and leaves this to member states to determine APP63, para 6.1.18.* "

The Advocate General's Opinion of the infraction proceedings, January 2012 para 48 states *"On several occasions, however, both in the pre-litigation stage and before the Court, the Commission did indicate that, as rule, exceeding the limit of 20 overflows a year would be a cause for concern, suggesting a possible failure to fulfil obligations"* Clearly the EC do consider more than 20 spills a year as potentially acceptable providing the objective of the UWWTD was not breached.

The European Commission Additional Reasoned Opinion dated 27/11/2008 states in para 21 *"an acceptable spill frequency ...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*." Thus the EC consider the state of the receiving waters important.

The Environment Agency in their notes of our meeting on 25th September 2014 note 6 state " "*Spills alone is not regarded by the Environment Agency as an indicator of failure to comply with the UWWTD."* "*provided spills have not caused a significant adverse impact on the quality of the river...overflow is regarded as satisfactory." "The EA will consider effect of discharges, rather than frequency.* " To me this means that, provided discharges do not cause significant adverse impact on the quality of a river or watercourse, then spill frequency is not in itself relevant. In effect the EA view means that overflows can occur at any time provided the overflow does not cause a significant adverse environmental impact.

Thus, there are no fixed guidelines on spill frequency, it is up to member states to set, and an acceptable spill frequency would be based on the impact on the receiving waters which the UWWTD is established to protect.

Such a situation exists at the Mogden STW and this is discussed in more detail below.

Annex 1A of the UWWTD states "*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." This is similar to the requirement in the Water Framework Directive for the cost not to be "*disproportionate*." This is discussed further in section 8.

3 Mogden spill impact

The Mogden STW has recently been much extended and upgraded to improve water quality of the effluent and to reduce spill frequency. This was completed in March 2013.

In Hansard Lord de Mauley has stated in a written answer PQ0401 14/15 that "*A discharge from Mogden STW storm tanks has occurred on 54 days in the 12 months from 31st March 2013."* My understanding is that the storm tanks spills are of sewage and storm water that has been screened only with no further treatment.

Mogden STW does not have a spill frequency in its consent to discharge. Mr Hughes of the Environment Agency wrote on 30th June 2014 *" The new permit for Mogden is designed to protect the receiving water, and the works is designed to capture and treat urban waste water in all but exceptional circumstances." The new permit is designed to protect the environment by significantly increasing the flow to full treatment. In doing so it is protective of the receiving water and limits pollution from the asset. That is the aim of the directive. "*

I am grateful to Mr Simon Hughes of the Environment Agency for confirming in his email of 24th July 2014 that "*spills...alone is not regarded by the Environment Agency as either an indicator of the failure of the scheme ... or of Mogden STW to comply with the UWWTR*." Since the UWWTR apply to all sewerage systems then I presume that this Environment Agency criterion would apply to all sewerage systems, including the Tideway.

This is amplified by his statement that "*The Environment Agency is not aware of any instances when storm discharges from Mogden STW have caused a significant adverse impact on the quality of the river since the upgrade of the works. On this basis, the overflow from Mogden STW storm tanks is regarded as satisfactory under the terms of the Urban Waste Water Treatment Directive."*

Lord de Mauley, in his answer to PQ0401 14/15 on 30th July 2014, stated " *the storm discharges from Mogden STW have not led to a significant adverse impact on the quality of the river since the upgrades. The Environment Agency will continue to assess the performance of the upgrade to ensure it continues to comply with the Urban Waste Water Directive."*

That means that the fact that a few of the Tideway CSOs may spill about 30 to 40 times in an average year (not the 50-60 claimed by Thames Water) then, provided they do not cause significant adverse impact on the quality of the Tideway, then their spill frequency is immaterial. I examine the impact of the CSO overflows in the sections below.

The three environmental considerations identified by the TTSS for the Tideway are ecology, for which fish are taken as a surrogate, health of the river users, and aesthetics. I consider each in turn below.

4 Tideway spill impact on ecology/fish

Current situation

Currently there are some 57 combined sewer overflows that discharge into the Tideway, some of them pumping stations. Some discharge rarely but some discharge up to about 50

times a year on average. This discharge results in lowering of the dissolved oxygen conditions in the Tideway, which, if excessive, can result in too low an oxygen level to support ecology and fish kills can occur.

The river is monitored by 7 Automatic Quality Monitoring Stations (AQMS) and, if these show low dissolved oxygen readings then one of the two bubbler boats is sent out to inject oxygen into the water. There are also 5 on land places where hydrogen peroxide has been dosed from the river bank, Mogden, Barnes, Kew, Western, and Beckton.

Objectives

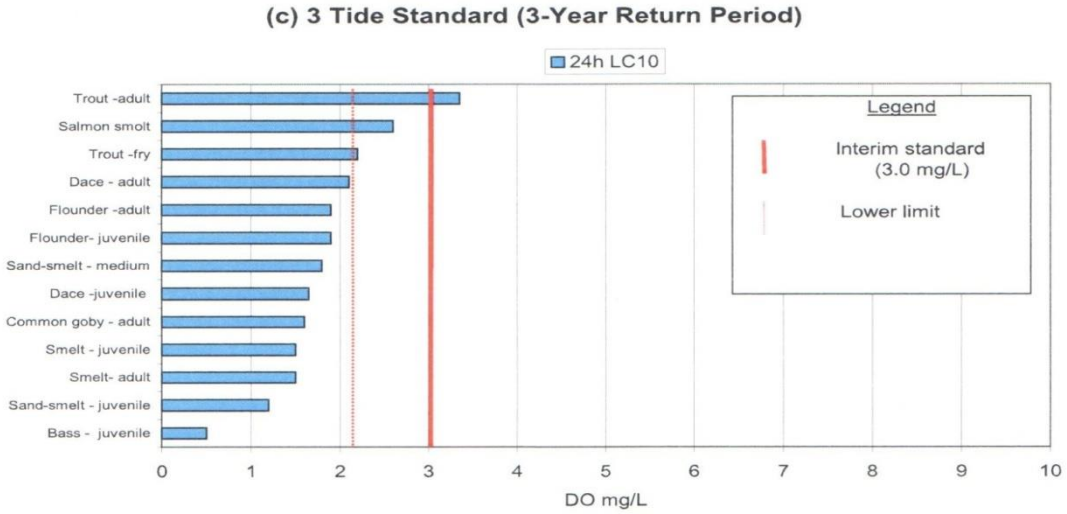
The Thames Tideway Tunnel and Treatment (TTTT) report, 2006 Vol 1 Objectives states "*since it is generally recognised that fish are the most sensitive indicator of ecological quality, the decision was taken to derive standards that are protective of relevant fish species."* Thus the objective is effectively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

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

Dissolved oxygen standards

Representative fish species

The Tideway water quality standards were set by the TTSS on the basis of the trials of the reaction to various dissolved oxygen conditions of a suite of fish species taken to represent those fish species present in the Tideway. Details of the assessment are given in Appendix B, Fish and dissolved oxygen standards. A mortality of 10% was taken as the limit of sustainability. The trials data shown below is the constant dissolved oxygen level that, lasting for 24 hours, would result in mortality of 10% of the relevant fish species.



As can be seen for the situation at 2mg/l, Threshold 3, (ignore the vertical thick red line) the mortality would be considerable for salmon, about 10% for dace, a numerous species, and limited mortality for flounder and others. Thus 2mg/l for 24 hours would be likely to cause mortality of those fish which have high levels of sensitivity.

From these trials the dissolved oxygen standards were derived.

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

Threshold 1, 4mg/l, *"was selected to ensure protection against chronic effects; these would include eg effects such as depression of growth and avoidance of hypoxic areas*." Thresholds 2 and 3, the latter the 2mg/l 6 hour, once in 5 years standard, were set so as "*to provide protection to stocks by managing the scale and frequency of mortalities. It was accepted that greater mortality would occur with the more severe of the two standards, but intended that for both standards, fish loss would be fairly limited. The minimum standard*" Threshold 4 " *was included to ensure protection from mass mortalities."* Thames Tideway Strategy :Experimental studies on dissolved oxygen requirements of fish Babtie 2004 page 75 and 76.

Thus any breach of thresholds 2, 3 or 4 is expected to result in a fish kill. If a breach occurs more often than allowed, then the Tideway would fail the standard. It should be noted that Threshold 1, 4mg/l, does not result in fish kill but is chosen so fish can avoid hypoxic zones.

Modelling of breach of the standards

The modelling consists of two main aspects, the modelling of the sewer flows and sewer discharges to the river and the modelling of their impact on the water quality of the river.

The dissolved oxygen model needs as its input such data as the quality, frequency, and volume of the CSO discharge and the quality and flow of the river water, its temperature, tidal conditions. All these variables would be different for each event. This variability must be considered when assessing the reliability of the model results.

Reliability of the sewer discharge model

As set out in Appendix C modelling, the robust data available for the sewer model is limited.

Critical summer rainfall varies over small distances so the rainfall input could be significantly in error.

It has been assumed that the sewer dry weather flows increase with population whereas, despite increasing population, but because of greater demand management and metering, water supplied by Thames Water decreases from 2006 to 2021, and hence sewer dry weather flow, will actually decrease.

There are few reliable sewer flow gauges in the complex sewer system.

The sewer pre storm conditions vary significantly.

There is very limited data on CSO spills. Spill quality is known to vary greatly during a storm due to the first flush effect and there is very limited data on spill quality and how it varies with time.

This is confirmed by the TTTT 2006 Vol 2 page 10 which states " *Of the 57 CSO which discharge to the Tideway, indicative flow data only exists for around 9 of the pumped*

discharges and there is some historical data. There is no flow data and virtually no quality data for the remainder. Obviously, comprehensive flow and quality data is essential for all these discharges if individual rainfall events are to be modelled precisely. " Which they are. "*It is likely that, depending on rainfall patterns, the quality of discharges from these outfalls will vary considerably throughout the event and each CSO will display a different pattern of discharge. It is also likely that antecedent conditions will influence the amount of solid material flushed from the system. Under these conditions it is unlikely that it will ever be possible to acquire sufficiently comprehensive data.*" Thus the assessment of the frequency and quality of discharge from the CSOs cannot be robust.

Further, the river water quality model requires reliable information on the water quality of the pre-event river, a variable depending on many factors such as the water quality and quantity of the flows entering the Tideway, preceding spill events, the temperature of the Tideway, the tidal conditions and any BoD in the different amounts of sediment stirred up by the spring or neap tide.

Thus the river dissolved oxygen model outputs can be appreciably in error.

Model output for the pre 2013 condition

The latest water quality modelling output is that shown by Thames Water in its Application for Development Consent doc 7.23 table 3.1 on page 10, below. The main fish kill criterion is threshold 3 of 2mg/l for 1 tide. The required standard is once in 5 years, ie 8 events in 41 years of modelling. The model output for the current situation is 99 occasions in 41 years, ie 24 fish kills in 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

1. A tide is a single ebb or flood. Failure = predicted exceedances > allowable exceedances

Baseline conditions post STW upgrades and Lee tunnel operational

The current baseline conditions are when the current works are all complete. This includes the STW upgrades, already completed, and the Lee tunnel expected to be completed in late 2015. The Thames Water baseline condition is that in 2020 which includes the assumed changes in climate change and sewer dry weather flows due to population increase but ignores the reductions in dry weather flow due to demand management and metering.

The EA state, point 9 of the meeting notes of 25th September " *We explained at the 25th September meeting that there will be an improvement in quality resulting from the other components of the LTI* " I think this means Lower Thames Improvements "*which is why we supported the works being done, but there is still a large impact on the WQ from the remaining spill volume which means that the tideway does not comply with the UWWTD and partial implementation of the LTI does not achieve the aims of the improvement programme or the requirements of the UWWTD.*"

The EA state in Point 10 "*the STW upgrades and the Lee tunnel do not deal with the spills from pumping stations in west London, so there is no mechanism for them to deal with the problem in the upper tideway*." Indeed the Tideway here is smaller so is more at risk of impact.

However, because of the many factors which are input into the model but for which robust data is not available, the results of the model should be considered indicative and cannot be considered robust.

Tideway Fish Risk Model

Not all fish are spread uniformly through the Tideway. Thus the Tideway Fish Risk Model (TFRM) combines, for each representative fish species, the proportion of stock in each river zone by month with the probability of a breach in that zone by each month to generate a risk matrix. This is then combined with a risk of mortality for that threshold to identify an overall population effect. This is more reliable in identifying sustainable conditions than the dissolved oxygen modelling as it takes a wider range of factors into account.

Page 76 of the FARL report Experimental Studies on the Dissolved Oxygen Requirments of Fish 2004, (TFR) when discussing mortality, states "*All fish populations can cope with a degree of mortality without the long-term population level being affected. This is a principle that underlies the commercial exploitation of fisheries, in which sustainable fishing mortality rates of 50+% are not uncommon (see e.g. Van Winkle, 1977). Mortalities are best withstood in the early juvenile phase, where natural mortalities are already high (typically 5-10% per day for pelagic larval stages). Hence, a 10% loss in the early fry stages is unlikely to be detectable and a 10% loss even at the adult stage is likely to be sustainable in a population that is not commercially exploited and under pressure already. Annual mortality rates of this magnitude would probably cause little or no detectable change in the population relative to one in an unexploited, unimpacted population in a pristine environment."*

Dr Turnpenny, in his response to the TTSS comments on the Babtie report, 2005 see TFR page 48 states "*Fish in the Tideway are generally scattered through a number of Tideway zones and therefore, while suffering high mortalities in the grossly polluted reaches, the bulk of the population may survive. This can mean that there will be heavy fish kills but that mortalities over the Tideway as a whole would still be sustainable.".*

As part of the fish studies and trials a tideway fish risk model (TFRM) was set up "*to better assess the risk of hypoxic (low DO) events. It takes account of the fact that CSO events do not affect the whole of the Tideway equally and that a breach of a standard is likely to affect some zones more than others. For instance, if a species were uniformly distributed throughout the Tideway but the LC10 (lethal concentration for 10% of the population was exceeded in only 20% of the Tideway habitat, then only 2% of the population (not 10%) would be likely to die. The TFRM applies this concept using the EA Tideway water quality Zones to estimate for any given month of the year, for each species/lifestage, what proportion of the Tideway population are likely to be present in a particular zone. Water*

quality (DO) data are then compared against lethality data to estimate the mortality by species/lifestage and Zone." Thames Tideway Strategy :Fish & Ecology Objective, 2005

Appendix F to Needs Report 2010 states on page 16 that the TFRM of the situation at that time shows that "*the fish populations would be sustainable, or marginally sustainable. The fact that this state is achieved with the large number of standards breaches associated with the Current baseline can be taken to imply that Tideway fish populations should already be sustainable, which potentially undermines the case for improvements."*

Appendix D of my Review shows that the baseline, 2020, TFRM needs correction as it does not take proper account of the fish trial data and that, once this is done, all representative fish species will be sustainable, both now with the STW upgrades in place and in 2020.

Further the TFRM was based on the Tideway water quality model. That has been shown to underestimate the minimum dissolved oxygen conditions. For instance the model had predicted 40 breaches of standard 2 in 41 years based on a 1 year in 3 criterion. Chiswick and Cadogan had no breaches in 5 years and Erith had no breach in 2014. Other standards are similar. Thus clearly the dissolved oxygen conditions in the Tideway are better than assumed in the TFRM and the fish populations are even more sustainable.

Fish kill data

The Environment Agency record of fish kills in the Tideway, sent to me on 13th January 2014, shows, for the CSOs and Abbey Mills spills, 3 fish kills in the previous 10 years, ie the equivalent of 12 fish kills over the 41 years of modelling. This compares with the 99 fish kills shown in the Thames Water water quality model. As the object is to have sustainable fish species, and the fish kill data is actual field data, should the model not be adapted to what actually is occurring rather than rejecting field data that does not accord with it ?

The EA state that "*It is likely many fish kills are not recorded/observed."* The EA stated that when fish were killed not all fish floated. First there are many fish in the Tideway. Whilst there might be a few small fish kills that occurred but were not recorded, fish kill events are more likely to occur in the summer when the river temperature is higher and the natural dissolved oxygen content lower, rather than in the winter. In summer the daylight hours are longer and thus fish kills are more visible. With the tidal excursion, the plume of effluent gets carried up and down river so would affect a significant area, and hence a significant number of fish. Further any dead fish would move with the tide and be more likely to be seen somewhere. The fish kill in the Barnes/Chiswick area in 2004 was extensively reported, both to the EA and in the press. Thus it does appear that significant fish kills would be fairly extensive and would be likely to be observed, and then reported.

As an upper bound one might assume that only half of the actual fish kills were reported. That would still mean the model considerably overestimates the actual fish kill.

Further the Environment Agency record for the last 10 years shows only one fish kill, of only one fish, recorded as having been killed by spills from the Combined Sewer Overflows to be connected to the proposed Thames Tunnel. The current allowable standard level 3 is one breach/fish kill in five years. Thus the one recorded fish kill in 10 years would meet even the current standard for fish kill. Whilst several fish might have been killed only one fish is recorded killed. Thus the actual Environment Agency record of fish kills shows that the Tideway may already meet the critical level 3 fish kill criterion.

Dissolved oxygen performance of the Tideway

Need for data

The Waste Water National Policy Statement Appraisal of Sustainability Post-Adoption Statement March 2012 page 27 states " *The SEA Directive requires monitoring of significant effects of the implementing the plan or programme, including unforeseen... effects.*

Article 10 (1) states "member States shall monitor the significant environmental effects of the implementation of plans and programmes in order, inter alia, to identify at an early stage unforeseen adverse effects, and to be able to undertake appropriate remedial action."

Thus it is a requirement, presumably on the Environment Agency, as the competent authority, to monitor and that would mean increasing the number of monitoring stations should the Environment Agency consider the current network inadequate. to take appropriate action. It would also mean that it could increase action or to decrease action, depending on the circumstances. For instance if a plan had already achieved its objectives it could curtail further action.

The EA stated in the notes of the meeting of 25th September 2014, point 7, that "*the WQ monitoring is a better indicator of how often each DO standard is breached. "*

Applicability of data provided

I asked the Environment Agency for 10 years of records for all the Automatic Quality Monitoring Station (AQMS) monitoring stations. I am grateful to the Environment Agency for providing me with 7 years of AQMS data for the three most representative stations of the Tideway, Chiswick AQMS primarily monitoring the effect of Mogden spills, Cadogan AQMS primarily monitoring the Hammersmith, Lots Rd, and Western pumping stations, and Erith primarily monitoring the Tideway downstream of the Beckton and Crossness STWs. The AQMS records at 15 minute intervals several parameters of the river water including the dissolved oxygen content.

Lord de Mauley, in his letter of 13th January 2015, states " *However they do not provide a good representation of all discharge and tide circumstances...*"The Environment Agency is the body responsible for monitoring water quality. It chose the AQMS sites and operates the network. Floating AQMS stations have operated in Cardiff Harbour satisfactorily for the last decade so one can only conclude that the Environment Agency is satisfied with the existing Tideway AQMS network. Elsewhere in the para it is said "*The whole of the Tideway is covered by a wider network of AQMS sites, but the three stations provide a reasonable coverage of the Tideway and generate reasonable quality data for the sites in which Professor Binnie is interested."* I originally asked for the data for all the AQMS sites and Lord Berkeley, in his response of 19th January, asked for "*the similar data for the other AQMS sites that provide a sufficient representation." "However, if there is further data, similar to that the Environment Agency used in its assessment of Mogden spills, then we would be grateful to receive it."* That was over 3 weeks ago. However no more data has been provided so I have to presume that the data already provided is sufficient coverage for the Tideway.

Lord de Mauley also states in his letter of 13th January that *"the data is insufficient to assess compliance with...standards 4,3,or 2 given the return periods associated with them of 10, 5, and 3 years respectively."* I take this to suggest that one needs several years of data to demonstrate compliance. In comparison the Environment Agency, supported by Lord de Mauley in his reply to PQ 0401 14/15, assessed the compliance of Mogden STW spills after

the 2013 summer period, only 1 year of data, albeit subject to further monitoring. Thus an assessment of Erith after one year, 2014, is similar and the assessment of Chiswick and Cadogan over a 5 year period is even longer. Thus this assessment is no less robust than that done by the Environment Agency for Mogden spills.

A more detailed assessment is set out in Appendix A, Note on dissolved oxygen performance of the Tideway.

Period of data analysed

Lord de Mauley bullet 5."*The period examined by Professor Binnie's report is far from typical, as the south east of England experienced one of the driest two-year periods on record and the wettest winter since 1766."*

Firstly, Professor Binnie asked for the last 10 years of data but the Environment Agency only sent the last 7 years. Thus the EA selected the period provided.

Secondly, the actual period used depended on when the improvements occurred. The Chiswick and Cadogan (Chelsea) AQMS appeared to have met all the dissolved oxygen standards since late 2009. The Erith AQMS only met the standards once the Beckton and Crossness STW upgrades were operational, in early 2014 I believe.

Failures of the dissolved oxygen standard seldom, if ever, occur in winter so the wettest winter is of minimal relevance. The period of interest is the summer. Thus I have taken the CEH rainfall for the Thames catchment for the period of April to October inclusive for the relevant years. This shows percentage of annual average rainfall for the summer period.

2010 71%

2011 108%

2012 161%

2013 77%

2014 106%.

This would indicate that, for the 5 year period 1010 to 2014 relevant to the Chiswick and Cadogan assessment, the summers were both wet and dry and typical. For Erith the 2014 period was, overall, marginally wetter than normal and therefore typical. For comparison, the period used by the Environment Agency for the assessment of whether the Mogden spill met the UWWTD, the summer of 2013, at 77% would appear to have been, overall, somewhat drier than normal. Thus the period examined by me included 2013 and a range of other summer rainfalls and is thus typical.

Validity of data

The AQMS stations are normally used for operational management but they also enable the situation of the dissolved oxygen of the Tideway to be compared with the requirements of the four dissolved oxygen standards in that section of the Tideway. Mr Hughes in his covering email of 14th November 2014 states "*Where available, the DOO mg/l data is generally less prone to errors and would be more suitable than the DO data sets.*" Thus I have used the DOO data set except on the rare occasions when it is not available when I have used the DO readings.

The Cadogan and Erith AQMS stations are on the same bank of the river, and relatively close to, the major pumping stations or sewage treatment works. The Environment Agency states that the Tideway is not well dispersed laterally. These AQMS are likely, therefore, to over-read the drop in dissolved oxygen in the river compared to the main body of the river.

In his letter of 13th January 2015 Lord de Mauley states."*Professor Binnie's analysis uses the average of all the dissolved oxygen readings from an AQMS for each tide, which is not the approach the Environment Agency would use to assess performance against the standards...*" This is not quite true as I have assessed the average for one tide as the minimum amount over any 6 ¼ hour period."*Thus the minimum dissolved oxygen readings for each tide would be more appropriate...*" The dissolved oxygen standards were set following the fish trials which used constant dissolved oxygen conditions. Clearly, taking the minimum of each tide is a significantly harsher assessment than the way the standards were set. Thus taking the average, with minor variations either side, would appear to be the most reasonable assessment, and that is what I have taken.

However, taking the average of the minimum readings for 1 to 3 tides, ie those standards based on leathality, would mean failure of Chiswick and Cadogan AQMS in 2011 but no breaches/failures in 2012, 2013, or 2014, or failure of Erith in 2014. Thus the conclusion would be similar, albeit Chiswick/Cadogan would only have met the standards for the last 3 years rather than the last 5 years.

Standard 1, 4mg/l for 29 tides return period 1 year, is a chronic situation rather than a lethality situation. Standard 1 "*was selected to ensure protection against chronic effects; these would include eg effects such as depression of growth and avoidance of hypoxic areas*. " Many fish naturally avoid such hypoxic zones. Thus, for standard 1 a minimum reading is even less relevant than an average reading.

Thus the data and the method of analysis appear appropriate.

Assessment of the data against TTSS standards

Erith. There were consistent failures of standard 1 (4mg/l for 29 tides once a year) in the summer until the Beckton STW and Crossness STW upgrades were completed about spring 2014, since when there have been no breaches of any of the standards. Once the Lee tunnel is operational, about late 2015, the total CSO spill volume will reduce from about 39 Mm3/year to about 18 Mm3/year, about half, thus dissolved oxygen conditions in the lower Tideway would improve appreciably thereafter and the risk of a breach/failure would reduce appreciably.

Chiswick. From 2010 to 2014, there was one breach of threshold 2, (3mg/l in 3 tides) in 2011. However in 2010, 2012, 2013, 2014, no breaches of the standards occurred. Since a breach of threshold 2 is allowable once in 3 years, the 2011 threshold 2 breach is not a failure of the standards. Thus Chiswick AQMS has met the standards since late 2009, some 5 years. With Mogden STW upgrade completed in March 2013, then it seems thereafter the upper Tideway would be even less affected than in earlier years.

Cadogan. No breaches in 2010, 2011, 2012, 2013, and 2014, a 5 year period. Minimum 1 tide DOO readings in the last 3 years is 3.7mg/l compared with the 2mg/l standard. Thus there seems no risk of the Tideway here breaching the 1 tide threshold of 2mg/l for 6 hours more often than the 1 in 5 years allowed. The same applies to the other standards.

In their notes of the meeting of 25th September para 13 the EA state *"There was a significant Tideway incident in August this year, and the modelling of a longer time series suggests this will continue to happen without the TT."* My limited assessment of the rainfall conditions indeed shows the rainfall lay within the range of annual peak rainfall conditions. However the Tideway, following the storm of 10th August 2014, meets all the Tideway dissolved oxygen standards, see Appendix A of this report.

Water Framework Directive

The Water Framework Directive requires waters to achieve good ecological status. The TTTT states that the standard is 95% of the time freshwater should be above 5mg/l. Analysis of Chiswick and Cadogan AQMS shows that there the Tideway achieves 99% above 5 mg/l, comfortably meeting the good criterion, see Appendix A.

Erith is partly saline and that changes the good dissolved oxygen limit to be achieved, freshwater 5mg/l and marine 4 mg/l. Were the requirement there to be 4.5mg/l, then the AQMS would currently just pass. I am not aware of what the appropriate standard should be. However with the completion of the Lee tunnel in late 2015 and the halving of the volume of spills into the Tideway, then the water quality in this stretch should improve appreciably and it is probable that the lower Tideway will also meet the WFD criterion for good dissolved oxygen then.

Modelling the future

The EA state Hughes/Binnie email 2nd December 2014, that "*The only way of attempting to predict future performance of the system is to use a model."* The TW model output of the conditions, post the STW upgrades and Lee tunnel, are 75 failures of standard 1 in 41 years or about 2/ year and an annual breach of standard 2. No breaches or failures of the dissolved oxygen standards actually occurred in 2014, a reasonably typical year. **Based on the AQMS data, the existing model appreciably overestimates the current actual number of breaches in the Tideway.** As set out earlier, there are many reasons why the model could be in error. Thus, before attempting to model the future, the model needs to be re-calibrated against the existing dissolved oxygen conditions.

Reliability of the Thames Water sewer model and the water quality model.

"the report does not form a sound or credible basis to challenge the Thames Tideway water quality model...The model is robust and sophisticated has been independently peer reviewed and found to be fit for puspose." Lord de Mauley letter of 13th January 2015 penultimate para

My understanding is that the model was peer reviewed several years ago before significant appropriate field data was available. The TTTT 2006 vol 2 states about the model "*Under these conditions it is unlikely that it will ever be possible to acquire sufficiently comprehensive data.",* see pages 9 and 10 for the full quote and reasoning.

The importance of any model is not so much whether it has been peer reviewed but whether the data input is sufficiently robust and whether its output actually reflects actual conditions that occur.

The outputs of the water quality model for the initial conditions and with the improvements is shown on the table on page 10 of his report. For initial conditions threshold 3, 2mg/l for 1 tide, several of the fish species should suffer fish kill. The model predicts 99 such breaches,

ie fish kills, in 41 years, ie 24 fish kills in 10 years. The Environment Agency record of the last 10 years is of 2 fish kills caused by Abbey Mills spills and one caused by CSO spill into the Tideway, a total of 3, albeit it is possible that a few other fish kills were not reported but, considering that fish kills occur in summer when daylight hours are long and the river is extensively viewed, these cannot be many more. Thus the model at 24 fish kills in 10 years greatly over estimates the number of fish kill occurrences in the Tideway of 3.

The water quality model shows that even after the STW upgrades and the Lee tunnel the Tideway would still fail the standards. Once the Lee tunnel is operational then the Environment Agency records show only one fish would have been killed in the last 10 years thus meeting the standards.

The Environment Agency state that the AQMS "*water quality monitoring is a better indicator of how often each standard is breached".* The water quality model shows that, after the STW upgrades and the Lee tunnel, there would be 75 breaches of threshold 1 ie about 2 breaches a year. In 2014, a typical year, even before the Lee tunnel becomes operational, there were no breaches of threshold 1.

Thus the water quality model has failed to reflect either initial conditions or conditions after the STW upgrades sufficiently. Thus it is not so much my report that challenges the water quality model, it is its failure to reflect actual conditions as found by field records and AQMS data that the Environment Agency consider a better indicator.

Whatever, the water quality model is clearly not fit for purpose and should be reassessed and now recalibrated against the AQMS data that is available.

Considering the future,

In the future, population increase and climate change could have an adverse affect on the Tideway. As set out in Appendix C of this report, because of demand management Thames Water fWRMP14 predicts water supplied, and hence sewer dry weather flow, will not reach 2006 amounts until at least 2040 and, projecting forward, possibly not until 2080.

Climate change will increase the size of large rainfall events and the increasing temperature in the Tideway will mean the water is unable to hold as much oxygen. Thus further measures may eventually be required. However these measures will not be required for a number of years, allowing time to plan and implement them in an economical way.

Section 9 and Appendix F consider some of the measures that could be used, either singly, or more likely in combination, to cope with these and any other deteriorating conditions.

Conclusions

Fish were used by TTSS to develop dissolved oxygen standards for the Tideway. Previously, modelling was used to assess compliance/failure with these standards. However there are many reasons why the data in the model might not represent actual conditions. The current AQMS dissolved oxygen records show the modelling appreciably overestimates the number of breaches.

The TFRM, once corrected for obvious errors, shows fish are currently sustainable.

The EA record of fish kills in the Tideway shows 3 fish kills over the last 10 years, with only one, of one fish, caused by overflow from the CSOs to be connected to the Tideway tunnel.

The EA states that water quality monitoring is a better indicator of how often each standard is breached. AQMS data shows that Chiswick and Cadogan AQMSs have not breached any of the dissolved oxygen standards since late 2009. In 2014 they met the WFD good criterion for dissolved oxygen.

Post the Beckton and Crossness STW upgrade in 2014, Erith AQMS has met all the dissolved oxygen standards. The Lee tunnel, once operational in late 2015, will about halve the volume of spill into the Tideway, thus appreciably improving the water quality in the lower Tideway.

The assessment that Mogden spills did not cause significant adverse impact on the quality of the river was based on about a years record. On a similar basis, **the AQMS data shows the CSO spills in the Tideway now meet the dissolved oxygen standards. Thus, even before completion of the Lee tunnel, the spills into the Tideway have not led to a significant adverse ecological impact.**

Thus there is no requirement for extra measures, such as another tunnel, except, a long time in the future, to meet certain long term ecological conditions such as those caused by climate change.

5 Impact on health of recreationists

The Tideway has a high tidal range, fast currents, a dirty look due to a high suspended sediment content, a shoreline that is generally muddy, and significant river traffic. It does not, therefore, naturally encourage recreation.

The Tideway is not a designated bathing water and so is not subject to the Bathing Water Directive. For navigational safety reasons, the PLA has banned bathing in the middle Tideway downstream of Putney except with a special licence normally requiring guard boats.

The TTSS was informed by the Environment Agency that the CSO spills resulted in about 120 days of elevated health risk each year. This was a major influence on the willingness to pay study output and the TTSS considerations.

The 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 study in 2006 changed this to "*To help protect river users by* ***substantially reducing the elevated health risk due to intermittent sewage discharges."*** My emboldening.

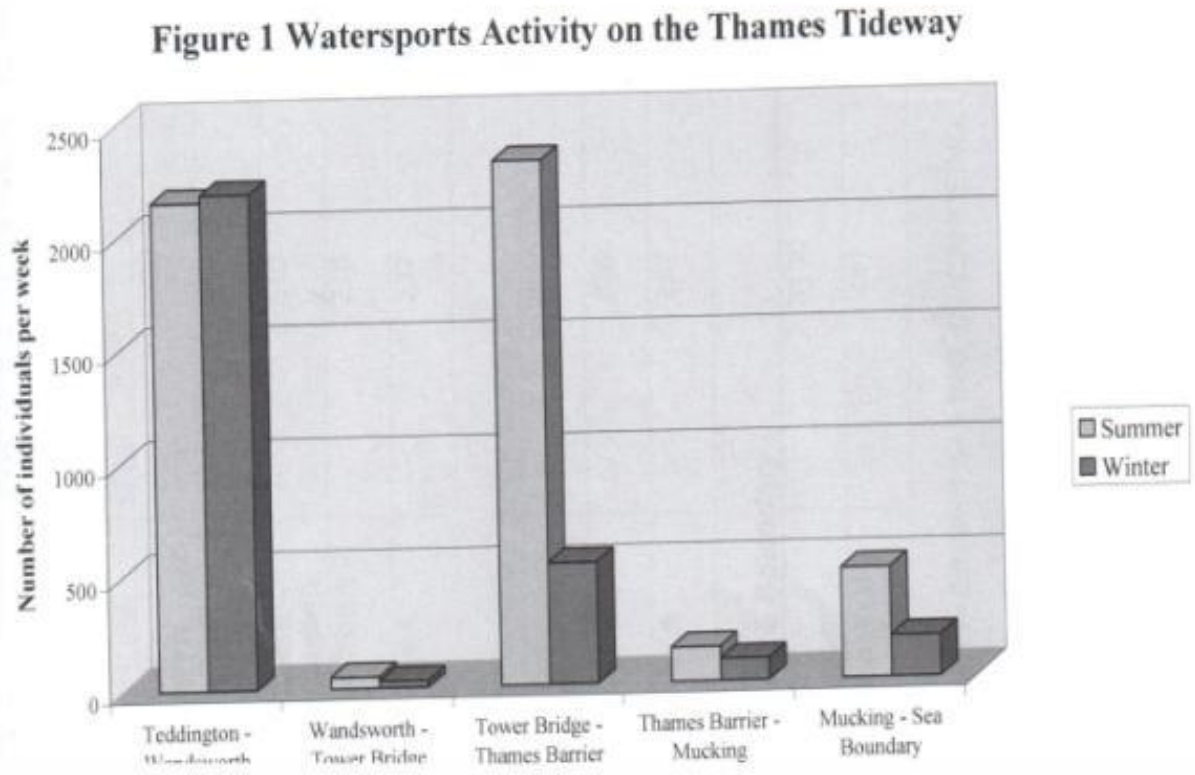
In his letter of 13th January 2015 Lord de Mauley states in para 6 that "*The Environment Agency is clear that the 34 most polluting CSOs in this stretch of the Thames need to be addressed to achieve compliance with the Directive."* Some of the CSOs are considered by the EA to be unsatisfactory because of their risk to health.

The Environment Agency carried out a study in 2004 to assess which CSOs were unsatisfactory due to health risk, An Assessment of the Frequency of Operation and Environmental Impact of the Tideway CSOs. "*The two most important factors that affect the degree of health risk attached to individual CSOs are considered to be the volume and location of the discharge... A matrix has therefore been prepared which relates these two factors and allows an assessment to be made of the significance of a CSO to an increase in health risk*." Thus the Tideway was split into five arbitrary stretches but no data was provided on the health implications of each stretch. An assumption was made as to the mean volume per discharge in each stretch to cause an adverse health effect. The assumed mean

volumes were from 1,000m3 to 30,000m3. No evidence was provided to support these assumed numbers. One graph of E-coli before and after a storm was shown, Fig 7 showing a raised incidence. However no data was provided of the type, numbers or frequency of recreationalists at risk, no data about the water quality of the discharges of the relevant CSOs, or any evidence about the health conditions of the recreationists. 19 CSO were designated unsatisfactory for health reasons. However the results of the study were not robust.

In 2011 a very similar study was done. It said it had referred to records of public complaints, visual observations and the Health Protection Agency 2007 study but it did not say what evidence from those data sources it had used. Again no actual field evidence was provided. It used a very similar methodology as the 2004 study. The same 19 CSOs were identified as allegedly providing a health risk. Again the results cannot be considered robust.

The Environment Agency, about 2006, carried out a study of the numbers of recreational users of the Tideway, see histogram below.



The foreshore is not frequently used as it is underwater for much of the day due to the tidal range of about 5m and there is limited access to it. It is generally muddy and uninviting. There is limited encouragement to use it. This is illustrated by the low numbers of users in the Wandsworth to Tower Bridge section of the Tideway. Thus its use is not significant.

The users in the stretch from Tower Bridge to the Thames Barrier were predominantly water skiers and dinghy sailors in the London Docks. The recreationalists beyond Mucking were largely dinghy sailors off Southend beach and effectively outside the extent of influence of the Tideway and its spills. Thus the predominant recreationalists were the rowers, largely in the Chiswick to Putney stretch.

It was only as a result of the Health Protection Agency Recreational Users study 2007 that it was found that the incidence of gastric problems amongst the prime recreational users, rowers, was 12.8/1,000/year compared to the general population incidence of 190 /1,000/year. Thus this aspect of the TTSS report, which alleged elevated health risk as a result of CSO spills, cannot be said to be robust.

The HPA evidence was analysed by NERA, a top economic consultancy, using the National Institute for Health and Care Excellence (NICE) Quality Adjusted Life Year methodology (QALY). " *assuming that the 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 2007.

The Minister stated in his letter of 24th February 2014 to Lord Berkeley *"However the Quality Adjusted Life Years (QALY) are also an imperfect measure, as they are based on an accepted cost of acquiring a health benefit, rather than the true value of that benefit."* The basis of the calculation is the number of people affected, and the annual value of the time lost to ill health to convert to capital cost that it would be worth spending to achieve no incidence at all.

He continued *"To the extent that health benefits in general might be viewed as having good returns (ie their benefit to cost ratios are greater than 1) we would expect a true valuation of the health benefit to be somewhat in excess of the QALY value."* Since the calculation actually calculates the benefit of not having ill health, this sentence is not understood.

Whatever, Defra agree that the maximum health benefit is "*somewhat in excess of £1 1/2m.*" May be that would be about £2m. It would not warrant expenditure of more than that amount on improvements to human health. That is hardly a significant adverse impact. Thus the spills from the CSOs classified as unsatisfactory for health reasons, do not cause a significant adverse effect on the health of the recreational users of the Tideway. Thus these CSOs cannot be considered as unsatisfactory for health reasons.

6 Aesthetics impact.

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."* TTSS Objectives Working Group Report vol 1 2005 section 6.3.1 page 16. This was re-endorsed in the TTTT Objectives report of December 2006.

Current situation

The Tideway, because the natural flood plain has been constrained between river walls and buildings, has a high tidal velocity which stirs up sediment particularly at spring tide. Thus the Tideway often appears a dirty colour. This is not pollution, it is just a natural feature of the Tideway water.

It is generally accepted that sewage derived litter makes up about 10% of the total litter in the Tideway.

"*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 study report page 52.

As part of their review for Ofwat the 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 both general and sewage derived litter by the litter collectors 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," including the tunnel " ***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, as well as improvements to the water quality and storm overflows from the 5 London sewage treatment works, in itself removing more than half the spill volume. 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.

Defra statement

In para 6 of his letter of 13th January 2015 Lord de Mauley states "*The Environment Agency is clear that the 34 most polluting CSOs in this stretch of the Thames need to be addressed*

to achieve compliance with the Directive." Most of the alleged unsatisfactory CSOs are due to aesthetic reasons, see Table 9 of the 2004 assessment. So let us look at the criterion for classification as unsatisfactory and whether the assessment followed the criterion or what was the field data on which the assessment was made.

Criteria for selection of unsatisfactory overflows

The criterion for a CSO being classified as unsatisfactory for aesthetics, as set out in the DETR (now renamed Defra) 1997 guidance on the UWWTD, is that it should have "*a history of justified public complaint*".

The Environment Agency, Bain/Binnie email, has stated that there were "*relatively few such complaints*".

Consideration of which CSOs were unsatisfactory

The approach taken by the Environment Agency in its assessment of which CSOs were unsatisfactory was not to consider directly the aesthetic impact from each CSO, or even to assess the overall aesthetics impact, but to consider which CSO were "unsatisfactory" based on other factors.

2004 assessment
The original classification was made in 2004 at a time when no remedial action had been proposed. Thus, as the guidelines of a history of justified public complaint were issued in 1997, then they should have applied in the 2004 assessment. The assessment page 14 states " *Two CSOs in the Victoria Embankment area (Regent St and Northumberland St) have been the subject of repeated public complaint and, although of quite small size, have been assessed as unsatisfactory. The Carlton CSO, adjacent to the Thames Barrier, has also caused past problems and is therefore assessed as having an adverse aesthetic impact*." No other records of public complaint are mentioned so one could assume that only these three would meet the criterion for unsatisfactory status of historic justified public complaint. Thus also it would appear that the Environment Agency did indeed know that the criterion for unsatisfactory CSO was historic justified public complaint but did not inform TTSS of this.

It would appear that Regent St and Northumberland Avenue are very likely to be able to be dealt with by floating booms for small expenditure. Carlton annual spill is quoted as 600m3/year and I understand has been dealt with by increased capacity at Crossness STW.

The 2004 assessment, An assessment of the frequency of operation and Environmental Impact of the Tideway CSOs, page 12 by the Environment Agency was done on a theoretical basis with no actual field data of litter in the river and no other data on the complaints that had been received. *"For those sites which discharge an average of greater than 50,000 m3"* (this is the average volume which the sewer model assessed would be discharged in the largest 21 storms over a 15 year period, ie about the average of the largest storm in each year*), "an assumption is made that they significantly contribute to the aesthetic impact, whilst for those below 1,000 m3, the assumption is that they do not. The CSOs that lie between these values are assessed for the nature of the area into which they discharge, by reference to figure 6 above*."

There is no evidence provided in the assessment to support the selection of the 21 largest storms in 15 years or of the choice of 50,000 m3 and 1,000 m3. The selection of the so called "sensitive areas" is where the river can allegedly be seen but there is no evidence provided to support that assessment. Further, 3 of these "sensitive areas" are only about

1km long and I cannot find where account has been taken in the 2004 assessment of tidal excursion which can be 15km. The conclusion was that not 3 CSOs but 33 CSOs were assessed as unsatisfactory.

Lord de Mauley in his February 24th 2014 letter to Lord Berkeley states *"it is true that there are few complaints to this issue. The public generally reports pollution if it is unusual."* But Regent St and Northumberland Avenue were the subject of repeated complaints. " *In the Tideway it has been the norm; the causes are well understood and river users may reasonably assume that reporting the issue to the Environment Agency will not result in remedial action."* There has been no mention that reporting incidence was higher before Defra announced in 2007 that the issue would be dealt with by the tunnel. In any case the public would know that the tunnel would take many years to complete and could have expected, if they had complained, that interim measures such as booms to have been implemented in the meantime. *"The number of reported complaints is therefore unlikely to be a true representation of the significance of the issue."* This seems a surprising statement from a government department that has set " *a history of justified public complaints"* as the criterion for the establishment of which CSOs are to be classified as "unsatisfactory" particularly when just two CSO had repeated complaints. In any case no action was committed until 2007.

2011 assessment
The 2011 assessment states that *"The areas where there is a history of public complaint are mainly associated with the upper reaches above Vauxhall, the Embankment, Greenwich, and the Thames Barrier."*

The 2011 assessment of the aesthetic impact, Assessment of Thames Tideway Combined Sewer Overflows, was based on the location of the CSO, ie proportion of time the discharge would be upstream or downstream of Tower Bridge based on a tidal excursion analysis, subjectively assessed visibility factors such as can it be seen from the river bank, the frequency of the discharge from the model and the annual volume of the discharge from the model. The frequency of discharge appears to occur twice in the calculation. I cannot find where any account has been taken of any variation in the effluent quality between CSOs, or over time of discharge (for instance the SCITTER trials showed that the volume of solids in the discharge varied with the time from the start of discharge), or whether the CSO is in the river wall and discharging over the foreshore or whether the CSO is well out in the river and submerged at all states of the tide.

The calculations provide a so called overall aesthetics impact. However it is interesting that Charlton CSO which spills 2 times a year with an assessed proportion of the aesthetics impact of 0.14%, Table B2, is included in the list of CSOs that spill frequently and have an adverse environmental impact, Table 1. Further, Church St and Norfolk St CSOs are shown in the calculations as not spilling and having no aesthetics impact but are shown in Table 1 as having an adverse environmental impact and being unsatisfactory. I cannot find where this inconsistency is explained.

Lord de Mauley continues "*Furthermore, storm sewage overflows from Abbey mills and Mogden are screened, so the Lee tunnel and Mogden improvements will have little effect on the volumes of sewage-derived litter entering the river*." In which case why is Abbey Mills, which has had screens since about 2004, listed in Table B2 July 2011 as the CSO with the largest aesthetics impact of all the CSOs? This is despite it discharging downstream of Tower Bridge into an area with limited sensitive location. The TTSS were told verbally that the screens at Abbey Mills retained very little debris, from memory about three skip loads a year. That would imply that the amount of sewage debris discharged to the Tideway by the other CSOs would also be low. Whatever, the Lee tunnel, once operational, would ensure

that any sewage debris which is currently discharged at Abbey Mills would be passed to the Beckton STW and, thus reduce the impact on the Tideway.

Conclusion
The Defra criterion for classification of CSOs as unsatisfactory is "*a history of justified pubic complaint*". The Environment Agency, Bain/Binnie email, has stated that there were "*relatively few such complaints*". Thus the selection of those CSO which cause aesthetics impact is not done in accordance with the Defra guidelines but on a wholly theoretical, largely subjective, largely unsubstantiated basis and, for some CSOs, what appears to be an inconsistent basis. Thus the assessment of these 33 CSOs as unsatisfactory is not robust.

Action taken since the first assessment to deal with sewage debris

Since the 2004 assessment, in 2007 Thames Water provided, and now operates, two litter collector boats/skimmers. TW say they are "***a real success story enabling us to collect large volumes of litter, which overflows from sewers during periods of heavy rain***. " and "***greatly contributed to improving its environmental and aesthetic quality***", my emboldening.

I cannot find any recognition in the 2011 CSO assessment that the litter collector boats/skimmers then existed or the appreciable benefit that Thames Water confirm they provide.

The EA state in note 12 of the meeting of 25th September 2014 *"the skimmers*" litter collectors *" are only acceptable as an interim measure*." The UWWTD requirement is to collect and treat and that is what the litter collectors do. The litter collectors/skimmers have been operating for nearly 10 years already and would, I believe, continue to operate until the tunnel is operational about 2023. This will be over 15 years. This is hardly an interim period.

The litter collectors collect both sewage derived litter and general and wind blown litter. The general guideline is that of all litter about 10% is sewage derived and about 90% general and wind blown litter. Thus, even when the tunnel would be operational, the litter collectors will still be needed to collect the general litter. I can find no reason why they would not be needed to operate in the long term irrespective of whether the Thames tunnel is operational or not.

Possible further action
Lord de Mauley continues "*In contrast, none of the central London CSOs have screens and the provision of screens in these locations was dismissed by the TTSS as impractical*." True. In most CSO sites there is not the on- land space for them.

But, from initial assessment, floating booms could be placed around most of the CSOs, (albeit not those where they would impede navigation,) thus retaining much of the floating litter for collection by river craft and transport to treatment. For more detailed assessment of the viability at each CSO see my report Measures to protect the river environment from the adverse effects of waste water discharges. See the image below of a typical floating boom in operation.

Lord de Mauley states in his letter of 1st April 2014 "*Similarly, we have previously explained that any solutions based on allowing pollution to enter the river and then using technology to ameliorate its affects (such as the Bolina booms proposed by Professor Binnie) would not be acceptable as this runs contrary to the principle under the Directive of collection and treatment...* "

The Waste Water National Policy Statement Appraisal of Sustainability Post-Adoption Statement March 2012 page 14 states "*For example, where CSOs do not cause a dissolved oxygen problem, the sewage derived litter and health impacts must still be tackled, and it is preferable to do this before the sewage enters the river, rather than ameliorating the adverse impacts after it has done so."* Thus in river measures, whilst less preferable, are acceptable within the WWNPS in which the Tideway is specifically mentioned.

Booms are not a general in river scheme but an end of pipe scheme at the relevant CSO, similar to, but less effective than, screens. Like the tunnel they are intervention at the interface between the sewers and the river. They are specifically designed to not allow floating debris to enter the river. The retained debris would be collected by floating barges and the collected debris subsequently treated. Thus they appear to meet the UWWTD requirement to collect and treat as well as meeting the objective "*to protect the environment from the adverse effects of water discharges".*

8 booms are already being used to collect debris on the Regents Canal in London, and they are also installed in Cardiff Harbour, and elsewhere in the country. DAWNUS CONSTRUCTION state about a permanent pollution boom installation provided by Bolina Booms "*The EA are delighted with your boom at Horton-that is why they have specified you again for this job."* Thus booms would appear to be acceptable.

The quotation for the booms around most of the CSOs is less than £2 million, miniscule in comparison with the cost of the tunnel.

In note 12 of the meeting of 25th September 2014 the EA say ""*they would only capture floating litter, not pathogens & faecal matter."* As stated above, the Tideway is not a designated bathing water and anyway, for navigational safety reasons, the PLA has banned bathing/swimming in the middle Tideway downstream of Putney except with a special licence including guard boats, thus pathogens would be of limited importance. In any case the river water, spills from Mogden, and also spills from the Thames tunnel were it to be built, would also have pathogens in them, so there will always be pathogens in the Tideway.

Most aesthetically offensive faecal material floats and most of that would be caught by the floating booms.

Booms are relatively easy to install, maybe taking about 18 months for design, planning permission including the PLA, and installation, ie probably operational in 2016. This would mean that, were there actually an issue with aesthetics, they would be useful as an interim measure until the tunnel becomes operational in about 2023. This would be similar to the bubblers and litter collectors which were considered interim measures at the time they were authorised but both of which cost significantly more than the booms would.

Booms were proposed by me about 2 years ago, see my Measures report. If there was really thought to be an aesthetics issue they could have been installed by now and provide a good benefit until the tunnel becomes operational in about 8 years time. By not considering and installing them where possible are not the authorities implying that the benefit of booms in collecting litter is less than their cost of about £2m? Thus it would seem that CSO spills do not result in a significant adverse aesthetic impact.

Conclusion of aesthetics.
1 The objective is *"to... limit pollution from... discharges... to the point where they case to have a significant adverse effect."*
2 "*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
3. " *little aesthetic change in the water is to be expected due to the Tideway Strategy options"* including the tunnel. Jacobs Babtie.
4 The Defra guidelines for an unsatisfactory aesthetic CSO are "a *history of justified public complaints*" but the EA stated in 2012 that there were relatively few such complaints.
5. The EA assessment of the aesthetics impact did not follow the defra guidelines
6 The EA did not use evidence of actual adverse aesthetics in selecting unsatisfactory overflows,
7. The EA assessment was done on a largely unsubstantiated theoretical basis,
8 The EA 2011 assessment did not take account of the benefits provided by the litter collector boats since 2007.
9. The 2011 EA analysis of aesthetic impact included spills from the large Abbey Mills PS whereas the base case is with Abbey Mills connected by the Lee tunnel to Beckton STW
10 The EA assessment did not consider whether floating booms might enable the Tideway to meet the aesthetic requirement, at vastly lower cost.

11. Thus, as the objective is to" *limit pollution ...to the point where it ceases to have a significant adverse effect.*" then it would appear that the base situation including the litter collectors, which would be needed to collect genral litter, would meet the requirments.
12 If more measures were required then the provison of floating booms, where possible, would improve the situation further at a cost estimate of £2m and within about 1-2 years.
13 By not considering and implementing booms during the 8 years or so before the tunnel becomes operational, are not the authorities confirming that there is not a significant adverse aesthetics impact?

7 Is there significant adverse impact on the Tideway ?

The objective of the UWWTD is "*to protect the environment from the adverse effects of...water discharges."* The Directive says that spills should only be allowed under certain conditions such as "*unusually heavy rainfall*".

"*The Environment Agency is not aware of any instances when storm discharges from Mogden STW have caused a significant adverse impact on the quality of the river since the upgrade of the works. On this basis, the overflow from Mogden STW storm tanks is regarded as satisfactory under the terms of the Urban Waste Water Treatment Directive."* Hughes/Binnie email 24th July 2014. Thus, provided there is no significant adverse impact, then the Environment Agency consider that spill frequency is immaterial as the objective of the UWWTD is already met. So is there significant adverse environmental impact?

Thus, for the **ecological/fish** objective,
Fish trials were carried out to establish dissolved oxygen standards for the Tideway.

There are many reasons why the data being fed into the sewer and dissolved oxygen models may over estimate dissolved oxygen sags and associated fish kills

The dissolved oxygen model shows that, prior to the STW upgrades, there would be 99 failures of Threshold 3 in 41 years, and these failures would have lead to fish mortality.

The record of fish kills is 3 in the last 10 years, equivalent to 12 in 41 years. This indicates the model overestimates the number of fish kills and hence overestimates the dissolved oxygen sags.

The record of fish kills in the last ten years is of one fish killed by the CSOs that would be connected to the tunnel.

The Tideway Fish Risk Model for the AMP4 condition, and for the 2020 situation, once corrected for obvious errors, shows the Tideway to be sustainable.

EA state that the record of the AQMS is "*a better indicator of how often each DO standard is breached".* Analysis of the AQMS dissolved oxygen records shows that Chiswick and Cadogan AQMS have met the dissolved oxygen standards since late 2009, ie 5 years. Once the Beckton and Crossness STW upgrades were completed in early 2014 the Erith AQMS has also met all the dissolved oxygen standards. Once the Lee tunnel is operational, about the end of 2015, water quality in the Erith reach should improve further.

Thus, post the STW upgrades, it would appear that, similarly to the current Mogden STW, storm discharges would not cause significant adverse impact on the quality of the river, and, in line with the Environment Agency statement about Mogden, the ecology of the Tideway should be regarded as satisfactory under the terms of the UWWTD.

Regarding **human health** the most numerous users of the Tideway are the rowers in the upper Tideway. They have been shown to be more healthy than the general population and that the financial benefit of curing all their gastric illness would be only £1.5million. Defra consider the actual benefit to be "*somewhat in excess*". This might be say £2 million, minimal in comparison with the cost of the tunnel. Thus the health impact is not significant.

Regarding **aesthetics/sewage** derived litter, Babties stated "*what there is appears to be invisible much of the time.*" The Defra guidelines for the selection of an unsatisfactory CSO are that it should have *" a history of justified public complaint*". The EA say that there are *"relatively few such complaints*". The EA did not base its 2004 assessment of unsatisfactory overflows solely on such information, but predominantly on an unsubstantiated theoretical analysis.

Since 2007 Thames Water have had two litter collector boats. TW say these are "*a real success story...* " and "*greatly contributed to improving its environmental and aesthetic quality."*

If further action is thought appropriate then floating booms could be built around most of the CSOs, ie at the interface between the sewers and the river as for the tunnel, and the retained debris collected for appropriate treatment and disposal. This would appear to meet the UWWTD requirement to collect and treat. Floating booms are estimated to cost about £2m and could have improved conditions until the tunnel is operational, in about 8 years. The authorities have not carried forward the booms proposal so presumably they consider that the benefit is less than the cost. If so there is not a significant adverse aesthetics impact.

Overall, the STW upgrades have been completed and the litter collectors have operated for many years and would continue to do so. The criterion for unsatisfactory CSO is that they should have a historic justified public complaint. However there are relatively few such complaints. The AQMS data shows the Tideway now meets the specific dissolved oxygen requirements. The health impact of the CSOs, at about £1 1/2m to cure all gastric events, is not significant. Post the Lee tunnel becoming operational in late 2015, the volume of spill would about halve and the water quality in the lower Tideway would improve further. If thought appropriate then floating booms could be constructed around most of the CSOs to retain floating debris which would then be collected and taken for treatment and disposal. Thus the Tideway, like Mogden currently, would appear to meet the UWWTD objective of not having significant adverse impact.

8 Best technical knowledge not entailing excessive cost.

Objective

Annex 1A of the UWWTD states "*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."* This is similar to the requirement in the Water Framework Directive for the cost not to be "*disproportionate*".

Working paper

In March 2004 Defra produced a Working Paper on its conclusions on the UWWTD. This states in para 28 1v) " *For those* " combined sewer overflows "*operating in conditions less severe than storm or unusually heavy rainfall,"* as some of those in the Tideway *" the appropriate solution must stop the discharges from operating in such conditions unless they are not having an adverse effect on the Tideway."*

In para 30 of the 2004 Working Paper it states "*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."*

Assessment

The solution that is nearly complete is the upgrading of the STWs and the construction of the Lee tunnel. This has already cost about £1.2bn, a substantial amount. The question then remains as to whether, since these works appear to meet the requirements of the UWWTD to limit pollution, whether further works are justified.

Clause 68 of the ECJ judgement states "*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."*

In Lord de Mauley's letter to Lord Berkeley of 24th February 2014 he states "*Given that our cost benefit analysis does not demonstrate disproportionate costs, neither the Commission nor the Court would be likely to agree a claim that the costs were disproportionate*."

The Defra Costs and Benefits of the Thames Tunnel, November 2011 does indeed conclude that, by its analysis, the benefits range of £3bn to £5bn encompasses the then anticipated capital cost of the tunnel of £4.1bn at 2011 prices. However a benefits cost ratio of several times this is normally required for governmental approval.

I have reviewed the basis of the Defra cost benefit analysis in my report Cost and benefits analysis submitted to Defra in early 2012. I have now received comments from Defra. I have taken account of all of these that are set out and I have revised my cost benefit analysis report accordingly, version with addenda 8 dated 1st May 2014. My assessment is done on the same basis as the Defra one. Even if one assumes that the aesthetics benefit is as in the willingness to pay survey and ignores the substantial benefit subsequently brought by the litter collectors, the result is a benefit of about £500m. This is set out in my revised cost benefit report and summarised, with response to the Defra comments in Appendix E of this report. In my view the benefit of about £500m is disproportionally less than the cost of the tunnel at over £4bn and the cost is also excessive in relation to the BATNEEC.

9. Spill frequency

This chapter was not in the original Review as issued by Tony Berkeley in December 2014 but has been included because of Lord de Mauley's comments of 13th January 2015 on the Review.

Corrections to spill frequency

In para 5 Lord de Mauley states that "*after the Lee tunnel is operational spills of between 50 and 60 times a year will spill from the CSOs into the tidal Thames."*. However the base case situation is after the Lee tunnel is operational, as shown in the latest TW modelling in the DCO application. Defra have this information so let us see how accurate the Defra allegation is.

After the Lee tunnel is operational Abbey Mills will not spill at all so its spill frequency will drop from 50 to zero.

Now that the Crossness STW has been upgraded the table provided by Thames Water shows its spill frequency dropping from 51 to 28, almost certainly due to increased capacity at Crossness STW.

Thames Water provide discharge notifications to rowers and others on a web site whenever the Hammersmith Pumping Station spills. On the assumption that discharges on consecutive days are the same discharge event, then the notifications show Hammersmith PS has discharged 61 times since July 2012. This is an average of 24 spills a year. This includes 2014 which CEH describe as "*the 4th wettest year on record back to 1910*".

A spill counter was put on West Putney and the assumed spill frequency dropped from 59 to 26, primarily due to revisions to the sewer model where much of the storm water was found to be discharged to the Beverley Brook. Similarly Frogmore Buckold Rd dropped from 29 to 19.

The DCO application showed the Savoy St spill had dropped from 47 to 18 spill/year. Acton spills dropped from 40 to 17, once the effect of the Acton detention tanks was incorporated.

Thus the latest analysis shows the base condition to be up to about 40 spills/year on average rather than the 50 to 60 spills alleged by Defra. This demonstrates the reliability of some Defra statements.

Environment Agency assessment.

As set out in chapter 2 and 3 of this review, the Environment Agency has stated "*Spills alone is not regarded by the Environment Agency as an indicator of failure to comply with the UWWTD." "provided spills have not caused a significant adverse impact on the quality of the river....overflow is regarded as satisfactory." "The EA will consider effect of discharges, rather than frequency."*

Thus the EA view appears to be that, provided the receiving water meets the objective of the UWWTD "*to protect the environment from the adverse effects of waste water discharges"* then the situation itself meets the UWWTD. A sensible approach.

ECJ judgement

"The Commission, relying on a TTSS report of February 2005, observes that there were approximately 60 waste water discharges from storm water overflows in London per year..." ECJ judgement para 85. Thus the ECJ based its findings on the original situation as found by the TTSSG in 2005, before the STW upgrades and Lee tunnel, when the spill frequency was assessed as "*on a frequent basis (some as often as 60 times a year)*", TTSS Steering Group report section 0.4.

However the current base case, once the Lee tunnel is operational later in 2015, is an average of up to about 40 spills a year, see above. Thus the evidence provided to the ECJ was incorrect.

The findings of the ECJ state in para 56 that for unusual events "*Member States are to decide on measures to limit pollution from storm water overflows*." However the UWWTD does not define "*unusua*l".

The ECJ states, para 28, "*The Commission...does not propose a strict 20 spill rule but points out that the more an overflow spills, particularly during periods when there is only moderate rainfall, the more likely it is that the overflow's operation is not in compliance with Directive 91/271*." Thus the Commission does appear to be prepared to allow more than 20 spills a year, provided the objective of the UWWTD is met. This appears to be the base case situation on the Tideway as shown in the previous chapters.

Thus surely it is now open to Defra, or others, to raise this situation with the Commission and seek guidance, particularly since the base case of the maximum spill frequency has already dropped from as often as 60 times a year to about 40 times a year and the Tideway environment appears to meet the standards required.

Further corrections to spill frequency

Whatever, it is probable that the current sewer model still overestimates the spill frequency and this is considered below.

Population increase effect on sewer dry weather flows.

Lord de Mauley alleges in bullet 4 about my report. "*The analysis also does not properly address the forecast increase in water use and population growth"* The analysis in the Review specifically covered this in some detail in Appendix C on pages 43 and 44 of the December report. Thus again Defra do not appear to have read or understood the report properly.

Population growth

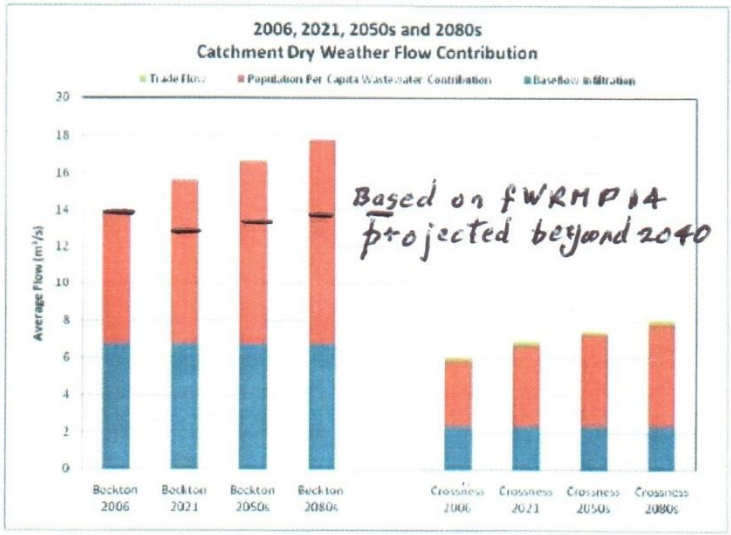
It is true that the population of Greater London is now growing. However, it is interesting to compare the population densities in 1939 with that in 2015, see plans on page 25 of the Economist of 7th February 2015. The total population of London is much the same, having gone down appreciably in the meantime and then risen in recent years. However the population in the inner boroughs has gone down and in the outer boroughs is going up.

However for reasons of historical growth London is split into the old central part that is predominantly combined sewers collected by the interceptors and with combined sewer over flows into the Tideway and the more modern suburbs where the sewers are largely separated foul and storm water. Further much of the more modern suburbs are taken to newer STW such as Mogden and Deephams rather than connected by the interceptors to Beckton and Crossness STW. Thus it is not the population of all of London that matters but the population contributing to the interceptor system.

TW assumption of increase in sewer dry weather flow

The histogram below shows how Thames Water have projected the sewer flows in the Beckton and Crossness STW catchment. This assumes a base flow in blue and a flow in red based on population growth with a constant per capita water use. Thus, they assume that there is an appreciable increase in sewer dry weather flow, and hence in spill frequency from the 2006 base year to the design year, assumed then to be 2021.

Population and Wastewater Flows



Wastewater Profile	Per capita (L/head/day)	Catchment
Beckton Combined	200	Beckton
Beckton City	150	Beckton
Beckton Separated	150	Beckton
Crossness Combined	200	Crossness
Crossness Partially Separat	155	Crossness
Crossness Separated	155	Crossness
Fraser Rd (Separated)	145	Crossness

Assumptions:

1. Population change based on latest GLA projection to 2030 and ONS from 2030 to 2050
2. No change to per capita rating
3. No change in baseflow infiltration
4. No change in impervious connected area
5. Point 2, 3 and 4 subject to compliance to other TW work such as SOLAR values

Projection of water supplied

The areas served by the Tideway sewers are not exactly the same as the areas served by the Thames Water water supply system but they are not much different and one could assume a similar relationship.

In their water supply zones Thames Water are promoting water demand management and increasing smart metering of water supplied so, in reality, the water supplied, and hence reaching the sewers, will be affected by those measures and will be going down. The numbers in the Thames Water final Water Resources Management Plans PR 09 and 14 for water into supply are

2006	2180 Ml/d
2012/13	2028 Ml/d
2020/21	1948 Ml/d.
2039/40	1993 Ml/d

The effect of this on the flow in the sewers is shown by the black marks on the histogram above for the Beckton catchment. Crossness would be similar.

Projections beyond 2040
I have been unable to find water supply projections beyond 2040, and anyway they would be speculative. However, taking the period 2020 to 2040 as a base, then water into supply is projected to rise by 45 Ml/d in that 20 years. Projecting that forward to 2080, another 40 years, would mean an increase of 90 Ml/d, to 2083 Ml/d. This is still below the water into supply in 2006 of 2180 Ml/d.

This is a very crude assessment but would indicate that increasing population, whilst a major issue in the previous TW sewer model calculations, may well not, by 2080, even return sewer dry weather flow to what they were in 2006.

Since it is the excess flow above sewer capacity that leads to spills, the spill frequency and volume assumptions in the TW sewer model would be significantly greater than those now projected by TW itself.

Comparison of assessments

Thus, from the quoted population projections, by 2020 the dry weather flow has been assumed by Thames Water to increase from 2006 by about 24%, see image above. The DCO document states that "*at peak times some sewers are running at 80% capacity*", page 13. Thus the flow in those sewers would, by 2023, reach about 99% capacity, hence spill much more frequently.

Based on the Thames Water WRMP numbers, by 2023, there would be a reduction of about 10% in water supplied and hence in sewer dry weather flow. Thus, for those sewers which were running at 80% capacity as quoted by TW in the DCO document, the capacity used at peak times in 2023 would actually be only 72% of capacity. This reduction in dry weather flow from 99% of capacity to 72% of capacity, would make a significant difference in the frequency and volume of spill.

Conclusions
Thus the TW sewer model underestimates the spare sewer dry weather capacity, and thus over estimates the CSO spill frequency.

Thus, in spite of the known population increase, the sewer dry weather flow is dropping and is unlikely to return to the 2012/3 flow until after 2040, by which time SuDs or other such measures could have been implemented to overcome any theoretical increase in sewer dry weather flows.

I have already recommended that the model be corrected and the spill frequencies for the base year be re-assessed. Thus, for the base year, the spill frequencies quoted by Defra and Thames Water appear likely to be appreciably higher than reality for the base year and should be re-assessed.

This has been pointed out in several previous reports and was included in Appendix C on page 44 of this report as issued to Defra. However this has been ignored or not been understood by Defra.

Measures to reduce actual spill frequency

Appendix F below and my report Measures to protect the river environment from the adverse effects of waste water discharges, sent to Defra and the EA set out an outline of some of the measures that could be adopted to reduce CSO spills. These include

Diversion of sewer flows to other STW and storm water flows to adjacent catchments.

Removal of restrictions in the sewer system

Separation of foul and storm water, particularly where the area is close to a river, the Tideway, Regents Park Canal, or another water course.

Local detention storage in tanks, shafts or silos

Real time control/active system control to make maximum use of the varying flows in the sewers during spatial and temporal variation,(Bloomberg quote Quebec where real time control alone reduced spill frequency from 45 to 26 a year)

Sustainable drainage systems, allied to blue green infrastructure, utilising green roofs, local storage and infiltration including into the terrace gravels that underlie much of the combined sewer catchment. (Whereas the TW study in Appendix E of the Needs report 2010 assumed

zero infiltration was available, the EA quotes the BGS as 28% area available, and Bloomberg states that, with some technical adjustments, 67% of the area could be developed for infiltration. A single example in Fulham indicates this could be even higher.)

Combination of measures.

Using the measures where they are each most economical should produce the most economical way of meeting the long term conditions.

The DEFRA River Basin Planning Guidance Vol 2 August 2008 states in 9.4 that "*the Environment agency should consider the full range of measures which are available"* and in 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 interrelationship between measures."* The July 2014 update includes almost identical words but adds "*13.8 The Agencies should, where possible, use cost effectiveness analysis to determine the combination of measures that will achieve WFD objectives at the lowest cost."*

The TTSS studied only single solutions and no combination of measures. I have been unable to find any document where a study of a combination of measures has been assessed.

I believe that a combination of measures could reduce the spill frequency from the current about 40 spills/ year to an acceptable at a much smaller cost than the tunnel.

10. Measures to maintain no significant environmental impact.

One needs to consider not just the 2020 baseline conditions but also future conditions. Thus, post 2020, London's population is expected to continue to grow, affecting the amount of water supplied and hence the dry weather flow in the sewers, and hence the spill frequency and volume. Due to climate change there would be an increase in bigger depth (greater intensity) rainfall events but a decrease in the frequency of lower depth events. Climate change would also increase the temperature of the river water, reducing its ability to hold oxygen, and thus increasing the risk of dissolved oxygen failure. Thus measures are needed to cope with these adverse effects.

However the TW fWRMP shows the water into supply for the increased population is not expected to get back to the situation in 2006 until after 2040, possibly post 2080, see Section 9 and Appendix C. Similarly the climate change effects are expected to build up over a long period of time. Thus there would be plenty of time to implement measures to overcome these effects.

In bullet 3 Lord de Mauley states "*The analysis does not account for climate change (which Professor Binnie acknowledges) and which has the scope to alter significantly the performance of London's sewer network over the lifetime of the Tunnel*." The original version of the Review as issued to Defra included the following para which clearly covers this point.

Appendix F below sets out an outline of the many measures that could be adopted to reduce future spills and cope with the rising temperature of the river water. These include a combination of sewer separation, diversion of storm water outlets, local storage, real time control, and sustainable urban drainage systems allied to blue green infrastructure, utilising green roofs, local storage and infiltration into the terrace gravels that underlie much of the sewer catchment. These are set out in greater detail in my report Measures to protect the river environment from the adverse effects of waste water discharges, with addenda up to 12, dated 13th April 2014.

Thus again Defra has not understood, or ignored, what is stated in the report.

11. Defra comments

In the last para of his letter Lord de Mauley states that "*In the light of this... I believe that the case for the Thames Tideway Tunnel remains strong."* However, it is clear that this conclusion is based on either misunderstanding or ignoring some of the facts presented and arguments raised;

Instead of the sewer dry weather flows rising, as projected by Thames Water and supported by Defra, then, based on the Thames Water WRMP numbers which have been approved by Defra, they are lower than in the base year of 2006 and likely to remain lower for many years to come, thus reducing spill frequency. Thus Defra has supported an assessment that is in conflict with a data set they have already approved. That has been pointed out by me to Defra several times.

Alleging that climate change measures have not been considered when they had been.

Stating that the proposal included bubblers, when it did not as they are not needed.

Ignoring that the proposal included floating booms as an end of pipe solution.

Ignoring the proposal that other measures can reduce spill frequency further.

Thus the conclusion made by Lord de Mauley is not soundly based.

12. Conclusions

Dissolved oxygen/ecology

1 The Environment Agency (EA) state that, since the upgrade of Mogden STW in March 2013, despite many untreated storm spills, they are not aware of any instances when spills have caused significant adverse environmental impact on the river water quality. Thus the EA concludes that it considers the Mogden spills comply with the Urban Waste Water Treatment Directive. "*The EA will consider the effect of discharges, rather than frequency."*

2 The TTSS established a suite of dissolved oxygen (DO) standards based on trials of a suite of fish thought then to be representative of the actual fish then in the Tideway.

3 Thames Water provided a model of the sewer system and an associated model of the Tideway water quality. This shows the STW upgrades and the Lee tunnel much reduce the DO failures but would not meet the required standards.

4 The EA record of fish kills in the Tideway shows 3 over the last 10 years, with only one caused by overflow from the CSOs to be connected to the Tideway tunnel. This compares with the TW models which show 99 failures of the fish kill standard 3 in 41 years, ie 24 fish kills in a 10 year period. This casts doubt on the robustness of the model output.

5 The Tideway Fish Risk Model for the AMP4 condition and for the 2020 situation, once corrected for obvious errors, shows the fish in the Tideway to be sustainable.

6 To meet its requirement to monitor the dissolved oxygen (DO) content of the Tideway the EA has established 9 automatic quality monitoring stations (AQMS) measuring the DO every 15 minutes. I asked for readings of all for 10 years and the EA provided 7 years for the 3 important ones. Lord de Mauley in his letter of 13th January queried the applicability of the

readings but my considerations set out above found the assessment to be similar to that by the EA for Mogden spills and the data sufficient. The EA state that the record of the AQMS is "*a better indicator of how often each DO standard is breached."*

7 Analysis of the dissolved oxygen records shows that Chiswick and Cadogan (Chelsea) AQMSs have met the dissolved oxygen standards since 2009. Once the Beckton and Crossness STW upgrades were completed, in early 2014, the Erith AQMS has also met all the dissolved oxygen standards.

8 There are many reasons why the sewer and river models may give erroneous results. Thames Water (TW) identify many potential errors in the data and state that "*it is unlikely that it will ever be possible to acquire sufficiently comprehensive data.*" to produce robust output. Comparison with the dissolved oxygen readings, and the fish kill records show the model to overestimate the fish kills and the sags in dissolved oxygen content of the Tideway.

9 The AQMS readings at Chiswick and Cadogan show that the upper Tideway now meets the Water Framework Directive dissolved oxygen good ecological status. It is probable that, once the Lee tunnel is operational in late 2015, the full Tideway will meet DO good ecological status.

10 Thus, post the STW upgrades, it would appear that, similarly to the current Mogden STW, storm discharges from the Tideway CSOs would not cause significant adverse impact on the ecological quality of the river, and, in line with the Environment Agency statement about Mogden, the Tideway should be regarded as satisfactory under the terms of the UWWTD.
9 Post the Lee tunnel becoming operational in late 2015, the spill volume into the Tideway will about halve, thus improving the water quality conditions in the lower Tideway further.

Health of recreationists

11 The Tideway is not a bathing water under the Bathing Water Directive. For navigational reasons the PLA have banned bathing downstream of Putney except with a special licence and guard boats.

12 The 2004 Environment Agency assessment used a theoretical matrix of location and volume of discharge to assess the impact of CSOs on health but provided no data on health impact to support its assumptions. It concluded that 19 CSOs were unsatisfactory for health reasons

13 The EA 2006 recreational users study found that most recreationalists were some 5,000 rowers, largely in the Chiswick-Putney area. The Health Protection Agency (HPA) found that their gastric illness was less than one tenth that of the general population. Using the Quality Adjusted Life Year analysis, as used by NICE, NERA found that the benefit of curing all gastric events would be £1 1/2m. Defra suggest that it would be "*somewhat in excess*", maybe £2m? Thus it would not be worthwhile spending more than this amount to deal with health aspects. Thus the health aspect of the CSO spills is not significant.

Aesthetics

14 The aesthetic objective is to limit pollution so it ceases to have a significant adverse effect. The HPA state the "*floating matter disseminates relatively quickly*" and Jacob Babties expect *"little aesthetic change due to the Tideway Strategy Options*" which includes the tunnel.

15 The 1997 Defra guidance criterion for unsatisfactory overflows is that they should have "a *history of justified public complaints*". For the 2004 assessment the EA identified only 3

CSOs as meeting this criterion. Instead the EA assessed CSOs on a largely theoretical and unsubstantiated basis, with no field data provided to support the assumptions. They then classified 33 CSOs as unsatisfactory for aesthetics reasons.

16 Since 2007 Thames Water has operated two litter collector boats which they say "*are a real success story enabling them to collect quantities of sewage litter*".

17 The EA carried out a similar assessment in 2011, but with no consideration of the benefit of the floating litter collectors, and this confirmed the same 33 CSOs as unsatisfactory. In 2012 the EA confirmed there were "*relatively few CSOs that have a history of justified public complaints"*. Thus there are few CSOs that should be classified as unsatisfactory for aesthetics reasons.

18 Should further measures be required to achieve no significant adverse aesthetics effect, then floating booms could be placed around most of the CSOs and the retained debris collected for treatment and disposal at a capital cost estimate of about £2m and achieved within about 1-2 years. Such a system appears to conform with the UWWTD to collect and treat. Such a boom litter collection system is already in operation elsewhere in London. Floating booms were proposed by me some two years ago. Despite its low cost, the authorities have not carried forward the idea of floating booms. Thus one could conclude that, since the cost is not significant in comparison to the tunnel and could provide about 8 years control of most of the sewer debris prior to tunnel commissioning, the authorities have concluded that their benefit is less than their cost. Therefore there is not a significant adverse aesthetics impact that would warrant such expenditure.

Overall impact

19 Thus, now the STW upgrades are operational, the conclusion is that the Tideway now meets the requirement for "no significant adverse environmental impact" from the CSOs and thus the UWWTD. The completion of the Lee tunnel in late 2015 and, if thought appropriate, the floating booms, will improve conditions further.

Cost Benefit analysis

20 In 2003 the TTSS carried out a willingness to pay (wtp) study based on a show card that stated there were 4 to 8 fish kills and 120 elevated health risk days per year, and assessed the benefits as some £5bn, substantially in excess of the then £1.7bn estimated cost of the tunnel. In 2006 a similar study used a show card with 1 or 2 fish kills per year and found the benefits varied from £1.5bn for householders in the Thames Water area who would pay for the tunnel and about £4bn for all householders in England.

21 The project was then split with some benefit applied to the improvement of the STWs and some for the Lee tunnel which between them would about halve the volume of spill into the Tideway. The cost of the Tunnel was then re-estimated at some £4.1bn at 2011 costs base. In 2011 Defra then issued a Cost benefit report, revising a number of key assumptions and estimating the benefit as between £3bn and £5bn. I have reviewed the Defra report. Putting in the NERA health benefit of £1.5m, assuming the DO and thus fish benefit as sustainable, keeping the benefit area as the TW area of those that would actually pay, correcting the economic growth since 2006 to what has actually happened, correcting the benefit split between the Thames tunnel and the other works, and including the construction and operation dis-benefits, resulted in a benefit of about £500m. This is a small proportion of the current cost estimate and would not normally receive funding.

Best Technical Knowledge Not Entailing Excessive Cost

22 Defra have stated "*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."* Since the STW upgrades and the Lee tunnel, cost about £1.2bn, appear to fulfil the objective of protecting the environment from the adverse effects of water discharges, it is concluded that no further measures are required until climate change effects become significant in a few decades time. Were it required to reduce the spill frequency then there are measures, see 26 below, that could do that, almost certainly to the relevant spill frequency required.

Spill frequency

23 Defra state that the CSO spill frequency is 50 to 60 spills/year. As shown in this report, the base case with the STWs upgrade, Lee tunnel connecting Abbey Mills to Beckton STW, and the 2013 DCO modelling, then the spill frequency is up to about 40 spills/year.

24 In the UWWTD, spills are allowed during unusually heavy rainfall. There is no definition of this but the European Commission (EC) has stated that it "*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 the EC appear prepared to consider more than 20 spills/year provided there is no significant environmental impact on the receiving water.

25 The TW sewer modelling assumes that post 2006 sewer dry weather flows increase with increasing population and thus that there is less spare capacity in the sewers and thus there will, in future, be more frequent storm rainfall spills. However Defra have approved the TW WRMPs that show that, despite increasing population, more metering, more efficient water using appliances and demand management will result in the water into supply reducing and not returning to the 2006 until late in the century. Thus the current sewer model almost certainly over-estimates spill frequency.

26 Ways of reducing spill frequency include removal of restrictions in the sewer system, separation of foul and storm flows into separate pipes, especially in areas close to the Tideway, or another water course, local detention tanks, real time control/active system control, sustainable drainage systems such as green roofs, swales and pervious pavements, and infiltration into the terrace gravels which underlie much of the combined sewer catchment.

27 These measures could be used in combination where each is most economical. Whilst it is a Defra requirement that, in the RBMPs, a combination of measures be studied, this has never been done fully or properly. It should be.

28 I believe that a combination of measures could reduce the spill frequency from the current about 40 spills/ year to an acceptable level at a much smaller cost than the tunnel.

Future

29 Over the next decades, the increasing population and climate change will worsen the situation but this would take place over many decades. Thus more measures, particularly SuDS, could be taken, to ensure that the no significant adverse environmental impact status remains.

13. Recommendations

I recommend that, before Thames Water places large and expensive construction contracts, the post STW upgrade records of dissolved oxygen be analysed, the water quality model be calibrated against these records, the spill frequency of the CSO be reassessed, and whether other measures could reduce the spill frequency to an acceptable level. A decision could then be taken as to whether the Thames tunnel is actually needed to achieve no significant adverse environmental impact and meet the requirements of the UWWTD. If so this would save the country, and in particular Thames Water customers, a substantial amount.

Prof Chris Binnie, MA, DIC, HonDEng, FREng, FICE, FCIWEM 16th January 2015

Appendix A Note on dissolved oxygen performance of the Tideway

Introduction

Objective

The objective of the UWWTD is "*to protect the environment from the adverse effects of...water discharges*."

Mogden situation

Mr Simon Hughes of the Environment Agency has said in his email of 24th July 2014 that *"The Environment Agency is not aware of any instances when storm discharges from Mogden STW have caused a significant adverse impact on the quality of the river since the upgrade of the works. On this basis, the overflow from Mogden STW storm tanks is regarded as satisfactory under the terms of the Urban Waste Water Treatment Directive."*

Lord de Mauley, in his answer to PQ0401 14/15 on 30th July 2014, stated " *the storm discharges from Mogden STW have not led to a significant adverse impact on the quality of the river since the upgrades. The Environment Agency will continue to assess the performance of the upgrade to ensure it continues to comply with the Urban Waste Water Directive."*

This is despite Mogden STW spilling on 54 days in 2013/14. Thus it seems important to establish whether the rest of the Tideway also conforms to "*no significant adverse impact."*

AQMS

There are 7 Automatic Quality Monitoring Stations (AQMS) which record dissolved oxygen in the Tideway every 15 minutes. My understanding is that the Environment Agency, in assessing the situation, monitor these readings. Thus it seems appropriate to compare these readings with the dissolved oxygen standards set for the Tideway, see table at the end of this note. These standards allow a certain limited number of breaches to occur whilst the Tideway continues to have no significant adverse impact. if the number of breaches exceeds the allowable frequency then the Tideway would fail the standards.

I had asked for the readings from all 7 AQMS stations. The Environment Agency has provided me with the AQMS data for the three important Tideway sections. Chiswick which monitors the effect of the freshwater catchment, Mogden spills, and occasionally Hammersmith pumping Station spills on the upper Tideway, Cadogan which monitors the effect of the Hammersmith, Lots Road, and Western pumping stations, and Erith which monitors the Tideway downstream of the Beckton and Crossness STWs.

Cadogan, at about 7km upstream of London Bridge, is pretty well on the minimum DO point for the storm of 10th August 2014, see graph at the end of this note, so, with tidal movement, would have picked up the minimum point in this section of the Tideway.

Applicability of AQMS data

The Waste Water National Policy Statement Appraisal of Sustainability Post-Adoption Statement March 2012 page 27 states " *The SEA Directive requires monitoring of significant effects of the implementing the plan or programme, including unforeseen... effects.*

Article 10 (1) states "member States shall monitor the significant environmental effects of the implementation of plans and programmes in order, inter alia, to identify at an early stage unforeseen adverse effects, and to be able to undertake appropriate remedial action."

Thus it is a requirement, presumably on the Environment Agency, to both monitor and to take appropriate action. That could be to increase action or to decrease action, depending on the circumstances.

The EA stated in the notes of the meeting of 25th September 2014, point 7, that "*the WQ monitoring is a better indicator of how often each DO standard is breached. "*

I asked the Environment Agency for 10 years of records for the all the AQMS monitoring stations. I am grateful to the Environment Agency for providing me with 7 years of Automatic Quality Monitoring Station (AQMS) data for the three most representative stations of the Tideway, Chiswick AQMS primarily monitoring the effect of Mogden spills, Cadogan AQMS primarily monitoring the Hammersmith, Lots Rd, and Western pumping stations, and Erith primarily monitoring the Tideway downstream of the Beckton and Crossness STWs. The AQMS records at 15 minute intervals several parameters of the river water including the dissolved oxygen content.

Representation of data

Lord de Mauley, in his letter of 13th January 2015, states " *However they do not provide a good representation of all discharge and tide circumstances...*"The Environment Agency is the body responsible for monitoring water quality. It chose the AQMS sites and operates the network. Floating AQMS stations have operated in Cardiff Harbour satisfactorily for the last decade so one can only conclude that the Environment Agency is satisfied with the AQMS network. Elsewhere in the para it is said "*The whole of the Tideway is covered by a wider network of AQMS sites, but the three stations provide a reasonable coverage of the Tideway and generate reasonable quality data for the sites in which Professor Binnie is interested."* I originally asked for the data for all 9 sites and Lord Berkeley, in his response of 19th January, asked for "*the similar data for the other AQMS sites that provide a sufficient representation."* However no more data has been provided so I have to presume that the data already provided is sufficient coverage for the Tideway.

Length of period of data

Lord de Mauley states in his letter of 13th January that *"the data is insufficient to assess compliance with...standards 4,3,or 2 given the return periods associated with them of 10, 5, and 3 years respectively."* In comparison the Environment Agency, supported by Lord de Mauley in his reply to PQ 0401 14/15, assessed the compliance of Mogden STW spills after the 2013 summer period, only 1 year, albeit subject to further monitoring. Thus an assessment of Erith after one year, 2014, is similar and the assessment of Chiswick and Cadogan over a 5 year period is even longer. Thus this assessment is no less robust than that done by the Environment Agency for Mogden spills.

Period of data analysed

5."*The period examined by Professor Binnie's report is far from typical, as the south east of England experienced one of the driest two-year periods on record and the wettest winter since 1766."*

First Professor Binnie asked for the last 10 years of data but the Environment Agency only sent the last 7 years. Thus the EA selected the period provided.

Secondly the actual period used depended on when the improvements occurred. The Chiswick and Cadogan (Chelsea) AQMS appeared to have met all the dissolved oxygen standards since late 2009. The Erith AQMS only met the standards once the Beckton and Crossness STW upgrades were operational, in early 2014 I believe.

Failures of the dissolved oxygen standard seldom, if ever, occur in winter so the wettest winter is of minimal relevance. The period of interest is the summer. Thus Prof Binnie has taken the CEH rainfall for the Thames catchment for the period of April to October inclusive for the relevant years. This shows percentage of annual average rainfall for the summer period.

2010 71%

2011 108%

2012 161%

2013 77%

2014 106%.

This would indicate that, for the 5 year period 1010 to 2014 relevant to the Chiswick and Cadogan assessment, the summers were both wet and dry and typical.

For Erith the 2014 period was, overall, marginally wetter than normal and therefore typical.

For comparison the period used by the Environment Agency for the assessment of whether the Mogden spills met the UWWTD, the summer of 2013 at 77%, would appear to have been, overall, somewhat drier than normal. This tallies with the analysis of the rainfall and Mogden spills from 2000 to 2014 done by me previously, where there were 7 summer spills in 2013 compared to the average of 9.6 spills. However 2014, where Mogden was, I understand, also considered by the Environment Agency to meet the UWWTD standards, was 106% of normal rainfall, typical.

Thus the relevant periods used by Prof Binnie was typical, ranging from 71% to 161% of normal Thames catchment rainfall.

The Environment Agency has correctly said that total rainfall is only a rough guide and spill frequency is a better guide. Prof Binnie has analysed the Mogden summer spill frequency from 2000 to 2013 and the average annual spill frequency was 9.6 with 2010 to 2013 varying from 6 spills to 12 spills. Thus again the period would appear to be reasonably typical.

Average of period or minimum reading

In his letter of 13th January 2015 Lord de Mauley states."*Professor Binnie's analysis uses the average of all the dissolved oxygen readings from an AQMS for each tide, which is not the approach the Environment Agency would use to assess performance against the standards...*" This is not quite true as I have assessed the average for one tide as the minimum amount over any 6 ¼ hour period."*Thus the minimum dissolved oxygen readings for each tide would be more appropriate...*" The dissolved oxygen standards were set following the fish trials which used constant dissolved oxygen conditions. Clearly, taking the minimum of each tide is an appreciably harsher assessment than the way the standards

were set. Thus taking the average, with minor variations either side, would appear to be the most reasonable assessment, and that is what I have taken.

Comparison of assessment

However, taking the average of the minimum level for 1 to 3 tides, ie those based on leathality, would mean failure of Chiswick and Cadogan AQMS in 2011 but no breaches/failures in 2012, 2013, or 2014, or failure of Erith in 2014. Thus the conclusion would be similar, albeit Chiswick/Cadogan would only have met the standards for the last 3 years rather than the last 5 years.

Standard 1, 4mg/l for 29 tides return period 1 year, is a chronic situation rather than a lethality situation. Thus a minimum reading is even less relevant than an average reading.

Data analysis

The standards for the Tideway consist of four levels of dissolved oxygen, averaged over a period such as 1 tide, with an allowable frequency such once in 3 years. The standards are shown in the Table at the end of this review. Since a certain frequency of exceedence is allowed, I have termed each excedence a breach and, if the breaches occur too frequently, a failure.

The data points are every 15 minutes. Thus for the assessment some 700,000 data lines were provided.

The standards refer to the average over a number of tides, ie 1 tide would be 6 hours, 24 consecutive data lines. The tidal average dissolved oxygen was assessed by scrolling through all data lines to identify periods of low DO. The average DO for the relevant period was assessed by inspection unless the outcome was marginal when a full calculation was done. I believe I have found all the near and actual breaches but, considering the mass of data, if I have missed any breaches I apologise, not intentional.

The data provided for 2014 goes up to 4th November. However the latest date of any breach in other years is 23rd September so the 2014 data set is considered sufficient for 2014.

The data set provides dissolved oxygen, DO, and DOO. These give somewhat different numbers. DOO is generally lower, viz cad1 9518 DOO is 3.33mg/l whereas the DO reading is 4.25 mg/l. The reason for this significant difference is not explained by the EA, or known by me. Mr Hughes in his covering email of 14th November 29014 states "*Where available, the DOO mg/l data is generally less prone to errors and would be more suitable than the DO data sets.*" Thus I have used the DOO data set except on the rare occasions when it is not available when I have used the DO readings.

Mr Hughes of the Environment Agency states that "*whilst the estuary is very well mixed vertically, it is much less so horizontally and DO sags therefore remain very discrete over several tide."* The Environment Agency also provided me with the grid references of the AQMS monitoring stations. Cadogan AQMS plots on the north bank of the river, probably on Cadogan Pier about 40m into the river which here has a width of about 200m. This is about 1km upstream of Western Pumping Station and about 1km downstream of Lots Road pumping station outfalls and on the same side of the river. It is also on the same side as the Hammersmith pumping station which is some distance upstream. Thus the spill is unlikely to have spread across the river here and, whilst there is no direct evidence, the Cadogan AQMS is more likely to be affected by the spill from these outfalls than the general river.

Thus DO sags measured by the Cadogan AQMS are likely to be somewhat greater compared to the general river.

Similarly, Erith AQMS appears to be about 100m out from the shore in an area where the estuary is about 700m wide. However it is only about 3 km downstream, and on the same side of the Tideway, as the outfall of the very large Crossness sewage treatment works. Thus again, although there is no direct evidence, the DO sags recorded by the monitoring equipment are likely to be somewhat greater than the general river.

2014 performance against the standards

Standards

The standards are set out in the Table at the end of this note.

Chiswick,

All readings way above the minimums so no dissolved oxygen breaches and none likely.

Cadogan

Cad 1 2014

9518, 12/8 min 3.33mg/l (DO 4.25mg/l), 1 tide av 3.7mg/l, Ok as above 2mg/l.

9608 13/8, min 3.63 mg/l (DO 4.35 mg/l), 1 tide av 3.9 mg/l, OK as above 2mg/l.

During the period between these tides the average is +4.5mg/l so the 3 tide standard of 3mg/l is also met by a wide margin. OK.

The minimum DO of 3.3mg/l and the1 tide DO of 3.7mg/l is considerably above the 1 tide standard of 2mg/l, so it would seem highly unlikely that the 2mg/l would be breached more often than once in 5 years as in the standard. See below for the review of other years.

Erith,

ER1 2014

8050 28th July DOO min 3.39mg/l, one tide average about 3.55mg/l, above 2mg/l so OK,

9792 15th August min 3.56 mg/l, one tide average about 3.9 mg/l, above 2mg/l so OK

9842 15th August min 3.33 mg/l, one tide average about 3.8 mg/l, above 2mg/l so OK,

For the period between the DO is +4mg/l so the 3 tide 3mg/l threshold is also OK

For the period 7939 to 8564 the Tideway is generally below 4.5mg/l, thus being close to the Threshold 1 standard of 4mg/l. 29 tides is some 720 lines of data, a daunting task to assess. However my assessment is that the Tideway does not breach the average 4 mg/l standard over 29 tides during this, or any other, period.

ER2, late 2013 and early 2014, high dissolved oxygen, so OK.

Thus in 2014 there were no breaches of level 1 (4mg/l for 29 tides), 2 (3mg/l for 3 tides), 3 (2mg/l for 1 tide) or 4 standards recorded at any of these AQMS stations. The DOO was generally way above these standards.

August 2014 spill incident.

From 9th August to 12th August there was considerable rainfall, 2 days 21.3mm, 4 days, 25.76mm. This was in line with similar summer rainfall storms in previous years, so not abnormally large or small.

The Environment Agency has provided the longitudinal plot of the resulting DO effect along the Tideway, see below.

The graphs show a minimum DO of about 3.5mg/l on 12th August 2014, close to the minimum 3.3mg/l recorded on the DOO at Cadogan AQMS. For that period the one tide average was assessed as 3.7mg/l, substantially above the relevant one tide standard of 2mg/l, therefore no breach of the standards occurred.

Period before 2014

Erith

2013

6915 13/7 breached 4mg/l for 29 tides.

10225 23/8 breached 4mg/l for 29 tides

2012

5767, 4/7 breached 4mg/l for 29 tides.

Thus, in 2013 and earlier, ie before the Beckton and Crossness STW upgrades were completed, the lower section of the Tideway breached the threshold 1 dissolved oxygen level of 4mg/l more often than allowed in the standards of once a year on average, hence was a failure.

Chiswick

2013 chi 3

7394 28/7 min 3.18mg/l, 1 tide about 3.7mg/l, above 2mg/l st so OK

7491 29/7 min 3.1mg/l , 1 tide about 3.6mg/l, above 2mg/l so OK

2012 chi 5

No 1 tide below 4mg/l

2011 chi 7

3187 7/6 min 0.72mg/l, 1 tide average 1.4mg/l, **breached** st 3 and 4

6161 8/7 min 1.87mg/l, 1 tide average 2.2mg/l, above the 1 tide 2mg/l standard so OK

10781 27/8 min 1.29mg/l , 1 tide average 2.1mg/l, above the 1 tide 2mg/l standard so OK

10834 27/8 min 0.94mg/l, 1 tide average 2.2mg/l, above the 1 tide 2mg/l standard so OK

But the 27/8 **breached** the 3 tide 3mg/l st 2, but this is allowed once in 3 years

2010 chi 9

No 1 tide DOO found below 4mg/l. OK.

Thus Chiswick had no breach in 2012 or later. Further it breached standard 2 in 2011 but this is allowed once in 3 years. It did not breach standard 2 in 2010, 2012, 2013, or 2014, so it did not fail standard 2 in 2011.Thus Chiswick AQMS has met the standards since 2009.

Cadogan

2013 cad 3

8071 28/7 min 3.3mg/l, 1 tide above 4mg/l . No 1 tide DOO readings below 4mg/l.

2012 Cad 5

10946 27/8 min 3.26mg/l, 1 tide average above 4mg/l.

10970 27/8 min 2.94 mg/l, 1 tide average above 4mg/l

No 1 tide DOO readings below 4mg/l

2011 cad 7

3095 18/6 min 2.11, 1 tide assessed average 2.6mg/l, therefore above the 2mg/l standard so OK

3130 18/6 2.64mg/l, assessed 1 tide average over 3mg/l, therefore above the 1 tide 2mg/l standard so OK.

Intervening tide average over 5mg/l, therefore 3 tide condition above 3.5mg/l, therefore no failure of the 3 tide 3mg/l standard.

6351 21/7 min 2.57 mg/l, assessed 1 tide average 2.8 mg/l, above the 2mg/l standard so OK.

9171 27/8 min 1.47mg/l, 1 tide av 2.1mg/l, so above 2mg/l, so OK.

9224 27/8 min 1.47mg/l 1 tide av 2.5mg/l so above 2 mg/l so OK

2010 cad 10

10936 27/8 min 3.28mg/l, assessed average 1 tide 3.45mg/l, well above the 2mg/l standard so OK

10976 28/8 min 3.23 mg/l, assessed average 1 tide 3.4 mg/l , well above the 2mg/l standard so OK

2009 cad 12

3059 8/6 min 2.15mg/l 1 tide about 3mg/l. OK

8790 7/8 min 2.4mg/l 1 tide 2.85mg/l OK

8838 7/8 min 2.02 mg/l 1 tide about 2.8mg/l OK Between about 3.6mg/l , no 3 tide failure (av 3mg/l)

8885 8/8 min 1.51 1 tide about 2.3mg/l .OK

In between about 3.8mg/l . Analysis shows average 3 tide 3.06mg/l, therefore no 3 tide failure.

8927 8/8 min 1.87 1 tide 2.1mg/l OK. Between 4.7mg/l therefore 3 tide OK.

8968 9/8 min 1.74 i tide 2.1mg/l OK. Between 5.2mg/l, 3 tide OK.

12613 17/9 min 0.99mg/l, 1 tide 1.44mg/l **breach** of st 4 (1.5mg/l) and st 3 (2mg/l)

12653 18/9 min 0.88, i tide 1.4mg/l **breach** of st 4, (1.5mg/l) and st 3 (2mg/l).

in between 5mg/l , **breach** of st 2 (3 tides 3mg/l).

12 698 18/9 min 1.5mg/l , 1 tide 1.55mg/l st **breach** st 3 (2mg/l)

12 751 19/9 min 1.25mg/l 1 tide 1.6 mg/l, **breach** st 3, (2mg/l)

12810 19/9 1.19 mg/l, 1 tide 1.8mg/l **breach** st 3 (2mg/l)

Between 17/9 and 23/9, 29 tides, 696 readings, the DOO average is below 4mg/l, hence **breach** of st 1 (4mg/l)

Thus Cadogan AQMS shows failure of the standard 3 in 2009.

From 2009 onwards Cadogan AQMS shows no breaches or failures over the following 5 year period.

Relevance of assessment period

Regarding peak rainfall, analysing the rainfall data for north London sent to me by the Environment Agency, peak annual 2 day summer rainfall since 2007, ie 8 years, varies between about 22mm and 35mm (2010). 2013 was 33.7mm on 13th September. Thus any sequencies which included 2013 would have included what was close to the maximum 2 day rainfall over the 8 year period. That includes Chiswick and Cadogan no breach sequencies.

For the Mogden STW upgrade, which became operational at the end of March 2013, compliance the Environment Agency concluded in their email of 24th July 2014 that it "*is not aware of any instances when storm discharges* " in that case from Mogden *" have caused a significant adverse impact on the quality of the river since the upgrade of the works. On this basis, the overflow, "*in that case from Mogden *" is regarded as satisfactory under the terms of the Urban Waste Water Directive."* Thus the Environment Agency is prepared, subject to continuing monitoring, to conclude a system is satisfactory on the basis of about one years monitoring.

Thus the monitoring period would appear acceptable.

Comparison with TW model

As can be seen in the table below , the TW model shows that, after the completion of the STW upgrades and the Lee tunnel which would significantly reduce the CSO spill volume, the model would expect on average 75+40+12+7=134/41= 3.2 breaches/year.

In 2014, a reasonably representative year, there were no breaches of any of the standards. Since 2009, 5 years, there have been no breaches of any of the standards at Chiswick or Cadogan. Completion of the Lee tunnel in 2015, reducing the spill volume from Abbey Mills Pumping Station into the Tideway by some 19 Mm3/year, will improve Erith conditions significantly.

Thus the model considerably overestimates the current number of breaches. Considering the problems with providing robust data input on summer rainfall such as localised thunderstorms, CSO discharge flows, discharge quality varying during any spill, and varying receiving river water temperature and quality, this is hardly surprising. Thus it appears that the current model is not reliable and needs updating to fit with the AQMS data.

Water Framework Directive

The TTTT 2006 vol 2 shows in figure 7.1 that, for freshwater to be of good status under WFD, it must have at least 95% of its dissolved oxygen readings above 5mg/l. For Cadogan AQMS and Chiswick AQMS the 2013/14 proportion is 99%., thus achieving good dissolved oxygen condition.

Erith is partly marine conditions. Table 5 of the HPA Thames Recreational Users Study 2007 gives the salinity at Erith as 6ppt. For marine the 95% of the dissolved oxygen readings must be above 4 mg/l. On the assumption that 4.5 mg/l is the appropriate level, then 96% of the 2013/14 dissolved oxygen readings exceed 4.5mg/l. Thus, on this unscientific assumption, Erith AQMS also achieved good dissolved oxygen conditions. In any case Erith dissolved oxygen condition will benefit from a reduction of 19 Mm3 of storm discharge from Abbey Mills once the Lee tunnel becomes operational in 2015.

Future conditions

The model uses population as a driver of sewer dry weather flow and hence if population increases it assumes that sewer flows will increase, hence less spare capacity in the sewers, and hence spill frequency and spill volume would increase. However, whilst population is indeed increasing, metering and demand management are appreciably reducing per capita demand. Thus the Thames Water 2014 Water Resources Management Plan shows that water into supply has fallen from 2180 Ml/d in 2006, to 2026 Ml/d in 2012/3

and is predicted to fall to 1948 Ml/d in 2020/21. Thereafter it is predicted to rise slowly to 1982 Ml/d in 2039/40. Thus, although population is rising, in comparison with 2006, population increase will not adversely affect spill frequency, volume, or Tideway dissolved oxygen content by 2040. Projecting the population effect forward at the 2020 to 2040 increase to 2080 would result in water into supply becoming 2050 Ml/d, still smaller than 2180 Ml/d in 2006.

Climate change will raise the temperature of the Tideway, thus eventually making DO temperature conditions more adverse and will also increase extreme rainfall. However any major effect is likely to be several decades away.

Conclusions.

The Environment Agency assessed Mogden STW discharges as complying with the UWWTD after about one year so a similar period would apply to the rest of the Tideway.

Erith. Consistent failures of standard 1 (4mg/l for 29 tides) until the Beckton STW and Crossness STW upgrades were completed in spring 2014. Since then there have been no breaches of any of the standards. Commissioning the Lee tunnel in 2015 will reduce Abbey Mills discharges into the Tideway by some 19 Mm3 /year, further improving the dissolved oxygen content in this section of the Tideway.

Chiswick. 2010 to 2014, one breach of standard 2, (3mg/l in 3 tides) in 2011, but none in 2010, 2012, 2013, and 2014. Since a breach of standard 2 is allowable once in 3 years, the 2011 standard 2 breach is not a failure of the standards. Thus Chiswick AQMS has met the standards since 2009. With Mogden STW upgrade completed in March 2013, then it seems the upper tideway would be even less affected than in earlier years.

Cadogan, potentially affected by Hammersmith , Lots Road, and Western pumping stations and Mogden STW. No breaches in 2010, 2011, 2012, 2013, and 2014, a 5 year period. Minimum 1 tide DOO readings in the last 3 years is 3.7mg/l compared with the 2mg/l standard. Thus there seems no risk of the Tideway here breaching the 1 tide standard of 2mg/l for 6 hours more often than the 1 in 5 years allowed. The same applies to the other standards.

Post the storm of 10th August 2014 the Tideway dissolved oxygen met all the standards.

Further the TW model output of the conditions post the STW upgrades and lee tunnel, 75 failures of standard 1 in 41 years or about 2/ year, is clearly considerably overestimating the actual dissolved oxygen sags in the Tideway as measured by the AQMS equipment, none in 2014.

Chiswick AQMS and Cadogan AQMS already meet the WFD requirements to have good status for dissolved oxygen. Under certain assumptions Erith AQMS does so now, and is almost certain to once the Lee tunnel becomes operational in 2015.

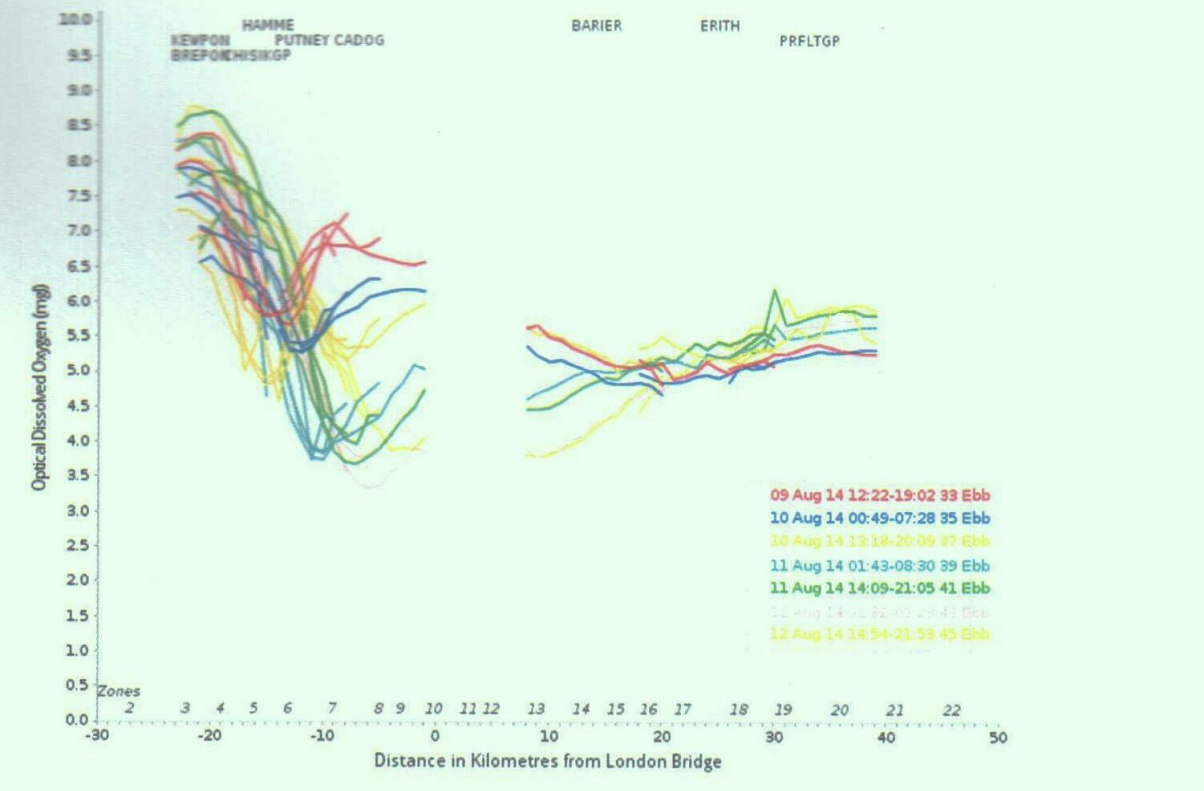
Thus the AQMS data shows the Tideway now meets its dissolved oxygen standards. Thus, even before completion of the Lee tunnel, the spills into the Tideway have no significant adverse ecological impact. Thus there is no requirement for extra measures, such as another tunnel, except, a long time in the future, to meet certain long term ecological conditions such as those caused by climate change.

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

1. A tide is a single ebb or flood. Failure = predicted exceedances > allowable exceedances

STW upgrades and no tunnels 2014 0 0 0 0


HAMME
KEWPON
PUTNEY CADOG
BREPONCHISIKGP
BARIER
ERITH
PRFLTGP
Optical Dissolved Oxygen (mg/l)
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
09 Aug 14 12:22-19:02 33 Ebb
10 Aug 14 00:49-07:28 35 Ebb
11 Aug 14 01:43-08:30 39 Ebb
11 Aug 14 14:09-21:05 41 Ebb
12 Aug 14 14:54-21:59 45 Ebb
Zones
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
-30 -20 -10 0 10 20 30 40 50
Distance in Kilometres from London Bridge

Appendix B Fish and dissolved oxygen standards

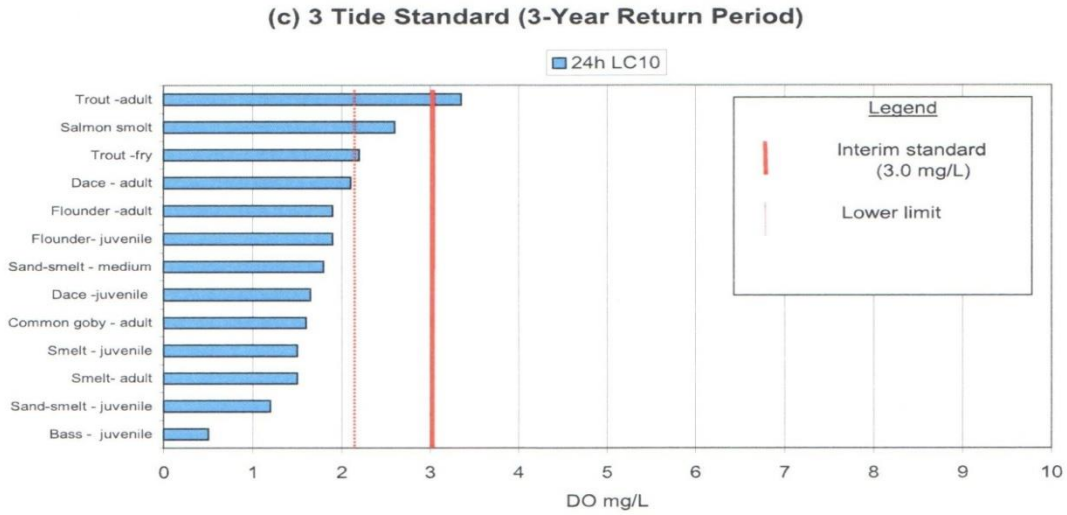
Objectives

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

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

Representative fish species

The Tideway water quality standards were set by the TTSS on the basis of the trials of the reaction to various dissolved oxygen conditions of a suite of fish species taken to represent those fish species present in the Tideway. The trials data shown below is the dissolved oxygen level that lasting for 24 hours would result in mortality of 10% of the relevant fish species.



Dissolved oxygen standards

The dissolved oxygen standards were set by the TTSSG as shown below. Threshold 1 *"was selected to ensure protection against chronic effects; these would include eg effects such as depression of growth and avoidance of hypoxic areas*." Thresholds 2 and 3, the latter the 2mg/l 6 hour, once in 5 years standard, were set so as "*to provide protection to stocks by managing the scale and frequency of mortalities. It was accepted that greater mortality would occur with the more severe of the two standards, but intended that for both standards, fish loss would be fairly limited. The minimum standard*" Threshold 4 " *was included to ensure protection from mass mortalities."* Thames Tideway Strategy :Experimental studies on dissolved oxygen requirements of fish Babtie 2004 page 75 and 76.

Thus any breach of thresholds 2, 3 and 4 would be expected to result in a fish kill.

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

As can be seen for the situation at 2mg/l, Threshold 3, (ignore the vertical thick red line) the mortality would be considerable for salmon, about 10% for dace, a numerous species, and limited mortality for flounder. Thus a failure of threshold 3 would be likely to cause a significant fish kill. Thus threshold 3 and 4 are important.

Relevance of salmon to the standards

This included salmon, which turned out to be the most sensitive one to low dissolved oxygen conditions. From the middle 1980s to the middle 1990s salmon were stocked in the river and some 200 salmon a year had been recorded at the Molesley Weir fish trap. In comparison the previously grossly polluted River Tyne now has a salmon run of about 30,000 salmon/year. Since 1997 the stocking regime changed and now stocking has ceased altogether such that returns are now in single figures, 2013 recording only 3 salmon. There is no record of any salmon spawning in the upper River Thames in the last hundred years.

Although salmon are a migratory species and are not resident in the Tideway, the TTSSG was told that they were sufficiently numerous that having them in the representative suite seemed appropriate.

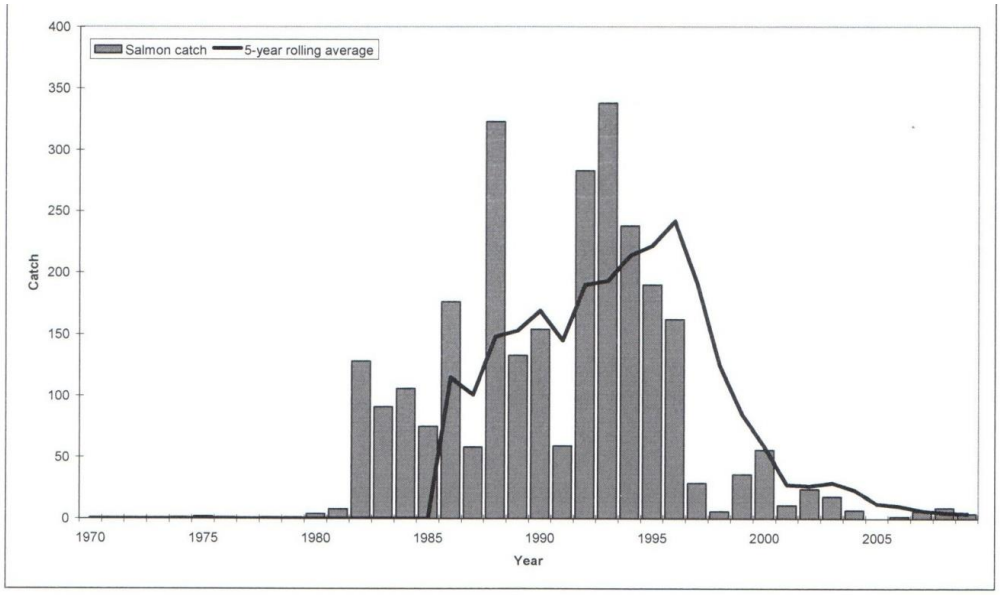


Figure 1 - River Thames recorded salmon catch and five year rolling average

I have no recollection that the information about the drop in salmon numbers was passed to the TTSSG for it to consider whether salmon, were still sufficiently numerous to be considered as representative. The record of returning salmon in 2013, when the Mogden STW effluent had been much improved and was classified as satisfactory by the EA, was 3 salmon. From this one could conclude that, since the dissolved oxygen conditions in the Tideway in 2013 would have been better than in the 1980s, that returning salmon were not significantly impacted by the then dissolved oxygen conditions in the Tideway. Thus current Tideway conditions would be less likely to affect salmon migration through the Tideway.

The EA have stated in their Report to the Regional Fisheries, Ecology, and Recreation Advisory Committee dated 20th September 2010 page 2 "*...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. He confirmed in a subsequent email that the unsustainable area included southern England.

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 representative fish suite. Discussion at the meeting on 31st May 2012 included consideration of other sensitive species that could replace salmon. These included sea trout. Generally about 15 are recorded as migrating each year and may be breeding but the evidence for this is limited, a small number. Shad are a rare migrant. One sturgeon has been found in the outer estuary but in the wild in Western Europe these are rare. No evidence was provided that any of these species would be present in sufficient numbers to be included within the representative suite of fish. as replacements for salmon.

As salmon were the most sensitive species and the next most sensitive species could tolerate appreciably lower dissolved oxygen, then, without salmon or a similar species, threshold 2, mortality at 3mg/l for 3 tides, would appear to be less relevant.

Threshold 1 4mg/l for 29 tides, is set to ensure that migration would not be precluded and for chronic effects such as depression of growth and avoidance of hypoxic areas. There are few migrating species that migrate in sufficient numbers

Appendix C Modelling of breach of the standards

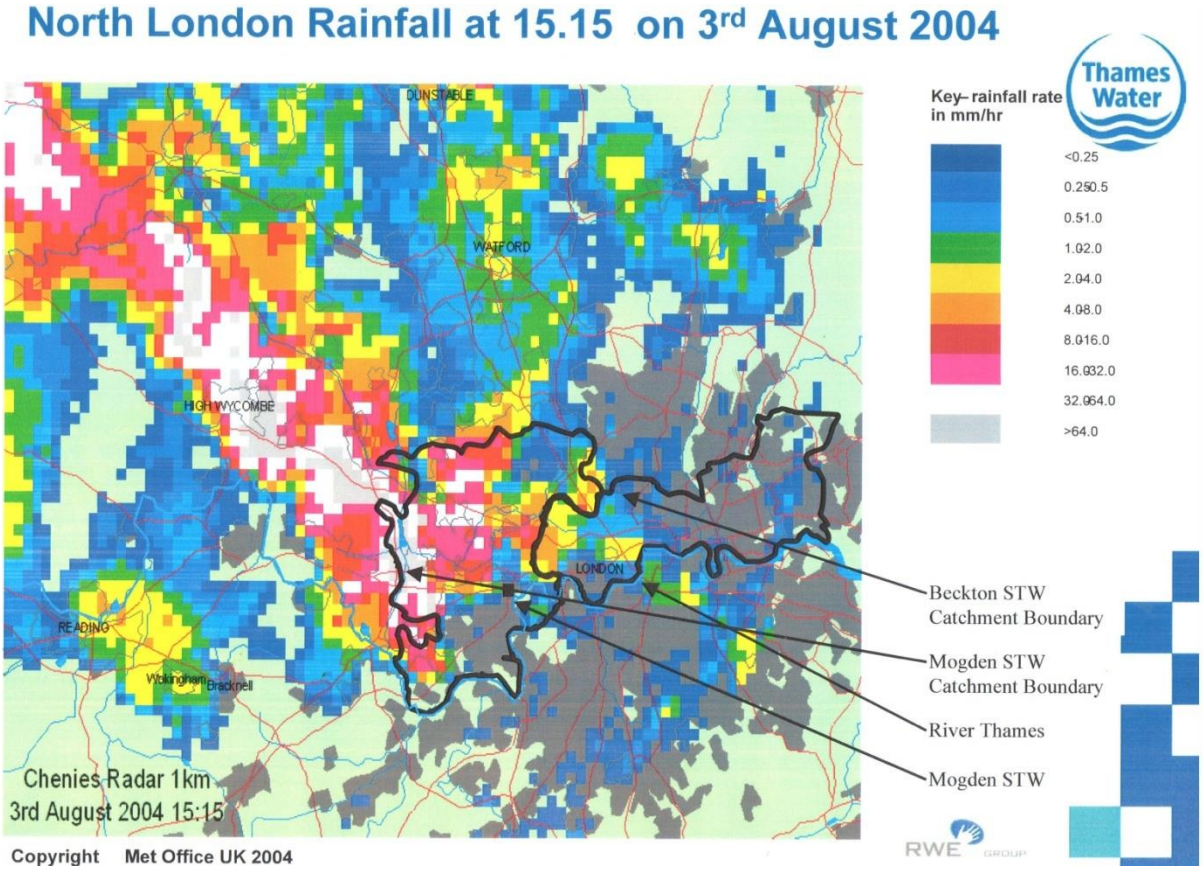
The dissolved oxygen model needs as its input such data as the quality and volume of the CSO discharge and the quality and flow of the river water, its temperature, tidal conditions. All these variables would be different for each event. This variability must be considered when assessing the reliability of the model results.

The modelling consists of two main aspects, the modelling of the sewer flows and sewer discharges to the river, and the modelling of their impact on the river.

Reliability of the sewer discharge model

Spill frequency and volume.
So how reliable is the modelling of the sewer discharges?

One of the basic data items is the rainfall. Rain gauges only measure rainfall at a particular spot. Rainfall radar shows rainfall over London can vary significantly from place to place. The critical events are summer thunderstorms and these can be very local., see image below where parts of the catchment would have had 10 to 12mm/hr whereas other parts would have had less than 0.25 mm/hr.



For the 242 events used in the model, the rainfall variability in location and time will not be that reliable.

As far as I am aware there are few, if any, reliable flow measurements in the sewer network, so, if that is still so, it would be difficult to either assess the particular event conditions or to calibrate the sewer model with reliability.

At the time of the TTSSG the only data about the volume of spills that was available was the pump run hours of the 8 pumping stations. The volume discharged by them was based on assumed pump discharge characteristics. Considering that these pumps are for sewage and are of variable age and the difficulty of calibrating them, then the accuracy of the assumed discharge characteristic may not be that reliable.

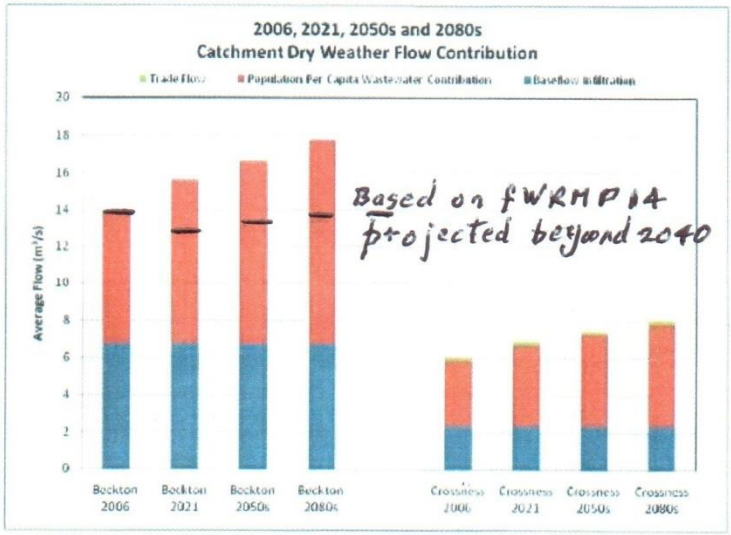
This is confirmed by the TTTT 2006 Vol 2 page 10 which states " *Of the 57 CSO which discharge to the Tideway, indicative flow data only exists for around 9 of the pumped discharges and there is some historical data. There is no flow data and virtually no quality data for the remainder. Obviously, comprehensive flow and quality data is essential for all these discharges if individual rainfall events are to be modelled precisely.* " Which they were. "*It is likely that, depending on rainfall patterns, the quality of discharges from these outfalls will vary considerably throughout the event and each CSO will display a different pattern of discharge. It is also likely that antecedent conditions will influence the amount of solid material flushed from the system. Under these conditions it is unlikely that it will ever be possible to acquire sufficiently comprehensive data.*"

Later some data was recorded for a period at the West Putney CSO. The original modelled spill frequency of the West Putney CSO is shown in Appendix E to the TW Needs report of 2010 as a spill frequency of 59 spills/ year. The annual average spill volume, quoted as having come from TW, was 36,700m3. A monitoring device was installed in a chamber before the CSO discharge at West Putney. The number of spills was found to be 28 for the year. The record of the CSO spill volume for the year Sept 2010 to Sept 2011 was 20,100m3. So how wet was the period? The Heathrow average annual rainfall is quoted as 604mm/year which compares with 527mm during this period, so the monitoring period was somewhat drier than normal. The revised TW Table of performance quotes the spill frequency as 28. This reduction in spill frequency from 59 to 28 demonstrates the accuracy of the initially modelled spill frequency.

I have been unable to locate any other measurements of spill frequency or spill volume from any of the other gravity CSO. This may be because such measurements are difficult to obtain. However that does indicate how much reliance should be placed on such information.

Future spill frequency and volume
"*The population figure used in the model represents 2023 conditions*" Application for Development Consent 2013 doc 7.23 page 14. The model assumes that dry weather flow in the sewers increases in line with population, ie as population increases then the dry weather flow increases and the spare capacity in the sewers decreases. Thus, from the quoted population projections, by 2020 the dry weather flow has been assumed to increase from 2006 by about 24%, see image below. The DCO document states that at peak times some sewers are running at 80% capacity, page 13. Thus the flow in those sewers would, by 2023, reach about 99% capacity.

Population and Wastewater Flows



Wastewater Profile	Per capita (L/head/day)	Catchment
Beckton Combined	200	Beckton
Beckton City	150	Beckton
Beckton Separated	150	Beckton
Crossness Combined	200	Crossness
Crossness Partially Separat	155	Crossness
Crossness Separated	155	Crossness
Fraser Rd (Separated)	145	Crossness

Assumptions:

1. Population change based on latest GLA projection to 2030 and ONS from 2030 to 2050
2. No change to per capita rating
3. No change in baseflow infiltration
4. No change in impervious connected area
5. Point 2, 3 and 4 subject to compliance to other TW work such as SOLAR values

The histogram above shows in red how TW have projected the sewer flows in the Beckton and Crossness catchments based on population growth.

The areas served by the Tideway sewers are not the same as the area served by Thames Water water supply system but they are not much different and one could assume a similar relationship. In their water supply zones Thames Water are promoting water demand management and increasing metering of water supplied so, in reality, the water supplied, and hence reaching the sewers, will be affected by those measures and will be going down. The numbers in the Thames Water final Water Resources Management Plan PR14 for water into supply are

2006	2180 Ml/d
2012/13	2028 Ml/d
2020/21	1948 Ml/d.
2039/40	1993 Ml/d

The effect of this on the flow in the sewers is shown by the black marks on the histogram above for the Beckton catchment. I have been unable to find water supply projections beyond 2040, and any way they would be highly speculative. However, taking the period 2020 to 2040 as a base, then water into supply is projected to rise by 45 Ml/d in that 20 years. Projecting that forward to 2080, another 40 years, would mean an increase of 90 Ml/d, to 2080 Ml/d. This is still below the water into supply in 2006 of 2180 Ml/d. This is a very crude assessment but would indicate that increasing population, and hence dry weather flow, whilst a major issue in the previous TW sewer model calculations, may well not, by 2080, even return to conditions that were in 2006. Since it is the excess flow above sewer capacity that spills, the spill volume assumptions in the TW sewer model would be significantly greater than those now projected.

As an illustration, by 2023, there would be a reduction of about 10% in water supplied and hence in sewer dry weather flow. Thus, for those sewers which were running at 80% capacity as quoted by TW in the DCO document, the capacity used at peak times in 2023 would actually be only 72% of capacity. This reduction in dry weather flow from 99% of capacity to 72% of capacity, would make a significant difference in the frequency and

volume of spill, and hence the number of modelled failures and volume of spill into the Tideway.

Spilled water quality
The river model also requires input about the water quality of the spilled water. The only study I have been able to identify on this is the SCITTER study done at Acton about 2002.The results of this were very variable with a first flush higher concentration of solids and a solids concentration dependent somewhat on the size of the storm. Thus it would be difficult to identify the water quality of the effluent spilled from any storm from the interceptor into the river.

Conclusion
There is likely to be a wide margin of error in such assumptions on the volume and quality of the CSO spills.

River water quality model

The dissolved oxygen model needs as its input such data as the quality and volume of the CSO discharge and the quality and flow of the river water, its temperature, the hydraulic conditions and the tidal conditions. Most of these variables would be different for each event. Thus there could be significant further variability/error in the river model output.

Automatic Quality Monitoring Stations.

The Environment Agency monitors river water quality in the Tideway at a number of Automatic Quality Monitoring Stations (AQMS). These collect data on several parameters including dissolved oxygen. "*The locations are either jetties or floating pontoons*." Greaves/Binnie email 9/10/14. The locations are

Upper Estuary		
Brentford AQMS	517975	177066
Cadogan AQMS	527436	177559
Chiswick AQMS	521565	177389
Hammersmith AQMS	522677	178254
Kew AQMS	519316	177758
Putney AQMS	524060	175771
Middle Estuary		
Barrier Gardens AQMS	541835	179399
Purfleet AQMS	556755	176806
Erith AQMS	550967	179898

I can find no statement as to whether the AQMS records have been used to calibrate the model and have had no response from the EA to that question. Thus my belief is that no such calibration has taken place.

Reliability of the water quality model

Reliability of the Thames Water sewer model and the water quality model.

"the report does not form a sound or credible basis to challenge the Thames Tideway water quality model..." Lord de Mauley letter of 13th January 2015 penultimate para

The importance of any model is not so much whether it has been peer reviewed but whether its output actually reflects actual conditions that occur.

The outputs of the water quality model for the initial conditions and with the improvements is shown on page 28 of his report. For initial conditions threshold 3, 2mg/l for 1 tide, several of the fish species should suffer fish kill. The model predicts 99 such breaches, ie fish kills, in 41 years, ie 24 fish kills in 10 years.

The Environment Agency record of the last 10 years is of 2 fish kills caused by Abbey Mills spills and one caused by CSO spill into the Tideway, a total of 3, albeit it is possible that a few other fish kills were not reported but, considering that fish kills occur in summer when daylight hours are long and the river is extensively viewed, these cannot be many more.

The water quality model shows that even after the STW upgrades and the Lee tunnel the Tideway would still fail the standards. Once the Lee tunnel is operational then the Environment Agency records show only one fish would have been killed in the last 10 years thus meeting the standards. Further the Tideway Fish risk Model, once corrected for obvious errors, show that the current Tideway conditions are sustainable for fish. Thus the water quality model does not reflect the relevant conditions.

The Environment Agency state that the AQMS "*water quality monitoring is a better indicator of how often each standard is breached".* The water quality model shows that, after the STW upgrades and the lee tunnel, there would be 75 breaches of threshold 1 in 10 years, ie about 2 breaches a year. In 2014, a typical year, even before the Lee tunnel becomes operational, there were no breaches of threshold 1.

This the water quality model has failed to reflect either initial conditions or conditions after the upgrades sufficiently. Thus it is not so much Professor Binnie's report that challenges the water quality model, it is its failure to reflect actual conditions as found by other analyses and field data.

Whatever, the water quality model is clearly not fit for purpose and should be reassessed and now calibrated against the AQMS data that is available.

Conclusion

Whilst I believe that the basic model and the modellers were the best that were available, the weakness in the basic data means that the model output in terms of failures of the dissolved oxygen standard could be very much at variance.

Appendix D Tideway Fish Risk Model

Not all fish are spread uniformly through the Tideway. Thus the Tideway Fish Risk Model combines for each representative fish species the proportion of stock in each river zone by month with the probability of a breach in that zone by each month to generate a risk matrix. This is then combined with a risk of mortality for that threshold to identify an overall population effect. This is more reliable in identifying sustainable conditions than the dissolved oxygen modelling as it takes a wider range of factors into account.

Page 76 of the FARL report Experimental studies on the dissolved oxygen requirements of fish 2004 , when discussing fish mortality, states "*All fish populations can cope with a degree of mortality without the long-term population level being affected. This is a principle that underlies the commercial exploitation of fisheries, in which sustainable fishing mortality rates of 50+% are not uncommon (see e.g. Van Winkle, 1977). Mortalities are best withstood in the early juvenile phase, where natural mortalities are already high (typically 5-10% per day for pelagic larval stages). Hence, a 10% loss in the early fry stages is unlikely to be detectable and a 10% loss even at the adult stage is likely to be sustainable in a population that is not commercially exploited and under pressure already. Annual mortality rates of this magnitude would probably cause little or no detectable change in the population relative to one in an unexploited, unimpacted population in a pristine environment.*

"In reviewing the " model*", it must be appreciated that the percentage mortality figures shown are unlikely to apply to the entire Tideway population of any species but only to those that are exposed to the DO sag. It is difficult to be specific about this, as CSO discharges can vary considerably in terms of volume, origin and dispersion but under any circumstances, the proportion of a population exposed is likely to be considerably less than 100%. "*

Dr Turnpenny, in his response to the TTSS comments on the Babtie report, 2005 see TFR page 48 states "*Fish in the Tideway are generally scattered through a number of Tideway zones and therefore, while suffering high mortalities in the grossly polluted reaches, the bulk of the population may survive. This can mean that there will be heavy fish kills but that mortalities over the Tideway as a whole would still be sustainable. Sustainability in this context I have previously proposed as meaning 10% or less mortality per annum for short lived species such as gobies or smelt and 20% or more for multi-spawning class species such as salmon, flounder or bass."* In the 2010 Needs report Appendix F Table 3-4. Sustainable mortalities, were established as 10% for goby, 20% for dace, and 30% for salmon, bass and flounder,

As part of the fish studies and trials a fish risk model (TFRM) was set up "*to better assess the risk of hypoxic (low DO) events. It takes account of the fact that CSO events do not affect the whole of the Tideway equally and that a breach of a standard is likely to affect some zones more than others. For instance, if a species were uniformly distributed throughout the Tideway but the LC10 (lethal concentration for 10% of the population was exceeded in only 20% of the Tideway habitat, then only 2% of the population (not 10%) would be likely to die. The TFRM applies this concept using the EA Tideway water quality Zones to estimate for any given month of the year, for each species/lifestage, what proportion of the Tideway population are likely to be present in a particular zone. Water quality (DO) data are then compared against lethality data to estimate the mortality by species/lifestage and Zone."* Thames Tideway Strategy :Fish & Ecology Objective, 2005

Appendix F to Needs Report 2010 states on page 16 that the TFRM of the situation at that time shows that "*the fish populations would be sustainable, or marginally sustainable. The fact that this state is achieved with the large number of standards breaches associated with the Current baseline can be taken to imply that Tideway fish populations should already be sustainable, which potentially undermines the case for improvements."*

The 2014 situation is that the Beckton, Crossness and Mogden STWs have been upgraded , what is called the AMP4 works. Thus the relevant TFRM is that once the AMP4 works are completed and that is shown below. Tideway Fisheries Review Appendix F to the 2010 Needs report page 21.

Table 3-2 (Fawley Table 6.10) Expected fish mortalities with the proposed AMP 4 STW Schemes in place, at the proposed Interim Standard levels of 1.0 2.0, 3.0 and 4.0 mg DO L^{-1}, modified by the Fish Risk Model. The effect of a 1.5 mgL^{-1} Minimum Standard is also shown.

AMP 4														
Species	Lifestage	Effect of Proposed Standard on Predicted Fish Mortality												
		1.0 mg L^{-1}	1.5 mg L^{-1} (6h in 10y)	2.0 mg L^{-1} (6h in 5y)			3.0 mg L^{-1} (18h in 3y)			4.0 mg L^{-1} (1 wk per y)			No. of >10% PL Effect @1.0mgL^{-1}	No. of >10% PL Effect @1.5mgL^{-1}
				Mortality Rate	Risk Factor	**Population Level Effect**	Mortality Rate	Risk Factor	**Population Level Effect**	Mortality Rate	Risk Factor	**Population Level Effect**		
Salmon	Smolt	100%	100%	100%	0.00	**0.0%**	10%	0.00	**0.0%**	10%	0.05	**0.5%**	4	4
	Adult	100%	100%	100%	0.35	**35.4%**	90%	0.63	**56.8%**	10%	0.53	**5.3%**		
Bass	Young Fry	**10%**	**10%**	10%	0.00	**0.0%**	10%	0.00	**0.0%**	10%	0.00	**0.0%**	0	0
	Juvenile	**10%**	**10%**	10%	0.35	**3.5%**	10%	0.63	**6.3%**	10%	0.53	**5.3%**		
Sand smelt	Egg/fry				0.00			0.11			0.00		2	0
	Juvenile	50%	**10%**	10%	0.35	**3.5%**	10%	0.63	**6.3%**	10%	0.59	**5.9%**		
	Adult	75%	**10%**	10%	0.35	**3.5%**	10%	0.63	**6.3%**	10%	0.87	**8.7%**		
Dace	Egg/fry	100%	100%	85%	0.00	**0.0%**	10%	0.00	**0.0%**	10%	0.00	**0.0%**	3	2
	Juvenile	50%	30%	10%	0.53	**5.3%**	10%	0.29	**2.9%**	10%	0.11	**1.1%**		
	Adult	50%	**10%**	10%	0.53	**5.3%**	10%	0.29	**2.9%**	10%	0.11	**1.1%**		
Smelt	Egg/fry				0.00			0.00			0.00		3	3
	Juvenile	100%	40%	40%	0.35	**14.2%**	10%	0.63	**6.3%**	10%	0.59	**5.9%**		
	Adult	100%	40%	40%	0.25	**10.0%**	10%	0.88	**8.8%**	10%	0.87	**8.7%**		
Flounder	Egg/fry				0.00			0.00			0.00	**0.0%**	2	2
	Juvenile	50%	50%	15%	0.35	**5.3%**	10%	0.63	**6.3%**	10%	0.56	**5.6%**		
	Adult	50%	40%	15%	0.25	**3.8%**	10%	0.83	**8.3%**	10%	0.83	**8.3%**		
Common goby	Egg/fry				0.00			0.00			0.00		2	2
	Juvenile	50%	40%	10%	0.35	**3.5%**	10%	0.63	**6.3%**	10%	0.53	**5.3%**		
	Adult	50%	40%	10%	0.00	**0.0%**	10%	0.00	**0.0%**	10%	0.00	**0.0%**		
										Total PL Effects occurrences >10%			16	13
										Total PL Effects 'not sustainable'			4	0

Threshold 4, the minimum DO was changed from 1.0mg/l to 1.5mg/l so ignore the 1.0mg/l column.

The FARL report states that for the TFRM the numbers in "*blue show possible marginal sustainability"* and the numbers in red "*are considered to indicate that the population may become unsustainable."* The conclusion is that, as there are no red numbers, there is no unsustainable species, hence the fish in the Tideway were sustainable.

Further the current baseline situation includes the Lee tunnel whose construction is scheduled for completion in late 2015. This would much reduce the annual volume of spills, previously 39 Mm3/year into the tideway down to about 18 Mm3/year. This would also increase the sustainability in the TFRM.

The salmon risk factor shown in the model above is about 0.5. This would mean that the salmon are in the Tideway almost all of the time. Salmon are a migratory species which would take probably about one week to pass through the main part of the Tideway. At other times they would be either at sea or higher up the river. The plot below, from Dr Solomon's report River flow and salmon migration in the River Thames at Molesey 2011, shows the

timing of the arrival of salmon at the Molesey weir 1994 to 2008. This shows that salmon arrived there between June and the end of November.

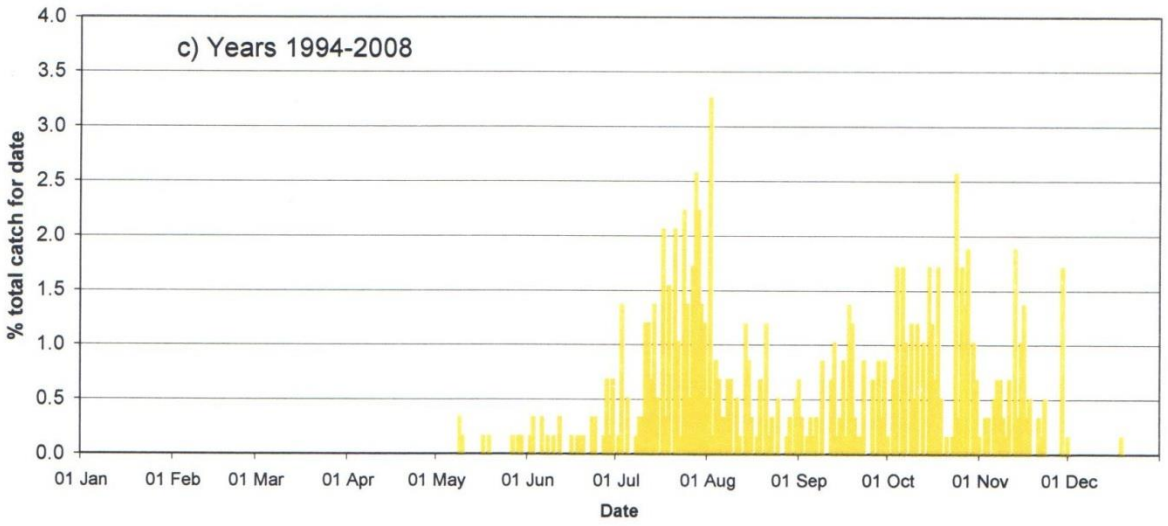


Figure 3.1. Seasonal pattern of trap catches at Molesey, totals for date. a) 1986-1996, b) 1986-1993, and c) 1994-2008.

Thus the salmon risk factor used in the model appreciably over-estimates the risk and hence the impact. Further as seen already, salmon are very limited in the Tideway, 2013 only 3 being recorded, the EA stating that they are not sustainable in the short to medium term and the models showing that due to changes in the Atlantic they will not be sustainable in the longer term. Sea trout are a similar species with similar sensitivity and could be a "replacement representative" species. However the numbers that I have for them are an annual average of about 15 recorded migrating into the Thames. It is questionable whether so few are sufficient to warrant becoming a representative species.

Subsequently an analysis was done of AMP4, ie STW upgrades, with assumed 2020 conditions, ie increased sewer dry weather flows and increased flow to the STW and the effect on the STW effluent and climate change induced temperature increase. That TFRM, shown on page 25, shows that there would then be several unsustainable fish species.

However this TFRM is based on the TW assumed dry weather flows whereas the latest fWRMP shows the dry weather flows would be significantly lower and thus the water quality in the rivrt model would be worse than would be now found.

Table 3-6 TFRM Outputs for AMP4 STW Improvements Scenario, based on the projected conditions for the year 2020

AMP4 Baseline A 2020 PE

Species	Lifestage	Standard 4 1.5 mg L^{-1} (6h in 10y)			Standard 3 2.0 mg L^{-1} (6h in 5y)			Standard 2 3.0 mg L^{-1} (18h in 3y)			Standard 1 4.0 mg L^{-1} (1 wk per y)			No. of >10% PL Effect @1.5mgL^{-1}	No. of Reproductive Age classes	Sustainable Mortality %*
		Mortality Rate	Risk Factor	Population Level Effect	Mortality Rate	Risk Factor	Population Level Effect	Mortality Rate	Risk Factor	Population Level Effect	Mortality Rate	Risk Factor	Population Level Effect			
Salmon	Smolt	100%	0.07	<10%	100.0%	0.09	<10%	<10%	0.18	<10%	<10%	0.13	<10%	3	3	30
	Adult	100%	0.65	64.7%	100.0%	1.00	100.0%	90.0%	1.00	90.0%	<10%	1.00	<10%			
Bass	Young Fry	10%	0.24	<10%	<10%	0.32	<10%	<10%	0.55	<10%	<10%	0.45	<10%	0	10	30
	Juvenile	10%	0.62	<10%	<10%	0.96	<10%	<10%	1.00	<10%	<10%	1.00	<10%			
Sand smelt	Egg/fry		0.18	<10%		0.31			0.59			0.30		0	2	10
	Juvenile	10%	0.67	<10%	<10%	1.00	<10%	<10%	1.00	<10%	<10%	1.00	<10%			
	Adult	10%	0.66	<10%	<10%	1.00	<10%	<10%	1.00	<10%	<10%	1.00	<10%			
Dace	Egg/fry	100%	0.19	19.0%	85.0%	0.24	20.4%	<10%	0.41	<10%	<10%	0.29	<10%	3	4	20
	Juvenile	30%	0.47	14.2%	<10%	0.71	<10%	<10%	1.00	<10%	<10%	0.99	<10%			
	Adult	10%	0.44	<10%	<10%	0.67	<10%	<10%	1.00	<10%	<10%	0.91	<10%			
Smelt	Egg/fry		0.18	<10%		0.24			0.42			0.30		4	7	10
	Juvenile	40%	0.68	27.3%	40.0%	1.00	40.0%	<10%	1.00	<10%	<10%	1.00	<10%			
	Adult	40%	0.76	30.3%	40.0%	1.00	40.0%	<10%	1.00	<10%	<10%	1.00	<10%			
Flounder	Egg/fry		0.00	<10%		0.00			0.00			0.00		4	2	30
	Juvenile	50%	0.66	33.2%	15.0%	1.00	15.0%	<10%	1.00	<10%	<10%	1.00	<10%			
	Adult	40%	0.79	31.6%	15.0%	1.00	15.0%	<10%	1.00	<10%	<10%	1.00	<10%			
Common goby	Egg/fry	0%	0.00	<10%	<10%	0.00	<10%	<10%	0.00	<10%	<10%	0.00	<10%	1	2	10
	Juvenile	40%	0.67	26.8%	<10%	1.00	<10%	<10%	1.00	<10%	<10%	1.00	<10%			
	Adult	40%	0.00	<10%	<10%	0.00	<10%	<10%	0.00	<10%	<10%	0.00	<10%			
											Total PL Effects occurrences >10%			15		
											Total PL Effects 'not sustainable'			11		

As an illustration the adult **salmon** risk factor has been increased to 1.0. That would mean that all of the salmon were in the Tideway all of the time and that none of them exhibited avoidance of hypoxia. These are unreasonable assumptions as salmon migrate through the Tideway spending a relatively short time in the section at risk and anyway they avoid hypoxic conditions, not to mention there are almost none of them. Correcting the risk factor for the improved river quality and the small proportion of salmon that would be affected by each adverse condition would almost certainly result in this species being sustainable.

Another anomaly is for **smelt** where mortality of 40% is assumed at threshold 3, 2mg/l. However the FARL tests show that at 1.5mg/l, ie significantly worse conditions, a mortality of only 10% occurred. Similarly at threshold 4, 1.5mg/l, a mortality of 40% was assumed when it should have been 10%. Both of these corrections result in smelt being sustainable.

Similarly for **flounder** at threshold 3, 2mg/l calculated 15% population effect was considered marginal when the sustainable mortality was quoted as 30%, thus the population effect is not marginal but sustainable. At threshold 4, 1.5mg/l for 6 hours, the TFRM shows juvenile mortality of 50%. However page 53 of the tests shows 10% mortality as 1.2mg/l. Thus the mortality at 1.5mg/l would be less than 10%, ie well below the limit of sustainable mortality of 30%. For the adult flounder there were discrepancies between the test results at Fawley and at Chiswick so page 52 states, "*The Chiswick results are therefore considered more reliable for adult flounder."* The TFRM shows the adult mortality at 2mg/l of 40%. However the Chiswick test results show 50% mortality at 0.9mg/l.. Studying the table on page 53 would indicate that at 2mg/l the mortality would be likely to be less than 10%. This would result in a population effect of less than 10%, well below the allowable sustainable population effect for flounder of 30%. Thus flounder would be sustainable.

Dace which has a reproductive life span of 4 years, is shown for its eggs/fry as having a failure at 20.4%. As the sustainable mortality is shown as 20%, surely this should be classified as marginal, rather than a failure. In any case page 49 of the Thames Tideway Strategy: Experimental studies on the Dissolved Oxygen requirements of Fish, Babtie 2004 the 24 hour test result shows larvae LC50 sd 2.1mg/l and LC90 1.6mg/l. Interpolation would result in 2mg/l resulting in mortality of about 70%. There were no 6hour test result , but the

mortality rate would have been lower. For instance the LC50 24 hour of 1.45mg/l drops to 1.05mg/l at 6 hours. Thus one would expect a mortality at 2mg/l for 6 hours for dace larvae to be significantly below 70%. Even at 70% the population effect would be 17% which is less than the sustainable mortality of 20%. Thus this alleged failure is not a failure of sustainability of dace.

A failure at threshold 4, 1.5mg/l for 6 hours, is also shown for juvenile **Goby** with a mortality rate of 40% and a risk factor of 0.67 resulting in a population effect of 26.8%, well above the sustainable mortality of 10%. However page 51 of the Thames Tideway Strategy: Experimental studies on the Dissolved Oxygen requirements of Fish, Babtie 2004 shows the results of the tests on Goby. Figure 4.8 and its associated table show the 6 hour LC10, ie 10% mortality after 6 hours, as being 1.1mg/l. for all ages. Thus the mortality at 1.5mg/l would have been lower than 10%. Thus Goby would be sustainable.

The widespread disregard of the actual results of the fish trials throws doubt on the rest of this version of the TFRM. In any case all species bar salmon are clearly sustainable under AMP4 conditons.

In any case this TFRM model run included the TW assumed 2020 situation, see Appendix F page 23, so the modelled dry weather flows in the sewers would have been higher than now assessed, see Appendix C above, and hence the CSOs spills would have been more frequent and of larger volume, hence the actual conditions in the Tideway would be significantly better than those used in the TFRM. Further, by 2016 the Lee tunnel will be operational which will reduce the annual average spill volume down to about 18 Mm3.

Thus it would appear that the baseline TFRM should be corrected and this would show that fish species would be sustainable, both now with the STW upgrades in place and in 2020.

Appendix E Cost benefit analysis

Introduction

In Lord de Mauley's letter to Lord Berkeley of 24th February 2014 he states "*Given that our cost benefit analysis does not demonstrate disproportionate costs, neither the Commission nor the Court would be likely to agree a claim that the costs were disproportionate*."

The Defra Costs and Benefits of the Thames Tunnel, November 2011 does indeed conclude that, by its analysis, the benefits range of £3bn to £5bn encompasses the then anticipated capital cost of the tunnel of £4.1bn at 2011 prices.

Benefit split.
There have been two willingness to pay (WTP) surveys to assess the amounts that the public would be prepared to pay towards the tunnel scheme. That in 2003 for the TTSS split the benefit down into its 3 components of fish kill, litter/aesthetics, and health. It was found that the split of the benefits was 15%, 25%, and 60%. The total benefit at about £5bn was found to be significantly greater than the then estimated cost of the tunnel to Beckton and Crossness STWs at £1.7bn.

The 2006 WTP study did not differentiate between the benefit of the three topics but arrived at a total benefit of £3,935m based on a particular show card. Since there is no breakdown of the 2006 survey and the two show cards are not that dissimilar, I have taken the split of the 2006 benefit as the same as the 2003 split. This may not be exact but there is no other data on which to do the split and anyway a change in one proportion would mean that the other proportions would need to be adjusted as well.

Minister de Mauley's letter of 1st April 2014 states *"it is not correct to assume that health values make up 60% of the value of the Tames Tideway tunnel benefits on the basis of an earlier survey carried out in 2003, as the basis of the 2006 survey was somewhat different to that undertaken in 2003.* " Both WTP surveys were done on the basis of what people would be prepared to pay to achieve the betterment stated. The surveys were done with show cards which were not dissimilar.

For instance the 2003 health benefit was based on a showcard saying the then current situation was "*120 days when health risk is elevated"*, Table 2.2. The 2006 survey showcard quoted the baseline as "*higher risk following each over flow, high risk at all other times...60 times per year for some overflows.*" 2006 report, table 4.1. Table 3.1.of the eftec 2005 CBA, states that the "*120 days is based on the assumption that risk is elevated on the day the CSO happens and the next day"* as used in eftec 2003 report. Thus the descriptions are not dissimilar.

For fish population the current situation in 2003 was described as *" 8 or 4 potential fish kills per year*" (Table 5.3 of the eftec February 2005 report shows that 8 fish kills were used in the analysis and Table 4.1 that these were 8 observed potential fish kills per year.) whereas in the 2006 study the baseline is described as "*1 or 2 times per year when oxygen levels in the water drop low enough to either kill some fish or prevent migration (eg salmon)."* Thus, as the baseline condition is improved between 2003, 8 observed fish kills/year and 2006, 1 or 2 fish kills per year, then one would expect the amount of money people would be willing to pay to protect against fish kills would reduce appreciably. That would mean one of the other proportions would have to increase.

For sewage litter the 2003 baseline, "*May be visible anywhere along the tidal Thames, but especially visible close to outfalls following overflows. Amounts to 10% of all litter."* The

2006 current situation is quoted as "*Some 10% of total litter*." Thus the willingness to pay for litter is unlikely to stay the same.

That would mean that the proportion applied to health is unlikely to go down between 2003 and 2006 and, if anything, is more likely to increase.

I am not aware that there is any better evidence and no revised split has been put forward by Defra. Thus one can only assume that the 2003 split is the best evidence available and should be retained until better evidence is provided.

Cost benefit approach

The cost benefit analysis is based on the eftec 2006 Thames Tideway-Stated Preference Survey. Lord de Mauley states on 1st April 2014 "*The original stated preference work was subject to two iterations and was overseen by a technical working group and an academic panel, including some eminent names in environmental economics. This qualified group supported the approach taken."*

The approach taken was commented on by Nera in their Thames Tideway Cost benefit Analysis 2006.They raised questions about the validity of some of the sweeping changes from the 2003 willingness to pay study to the 2006 study.

1. the extension of the benefit area from the Thames customer base who would pay for the tunnel as in the 2003 WTP survey to most of England,
2. the exclusion of zero willingness to pay protest votes in assessing the amount people would be willing to pay, and
3. the increase in the appraisal period from the 60 years as in the 2003 WTP survey to 100 years.

Despite the concern about the validity of these sweeping changes, I have followed the eftec approach and have not altered any of these assumptions.

Cost benefit calculations

However, my Costs and benefits analysis first issued in February 2012, challenged many of the other calculations in the Defra report. This included the health benefit and fish benefits, miscalculation of the benefit split between the Lee and Thames tunnels, application of a single issue approach whereas there were multiple requirements for funding, lack of inclusion of the disbenefits such as construction impact and operational energy, and the assumption of appreciable increase in wealth post 2008 when in reality wealth went down and has only now recovered to a similar level. Even if one assumed that the aesthetics benefit would be as found in the willingness to pay survey and ignored the substantial benefit subsequently brought by the litter collectors, I concluded that the benefit would only be about £180m. This would make the estimated costs of the tunnel at about £4,100m at 2011 prices, disproportionate in comparison with the benefit.

Whilst my cost benefit analysis was sent to defra and others in March 2012 the first specific comment I received on it was in Lord de Mauley letters to Lord Berkeley of the 24th February 2014 and 1st April 2014, some two years later.

The former states *"In addition, we do not accept Professor Binnie's criticism of our cost benefit analysis or his revised assessment of the benefits. There will always be uncertainty*

when trying to estimate environmental and health benefits, which is why we have presented the benefits of the proposed Thames Tideway tunnel as a wide range (securing £3-£5 billion worth of economic benefits, where estimable). We do not believe that we have over-claimed on these" I have considered the health benefit in that section earlier but the letter does say that "*we would expect a true valuation of the health benefit to be somewhat in excess of the QALY value"* which is £1 1/2m. This is substantially less than the health benefit of 60% of total benefit (found in the earlier, 2003, WTP survey,) of the £4bn total base benefit found in the 2006 WTP, prior to adjustment. Using that comparison, the £2,400n benefit would be reduced to "somewhat in excess of £1 1/2m", possibly about £2m. Thus the health benefit in the 2012 CBA does seem to be an over-claim.

The Minister states in his letter of 1st April "*I also do not agree with the assertion that the benefits of the Tunnel should be valued at £180million. This is based on a number of false or misleading assumptions."* Since information is only given about one of these allegations I am unable to consider any of the others. "O*ne of Professor Binnie's points is that the stated preference work by Eftec which forms the basis of the benefit analysis for the Tideway improvements is of the "single issue" type and that this means the benefits are likely to be overstated.."*

Eftec, during their WtP data collection, asked respondents what was their priority for public spending. Table 4.3 shows "*water quality in local rivers*" got 6.2% first preference and 10.3% second preference in the TW area, and 11.6% and 9.2% in the non TW areas. This of course would come out of a larger sum as it included such topics as air pollution, but the amount would need to cover all rivers. Thus, whilst not monetised, it would indicate that the £10/hh in £43/hh would be significantly too high, and could be as low as about £5/hh/year, a reduction of about 80%. In reality to allow for funding of river issues elsewhere, the reduction ought to be even greater. Thus I believe the eftec WTP numbers should be reduced by 60% of those found in the analysis to take account of the single/multiple issue effect.

Lord de Mauley continued ".*Eftec and the wider group considered this carefully in preparing the 2006 survey and to address any risk of overvaluing benefits included frequent prompts to respondents about other issues, and competing demands for their income which they might want to take into account."* I have been unable to find evidence to support this allegation. The NERA 2006 report ThamesTideway Cost Benefit Analysis considers aspects of the Eftec WTP report and states on page 27 *"It is noted there, for example, that questions about one environmental benefit, such as a cleaner river, may yield different higher valuations*" single benefit " *from questions about allocating money across a wider set of benefits,*" Multiple benefits. "*We believe that such factors are legitimate reason for caution in reliance on stated preference results, but we do not consider them further in this report."*

Andrew Whetnall has emailed me on 9th December to say "*I was part of the cost benefit working group at the time and asked some questions on single issue overvaluation. Also of a later group looking across the board at the appraisal of projects for PR09. Everything I saw in both contexts confirmed me in the view that single issue surveys overvalue. People tend to give a similar range of wtp amounts whatever they are asked about, so if they are asked about ten issues the average value of each very roughly works out near one tenth of the value they give if asked about one issue. The reminders that there will be other pressures/other things to spend their money on have little effect. And when you add up a range of single issue or basket valuations affecting the same paying population, it turns out*

they are willing to spend more than all of their income growth on water/sewerage investment Suffice it to say that I am sure you are right about overvaluation."

However to minimise any disagreement by Defra with my cost benefit report, I have excluded any reduction for the single/multiple effect. Thus, in the revision of my cost benefit analysis report of May 2014, I have taken account of this ichange and all the specific comments. The revised benefit effect is now about £500m.

Other benefits

Lord de Mauley in his letter of 24th February "*there are some benefits to which we have not been able to attach monetary values and which are therefore excluded. One is the benefit to ongoing economic development of London, which could be significan*t."

One aspect that could boost the economic development of London is the capital expenditure on the tunnel. However the tunnel boring machines, a major expenditure, are likely to be supplied from outside UK and many of the workers are likely to be from outside London. On the other hand almost all London households would have to pay the increased sewerage charge, estimated to be about £80/household/year.

A potential drag on the economic development could be the aesthetic quality of the Tideway. On page 11 Jacob Babties report 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.

Thus the benefit of the tunnel to the economic development of London would appear to be limited.

Disbenefits

One factor not included in the Defra cost benefit assessment are the disbenefits, such as the extra traffic, noise and CO2 emission generated during construction and the energy used to pump out some 18Mm3/year from a depth of about 60m on average. The Entec report Environmental costs and market benefits of reducing combined sewer overflows, December

2006 includes consideration of these aspects and my report includes numbers taken from that report. These aspects ought to have been included in the Defra cost benefit assessment but were not.

Conclusions

Thus the benefit assessment as calculated by defra as some £3bn to £5bn has been calculated by me as about £500m, see the Table below from my Costs and benefits analysis addenda 8 1st May 2014. The assessed benefit is substantially, and disproportionally, less than the cost of the tunnel at over £4bn.

Item	2003/5	2006/7	2011	Comment	Adjust
	CBA	CBA	CBA		ment
Base amount			£3,935m		£3,935m
Health	60%	combined	combined	QALY not WTP	To £2m
Fish	15%		combined		To 0
Litter/aesthetics	25%		combined	Property benefit minor	Keep £1,000m
Jurisdiction	Admin	A+B	A+B	Benefit Jurisdiction doubt	none
Single/multiple	single	single	single	Multiple in FBP	none
Other rivers				No allowance. ? half	none
Mean/median			mean	Median about half	none
Protest votes	included	included	excluded	15% increase	none
Distance decay	No	Yes	Yes	Results look odd	none
Monetary values	no	No	No	15% constant nominal	none
Thms/Lee split	NO	No	TT 60%	Adjust tonnage	-52%
Benefit of Lee T	No	No	No	Lee tunnel needed for Thms T	none
Appraisal period	60 years	60 years	100years	60 years	No increase
			+14%		£481m
Reduced hh flood			no	Entec Table 4.3	+£7m
Disbenefit	no	no	no	Half upper of £85m	-£42
Base amount					£446m
GDP deflator 06-11			+10.6%	Fall of 6.5%	
2011			2,969m		£446m
Population rise	No	No	+14%	Ldn % applied to benefit area	+14%
amount			3,391m		£508m
Real income growth	NO	No	+33%	2006-2011 -6.5% not 10% GDP includes population.	zero
Spill volume			Not included		Not included
Amount			4,502m		£508m
Quoted range			2,969-5,058	.	

Appendix F Measures to reduce spill frequency

One needs to consider not just the 2020 baseline conditions but also future conditions. Thus London's population is expected to continue to grow, affecting the dry weather flow in the sewers, and affecting the spill frequency and volume. Due to climate change the temperature of the river water will increase, reducing its ability to hold oxygen, and thus increasing the risk of dissolved oxygen failure. Thus measures are needed to more than mitigate these adverse effects.

Design flow conditions.

Thames Water, in its presentation to me on 30th September 2011, showed design sewer dry weather flows increasing in line with population increase, thus reducing spare flow capacity in the sewers and increasing spill frequency, see Appendix C modelling above.

However Thames Water's 2014 final Water Resources Management Plan shows that, with demand management and increased metering, water supplied is reducing from 2180 Ml/d in 2006 to 1993 Ml/d in 2039/40 thus providing greater storm water capacity in the sewers than in 2006 and reducing spill frequency and spill volumes. This is discussed in more detail in Appendix C, modelling, of this report.

Remove restrictions

It is known that there are some restrictions in the London sewer network, one being the too small connection between the large Fleet sewer and the Northern Low Level Interceptor, resulting in a higher spill frequency for the Fleet CSO. Hamburg removed 80 restrictions to improve flow and reduce spills. London should also investigate this potential benefit.

Sewer separation

Separation of the combined sewers into foul and storm sewers could be economical where there is a nearby discharge place. This could be near the banks of the Tideway where there is appreciable development taking place, near the tributaries such as the River Wandle or Lee, near the Regents Park Canal to which the storm water from the Liverpool Street redevelopment is due to be connected, near the existing Thames to Lee water transfer tunnel shafts or near an existing separate sewer system.

Technology development

Since 2003, when the tunnel solution was effectively chosen, technology such as real time control has developed and international practice has switched away from tunnel solutions to sustainable drainage solutions. As an example see the EC Blueprint for Water and examples from the USA such as Philadelphia. In addition it would be sensible to adopt a combination of measures, using each where it was most cost effective.

Real Time Control/Active system control

The greatest impact on the water environment comes during summer thunderstorms when the rainfall can be intense but the river flow is lower and the temperature higher with less available oxygen. However thunderstorms are relatively local, with areas further away having much less rainfall, see the image on the first page of Appendix C modelling.

The sewer network has many interconnections between the near horizontal west east interceptors and the much steeper storm relief sewers down the historic stream courses. The interconnections are fixed weirs put in as long ago as a century. Thus development, and

hence storm runoff, may have changed much since then. The technology of Real Time Control/Active System Control has been developed in the last decade. This utilises rainfall radar to assess likely flows, in sewer sensors, and moveable weirs to make maximum use of spare sewer capacity. In Quebec real time control alone reduced spills from 45 to 26 a year. I am told it is being implemented in Lisbon, Marseilles, Vienna and elsewhere.

UKWIR report 13/SW/01/5 states "*analysis of radar rainfall over London carried out by Thames Water (unpublished) indicated that extremely high intensity rainfall is constrained to a very small area with storm depths being reduced by half over distances of one to two kilometres. This indicates that there is potential for managing the flooding by diffusion through a highly inter-connected system, especially in relatively flat areas with inter-connected sewers."* as occurs in much of London.

Concerning ASC it states that the Environment Agency "*requires it to be considered as part of the options appraisal stage of all schemes."* The feasibility, benefit and cost of this should be considered.

Sustainable Urban Drainage systems/Blue Green Infrastructure.

The technology now being used in many major cities elsewhere is Sustainable Urban Drainage Systems (SuDs). This involves systems for storing water locally such as roof gardens, swales, porous pavements, and storage tanks under pavements and roads, etc. Below is an image of a typical modern storage tank system.

The Waste Water National Policy Statement Appraisal of Sustainability Post-Adoption Statement March 2012 page 8 states "*Appraisal of Sustainability Summary of Recommendations "stipulate that sustainable drainage techniques (SuDs) be adopted to manage surface drainage of the NSIP, unless demonstrably not possible. Examples include surface storage and attenuation or infiltration to ground if suitable hydrogeology exists."*

Thames Water 2010 Needs report

In 2010 Thames Water (TW) published its Needs Report. In Appendix E it considered the alternative of Sustainable Urban Drainage Systems (SuDs) in the Putney area and concluded that SuDs would not reduce the spill frequency to below 10 spills a year and SuDs was rejected. Subsequently it was found that some of the sewer modelling output was wrong. Also, despite there being river terrace gravels in the area into which storm water could infiltrate, the study team was instructed by TW to ignore the benefit of infiltration. There is also an instance where a very short length of new sewer could take storm water from being discharged to a combined sewer to discharging to the Beverly Brook, thus reducing the spill frequency of that CSO. Only the single measure SuDs solution was considered and no combination of measures.

There is terrace gravel under much of central London and this can be used for storm water infiltration. The cross section on page 75 of the BGS publication Geology of London shows that there are several river gravel terraces up to 6m thick, sometimes overlain by about a meter of Langley silt. Thus even in areas shown on the BGS map as Langley silt there may well be terrace gravel beneath that would be useable for infiltration.

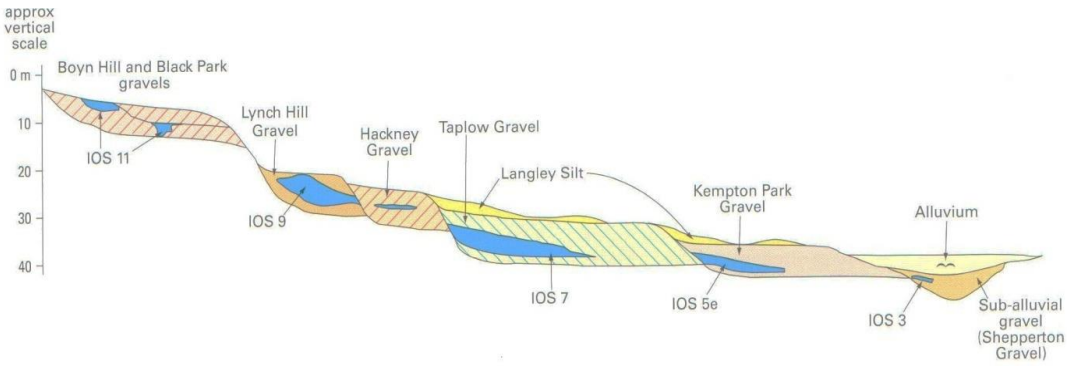


Figure 41 Schematic cross-section through the Thames River Terrace Deposits showing their relationship to interglacial deposits and their oxygen isotope stages (IOS) (after Bridgland, 1994).

Bloomberg 2013 report Tunnel Vision page 19 reported that, "*subject to some technical adjustments, SuDs infiltration could be developed 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.* " Infiltration has been excluded from previous analyses by Thames Water and the Environment Agency. It should be considered.

An extension, Blue Green Infrastructure includes the use of trees and other features to provide other benefits such as reducing temperature and improving health. The Mayor's recent London Infrastructure Plan consultation states on page 5 of the supporting document, *"green infrastructure is still not considered as infrastructure in its own right. A lack of a strategic London wide approach that makes investment decisions considering the whole range of benefits green infrastructure brings (drainage, shade, walk and cycle ways and much more) has resulted in below optimum investment*." As an instance in 2011 the city of Philadelphia created the Green City, Clean Waters programme, a 25 year plan of approximately £1.5 bn to protect and enhance the city's watersheds by managing stormwater with innovative green infrastructure. The city estimates that the use of green infrastructure in lieu of traditional approaches will save around £4.7bn over the life of the programme.

Energy use

At the time of the TTSS study there was little emphasis on energy use and greenhouse gas emissions due to its use. This is now required to be considered in new projects. Appreciable amounts of energy will be required to drive the tunnel boring machines and also to construct the tunnel,

The Waste Water National Policy Statement Appraisal of Sustainability Post-Adoption Statement March 2012 page 9 "*inclusion of a requirement for the sustainable use of raw materials."* Not proceeding with the tunnel would save the raw materials which would otherwise be used in its construction.

The CSO discharges to the tunnel will require pumping out before the next storm arrives. This will mean pumping the annual average of about 19 Mm3 up an average height of about 60m. In contrast surface measures, such as SuDs, would use minimal amounts of energy, an important advantage.

Measures for raising dissolved oxygen concentrations

Since 1989, or earlier but my records do not go back further, there have been two bubbler vessels in the Tideway capable of injecting oxygen into the river wherever there are likely to be excessive oxygen reduction due to discharges into the Tideway. The records that I have show that the bubblers were mobilised 126 times between 1989 and 2006, a 17 year period. That would indicate that they were mobilised on average about 7 times a year, to improve oxygen conditions in the Tideway.

One advantage of the bubblers is that they are mobile and so can be moved to an area of greater oxygen loss and can follow it up and down stream with the tide.

However with the improvements at Mogden, Beckton and Crossness STWs, as set out above, the AQMS data shows the Tideway now meets its required dissolved oxygen standards and, post the Lee tunnel being operational later in 2015, is likely to meet the WFD dissolved oxygen standard for good ecology. Thus there would appear to be no further need for the bubblers unless the Environment Agency considered them as an insurance in case some exceptional incident occurred.

Combination of measures to meet long term issues

More information about the measures is given in my report Measures to protect the river environment from the adverse effects of waste water discharges, dated 13th April 2014.

TTSSG studied stand alone schemes

The TTSSG, which I chaired, studied several alternatives which, by themselves, would be complete solutions. For instance for sewer separation we were provided by Thames Water with the cost of a completely new sewerage system in London which would then act as a separate sewer in parallel with the existing sewers. We did not consider a combination of measures for which I, as chairman, must take part of the blame. All these standalone systems were considerably more expensive than the then cost of the full length tunnel of £1.7bn. Thus at the end of phase 1 in 2003, we recommended the tunnel, and this was amplified in our final report in 2005.

Combination of measures.

Using the measures where they are each most economical should produce the most economical way of meeting the long term conditions.

The DEFRA River Basin Planning Guidance Vol 2 August 2008 states in 9.4 that "*the Environment agency should consider the full range of measures which are available"* and in 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 interrelationship between measures."* The July 2014 update includes almost identical words but adds "*13.8 The Agencies should, where possible, use cost effectiveness analysis to determine the combination of measures that will achieve WFD objectives at the lowest cost."*

As set out above there are many other ways, such as a combination of measures including real time control and SuDs, of meeting the requirements. These are set out in my report Measures to protect the river environment from the adverse effects of waste water discharges 2014 which was first issued to the Environment Agency in 2013.

Appendix G Relevant correspondence

Department
for Environment
Food & Rural Affairs

Nobel House
17 Smith Square
London SW1P 3JR

T 03459 335577
helpline@defra.gsi.gov.uk
www.gov.uk/defra

Lord Berkeley
House of Lords
London
SW1A OPW

Our ref: PO365830/ARG

17 January 2015

From Lord de Mauley
Parliamentary Under Secretary of State for Natural Environment and Science

Dear Tony

Thank you for your further letter of 11 December about the Thames Tideway Tunnel project. I apologise for the delay in replying.

In your letter, you suggest there is no longer a need for the Thames Tideway Tunnel. Your statement is based on Professor Chris Binnie's latest report of 10 December on the environmental impact of the Combined Sewer Overflow (CSO) spills into the River Thames, a copy of which you enclosed.

The essential claim of Professor Binnie's report is that the recently-completed London sewage treatment works upgrades and the Lee Tunnel, once operational later this year, will reduce the number of sewage spills and improve the environment of the Thames Tideway so that the requirements of the Urban Waste Water Treatment Directive ("the Directive") are satisfactorily met. He argues that this means the Thames Tideway Tunnel is no longer necessary. Professor Binnie focuses primarily on dissolved oxygen levels, but also looks at health risks to river users and the aesthetics of floating sewage litter. He also interprets the Environment Agency's position as being that the number of sewage spills into the river is of little importance so long as there is no adverse impact on water quality and thus the requirements of the Directive are satisfied.

The Court of Justice of the European Union's October 2012 judgment[1] that found the UK to be in breach of the Directive in London was clear that the Directive requires urban agglomerations to have appropriate systems in place to collect and treat all waste water in normal climatic conditions, although it recognises that overflow spills into watercourses may occur in exceptional circumstances, such as periods of unusually heavy rainfall. The Court did not set figures for the number of spills that might be tolerated under the Directive, and declined to do so. The Advocate General's Opinion of January 2012, which preceded the Court's judgment and mentioned a figure of 20 spills that the European Commission had previously indicated as a maximum beyond which concerns would be raised about a possible failure to fulfil obligations under the Directive, is immaterial from a legal or guidance point of view, as the Court's judgment is the final word on the matter.

[1] C-301/10 (Commission v United Kingdom)

The Thames Tideway Improvement Scheme consists of three pillars – the Lee Tunnel, the five London sewage treatment works upgrades, and the Thames Tideway Tunnel. The Lee Tunnel and sewage treatment works upgrades are expected to combine to remove some 21 million tonnes of waste water containing sewage, out of the 39 million tonnes that typically enter the Tideway in an average year. That still leaves some 18 million tonnes continuing to spill between 50 and 60 times per year from the CSOs into the tidal Thames in London. Additional sewerage capacity is needed to provide a collection system that addresses these overflows.

The Environment Agency is clear that the 34 most polluting CSOs in this stretch of the Thames need to be addressed to achieve compliance with the Directive, and additionally contribute to meeting the Water Framework Directive target for the Thames Tideway of good ecological potential by 2027 from its current moderate potential status. The Thames Tideway Tunnel is intended to capture the spills from these 34 CSOs that will, according to Thames Water's Tideway water quality model[2], continue to overflow in non-exceptional circumstances despite the sewage treatment works upgrades and the Lee Tunnel. To allow sewage to continue to enter the river and apply in-river treatment (bubblers and skimmers) instead, as proposed by Professor Binnie, does not constitute an adequate waste water collection and transfer system, and therefore fails to meet the requirements of the Urban Waste Water Treatment Directive.

Professor Binnie makes a number of other assumptions in his report that raise concerns about the analysis of agreed data provided to him by the Environment Agency following their meeting of 25 September 2014:

- This data was from three automatic quality monitoring stations (AQMS) data going back only a few years. The whole of the Tideway is covered by a wider network of AQMS sites, but the three stations provide a reasonable coverage of the Tideway and generate reasonable quality data for the sites in which Professor Binnie is interested. However, they do not provide a good representation of all discharge and tide circumstances, and the data is insufficient to assess compliance with dissolved oxygen standard 4, or reliably assess compliance with standards 3 and 2, given the return periods associated with them of 10, 5, and 3 years respectively. This analysis is also not a good predictor of future environmental performance. These shortcomings were specifically pointed out to Professor Binnie by the Environment Agency when the data was provided.

- Professor Binnie's analysis uses the average of all the dissolved oxygen readings from an AQMS for each tide, which is not the approach the Environment Agency would use to assess performance against the standards when examining the data from the whole AQMS network. Using the minimum dissolved oxygen readings for each tide would be more appropriate for analysing Professor Binnie's limited AQMS data.

- The analysis does not account for climate change (which Professor Binnie acknowledges), and which has the scope to alter significantly the performance of London's sewer network over the lifetime of the Tunnel.

[2] Developed by the Water Research Council, (now the WRc Consultancy), for Thames Water Utilities Ltd.

- The analysis also does not properly address the forecast increases in water use and population growth in London. The Environment Agency has previously discussed Professor Binnie's use of meteorological and water use data with him, and disagrees with many of his assumptions and the analyses he uses because they mask significant variability. Should Professor Binnie require it, the Environment Agency is happy to provide him with further data.

- The period examined by Professor Binnie's report is far from typical, as the south east of England experienced one of the driest two-year periods on record and the wettest winter since 1766.

Taking all these points together, the report does not form a sound or credible basis to challenge the Thames Tideway water quality model, which accounts for climate change and has taken the sewage treatment works upgrades and the Lee Tunnel improvements into its baseline conditions. The model is robust and sophisticated, has been independently peer-reviewed, and found to be fit for purpose. Professor Binnie does not indicate whether his report has been independently peer-reviewed.

In the light of all this, and while I thank you and Professor Binnie for your further thoughts, I believe that the case for the Thames Tideway Tunnel remains strong.

From Lord Berkeley

0044 7710 431542, berkeleyafg@parliament.uk

@tonyberkeley1, Lordsoftheblog

The Lord De Mauley

Minister of State

DEFRA

19 January 2015

Dear Rupert,

Thames Tideway Tunnel

Lord de Mauley letter to Lord Berkeley 13th January 2015

Thank you for your letter of 13th January 2015 responding to Professor Chris Binnie's Review of Tideway spills and their environmental impact. I review your response in turn.

The Urban Waste Water Treatment Directive has "the objective to protect the environment from the adverse effects of the ... waste water discharges." In para 3 you state that Professor Binnie interprets the Environment Agency position. He quotes the Environment Agency as saying ""Spills alone is not regarded by the Environment Agency as an indicator of failure to comply with the UWWTD." "provided spills have not caused a significant adverse impact on the quality of the river...overflow is regarded as satisfactory." "The EA will consider effect of discharges, rather than frequency. " That seems eminently sensible.

In your answer to PQ0401 14/15 on 30th July 2014, you stated " the storm discharges from Mogden STW have not led to a significant adverse impact on the quality of the river since the upgrades. The Environment Agency will continue to assess the performance of the upgrade to ensure it continues to comply with the Urban Waste Water Directive." Thus, considering that Mogden STW spilled on 54 days in the first year of the upgrade, 2013/14, you appear to support this position.

In para 5 you state that "after the Lee tunnel is operational spills of between 50 and 60 times a year will spill from the CSOs into the tidal Thames." The three most frequent CSOs are Abbey Mills, Greenwich and Hammersmith Pumping Stations, all previously shown in the Thames Water sewer model table as about 50 spills a year.

After the Lee tunnel is operational Abbey Mills will not spill at all so its spill frequency will drop to zero.

Now that the Crossness STW has been upgraded the table provided by Thames Water shows its spill frequency dropping from 51 to 28, probably due to increased capacity at Crossness STW.

Thames Water provide discharge notifications to rowers and others on a web site whenever the Hammersmith Pumping Station spills. On the assumption that discharges on consecutive days are the same discharge event, then the notifications show Hammersmith has discharged 61 times since July 2012. This is an average of 24 spills a year. This includes 2014 which CEH describe as the 4th wettest year on record back to 1910.

I understand there are few records of when CSOs spill and pumping station discharges are assessed on the basis of hours pumped. Thus the spill frequency data is not robust. The CSOs were monitored and their spill frequency reduced. West Putney 59 spills/year, reduced to 26 spills/year, Frogmore 29 spills/year, reduced to 19 spills /year. This illustrates the reliability of the spill frequency.

For other CSOs the spill frequency model is based on constant per capita water consumption whereas Thames Water WRMP, encouraged by Defra and the Environment Agency, shows significant reduction in water use, thus the sewer model will, like at Hammersmith, over estimate the future spill frequency. We have already recommended that the model be corrected and the spill frequencies be re-assessed. Thus, for the base year, the spill frequencies you quote appear to be substantially higher than reality and should be re-assessed.

In para 6 you allege that “To allow sewage to continue to enter the river and apply in-river treatment(bubblers and skimmers) instead , as proposed by Professor Binnie, does not constitute an adequate waste water collection and transfer system and therefore fails to meet the requirements of the Urban Waste Water Treatment Directive.”

First the water spilling from the overflows is basically storm water with a foul water component, thus it is not just sewage as you imply but diluted sewage.

As the objective of the UWWTD is “to protect the environment from the adverse effects of waste water discharges”, the rejection of bubblers and skimmers, actually litter collectors, which have already been in use for many years, seems illogical.

In any case Prof Binnie finds that the Tideway dissolved oxygen levels already appear to meet the standards and therefore do not need to have a further permanent bubbler system. I cannot find where he proposes bubblers in his report and believe you are mistaken on this..

To cope with aesthetics he proposes booms, which are an end of pipe solution, to limit sewage litter discharge into the Tideway. The litter collectors (skimmers), which are declared by Thames Water to be “a real success story”, would be required anyway to collect wind blown litter, which is reputed to make up about 90% of the total litter.

The objectives of the UWWTD are to protect the environment from the adverse effects of waste water discharges. Professor Binnie believes that the current system, once the Lee tunnel has been commissioned, along with the booms, would do just that.

The main points of your rebuttal are the bullets which I take in turn.

1. “The data was from three automatic quality monitoring stations (AQMS) data going back only a few years The whole of the Tideway is covered by a wider network of AQMS sites , but the three stations provide a reasonable coverage of the Tideway and generate reasonable quality data for the sites in which Professor Binnie is interested.” These are probably the most important 3 stations. The Cadogan AQMS is in the section of the Tideway

where it is relatively small and there are the Hammersmith, Lots Road, Western and Heasthwall pumping stations nearby. The Erith AQMS is in the stretch of Tideway downstream of the very large Abbey Mills pumping station and near the Beckton and Crossness very large sewage treatment works, thus this is also an important AQMS site. Prof Binnie asked for the data readings for all the 9 AQMS sites but was only provided with these 3.

You state that “they do not provide a good representation of all discharge and tide circumstances”. However, the Environment Agency in its notes of the meeting on 25th September stated “ We have explained that the WQ monitoring is a better indicator of how often each DO standard is breached.”

Above you state that the 3 sites provide “reasonable coverage of the Tideway”. The AQMS stations provide data every 15 minute intervals, as selected by the Environment Agency, so temporal representations seems sufficient to cover discharge and tidal conditions and the 9 locations were selected by the Environment Agency.

The AQMS stations were sufficient for the Environment Agency to consider, after one year, that the Mogden STW spills met the UWWTD. Thus I would be grateful if you would provide the similar data for the other AQMS sites that provide a sufficient representation.

You suggest that, "The data is insufficient to assess compliance with dissolved oxygen standard 4, or reliably assess compliance with standards 3 and 2 given the return periods associated with them of 10, 5 and 3 years respectively.”

However one year’s data, April 2013 to March 2014, was sufficient for the Environment Agency, and you, to declare that, subject to continuing monitoring, Mogden spills met all the dissolved oxygen standards and the UWWTD. This seems a reasonable approach.

In any case the Chiswick and Cadogan AQMSs have already met the relevant standards for the last 5 years, much longer than the one year used initially at Mogden.

The dissolved oxygen readings at the Erith AQMS, which has met the DO standards since autumn 2013, will improve appreciably once the Lee tunnel is commissioned in about a years time.

However if there is further data, similar to that that the Environment Agency used in its assessment of Mogden spills, then we would be grateful to receive it.

You suggest that “this analysis is not a good predictor of future environmental performance.” As mentioned in our response to bullet 4 below, the WRMPs show projected water into supply, and hence sewer dry weather flow, will not return to 2012/13 amount until after 2040 hence spill frequency change will be restrained. The main environmental performance effects will be temperature increase and the increase volume in very large storms due to climate change. However, whilst this will have a significant effect, these changes will occur slowly and further measures such as SuDs, BGI, Real Time Control etc are very likely to be able to be implemented in time to cope with such changes..

2.You suggest “ Using the minimum dissolved oxygen readings for each tide would be more appropriate for analysing professor Binnie’s limited AQMS data.”

The dissolved oxygen standards were assessed for the Thames Tideway Strategy Steering Group, chaired by Professor Binnie, by the response of different fish species to a steady dissolved oxygen level for a particular length of time. In the Tideway the dissolved oxygen levels vary somewhat during the critical period. For the one tide condition, Prof Binnie took the minimum average of 24 consecutive every 15 minutes readings to get the worst period, irrespective of whether this was part of different tides or not. Whilst the readings vary somewhat during the tide, taking the average is much more logical than taking the minimum reading. In my view the variation is so limited that taking the average during the tide is sufficient, and taking the minimum during the tide would be a wrong interpretation of what the standard requires. For instance threshold 1, the 4mg/l level for 29 tides, is a week, ie 725 readings. Taking the minimum reading during the 29 tides/1 week would mean that if one tide had a single reading below 4mg/l with all the other readings in the 5, or 6 mg/l then, by taking the minimum reading, breach of the 4mg/l 29 tide standard would occur. That would be clearly at odds with the fish testing and the standards. Thus taking the average of the every 15 minute readings is the most logical and reliable assessment.

3 “The analysis does not take account for climate change (which Professor Binnie acknowledges) and which has the scope to alter significantly the performance of London’s sewer network over the lifetime of the Tunnel.” Indeed. The lifetime of the tunnel could well be in excess of 120 years. Climate change effects include changes to storm patterns and increased temperature in the receiving water, thus changing its ability to hold oxygen. Both effects would worsen conditions. However such changes are expected to take place slowly, albeit they may not be uniform, and 2080 is often taken as an appropriate date to consider the extent of such effects. Thus, even if the tunnel were not built, it would be possible to bring in other measures such as SuDs, BGI, real time control and/or other measures to more than cope with long term climate change.

4. “The analysis also does not properly address the forecast increase in water use and population growth”

It is true that the population of London is growing. However what is important is any increase/decrease in water use, and hence sewer dry weather flow, as the higher/lower the sewer dry weather flow the more/less frequently the interceptor sewers would spill into the Tideway. However, due to Thames Water’s water demand management measures and Thames Water bringing in smart metering, overall water use is declining significantly.

Whilst the Thames Water combined sewer area and the Thames Water water supply area are not exactly the same, they overlap greatly and are sufficiently similar to assume that the trends of flow would be similar.

The base of the Thames Water sewer model is the flow in 2006/7. The Thames Water Water Resources Management Plans, which included the most up to date population data, show the projected water into supply to be

2006/7 2180 Ml/d

2012/3 2028 Ml/d

2020/1 1948 Ml/d

2030/1 1923 Ml/d.

2040 1993 Ml/d.

Thus, in spite of the known population increase, the sewer dry weather flow is dropping and is unlikely to return to the 2012/3 flow until after 2040, by which time SuDs or other such measures could have been implemented to overcome any theoretical increase in sewer dry weather flows. This has been pointed out in many previous reports and is included in Appendix C on page 44 of this report.

“The Environment Agency has previously discussed Professor Binnie’s use of meteorological data with him and disagrees with many of his assumptions and the analyses he uses because they mask significant variability.” Whilst meteorological data has been discussed previously, we are not aware that the current report relies on any such analysis of meteorological data.

5.”The period examined by Professor Binnie’s report is far from typical, as the south east of England experienced one of the driest two-year periods on record and the wettest winter since 1766.”

First Professor Binnie asked for the last 10 years of data but the Environment Agency only sent the last 7 years. Thus the EA selected the period provided.

Secondly the actual period used depended on when the improvements occurred. The Chiswick and Cadogan (Chelsea) AQMS appeared to have met all the dissolved oxygen standards since late 2009. The Erith AQMS only met the standards once the Beckton and Crossness STW upgrades were operational, in early 2014 I believe.

Failures of the dissolved oxygen standard seldom, if ever, occur in winter so the wettest winter is of minimal relevance. The period of interest is the summer. Thus Prof Binnie has taken the CEH rainfall for the Thames catchment for the period of April to October inclusive for the relevant years. This shows percentage of annual average rainfall for the summer period.

2010 71%

2011 108%

2012 161%

2013 77%

2014 106%.

This would indicate that, for the 5 year period 1010 to 2014 relevant to the Chiswick and Cadogan assessment, the summers were both wet and dry and typical.

For Erith the 2014 period was, overall, marginally wetter than normal and therefore typical.

For comparison, the period used by the Environment Agency for the assessment of whether the Mogden spills met the UWWTD, the summer of 2013 at 77%, would appear to have been, overall, somewhat drier than normal. This tallies with the analysis of the rainfall and Mogden spills from 2000 to 2014 done by Prof Binnie previously, where there were 7 summer spills in 2013 compared to the average of 9.6 spills. However 2014, where Mogden

was, I understand, also considered by the Environment Agency to meet the UWWTD standards, was 106% of normal rainfall, typical.

Thus the relevant periods used by Prof Binnie were typical, ranging from 71% to 161% of normal Thames catchment rainfall.

The Environment Agency has correctly said that total rainfall is only a rough guide and spill frequency is a better guide. Prof Binnie has analysed the Mogden summer spill frequency from 2000 to 2013 and the average annual spill frequency was 9.6 with 2010 to 2013 varying from 6 spills to 12 spills. Thus again the period would appear to be reasonably typical.

Penultimate para."Professor Binnie does not indicate whether his report has been independently peer-reviewed." His report has not been peer reviewed. However he lives outside the Thames catchment so has no financial interest in the scheme. He is an independent consultant and has been a Fellow of the Royal Academy of Engineering for some 20 years and a Past President of the Chartered Institution of Water and Environmental Management thus is acknowledged by his peers for his independent judgement. This was confirmed when he was appointed as the independent chairman of the TTSSG for 5 years and then Chairman of the Independent Engineering and Technical Expert Panel for the DECC Severn energy studies..

"The model is robust and sophisticated..."

Whist Professor Binnie believes that the modelling system are probably the best available at the time, the problem is with the quality and reliability of the input data. As his report identifies in Appendix C these issues include:

- Rainfall spatial variation particularly of the critical summer thunderstorms
- Few reliable sewer flow gauges in the complex sewer system
- Lack of discharge measurements at most CSOs
- Use of wrong data on future sewer flows
- Limited data on quality of spilled flows
- Variability of Tideway water quality.
- Variability of tidal data.
- Variability of tributary flow and water quality.

No amount of peer review can overcome these fundamental issues of data weakness. Certainly the model output cannot be described as "robust".

"the report does not form a sound or credible basis to challenge the Thames Tideway water quality model..."

The importance of any model is not so much whether it has been peer reviewed but whether its output actually reflects actual conditions that occur.

The outputs of the water quality model for the initial conditions and with the improvements is shown on page 28 of his report. For initial conditions threshold 3, 2mg/l for 1 tide, several of the fish species should suffer fish kill. The model predicts 99 such breaches, ie fish kills, in 41 years, ie 24 fish kills in 10 years.

The Environment Agency record of the last 10 years is of 2 fish kills caused by Abbey Mills spills and one caused by CSO spill into the Tideway, a total of 3, albeit it is possible that a few other fish kills were not reported but, considering that fish kills occur in summer when daylight hours are long and the river is extensively viewed, these cannot be many more.

The water quality model shows that even after the STW upgrades and the Lee tunnel the Tideway would still fail the standards. Once the Lee tunnel is operational then the Environment Agency records show only one fish would have been killed in the last 10 years thus meeting the standards. Further the Tideway Fish risk Model, once corrected for obvious errors, show that the current Tideway conditions are sustainable for fish. Thus the water quality model does not reflect the relevant conditions.

The Environment Agency state that the AQMS "water quality monitoring is a better indicator of how often each standard is breached". The water quality model shows that, after the STW upgrades and the Lee tunnel, there would be 75 breaches of threshold 1 in 10 years, ie about 2 breaches a year. In 2014, a typical year, even before the Lee tunnel becomes operational, there were no breaches of threshold 1.

This the water quality model has failed to reflect either initial conditions or conditions after the upgrades sufficiently. Thus it is not so much Professor Binnie's report that challenges the water quality model, it is its failure to reflect actual conditions as found by other analysis.

Whatever, the water quality model is clearly not fit for purpose and should be reassessed and now calibrated against the AQMS data that is available.

"I believe that the case for the Thames Tideway Tunnel remains strong." Subject to receiving more appropriate data, as requested, I believe there is not one reason put forward that the report by Professor Binnie should not be accepted in full

His recommendation is that, "before Thames Water places large and expensive construction contracts, the post STW upgrade records of dissolved oxygen be analysed and a decision taken as to whether the Thames tunnel is actually needed to achieve no significant adverse environmental impact and meet the requirements of the UWWTD." This should also involve reassessing the spill frequency of the CSOs and whether other measures within the next 8 years could reduce the spill frequency to an acceptable level, thus saving the country and all Thames Water customers a substantial amount.

I therefore repeat my statement that the Thames Tideway Tunnel is not necessary, and should be stopped before any customer's many is wasted on an unnecessary project.

Tony Berkeley