Thames Tideway Tunnel
Thames Water Utilities Limited

Application for Development Consent

Application Reference Number: WWO10001

Tackling London's Sewer Overflows

Doc Ref: **8.2.2**

Objectives and Compliance Working Group Report: Volume 1

APFP Regulations 2009: Regulation **5(2)(q)**

Hard copy available in

Box **60** Folder **A**
January 2013

Thames Tideway Tunnel
Creating a cleaner, healthier River Thames

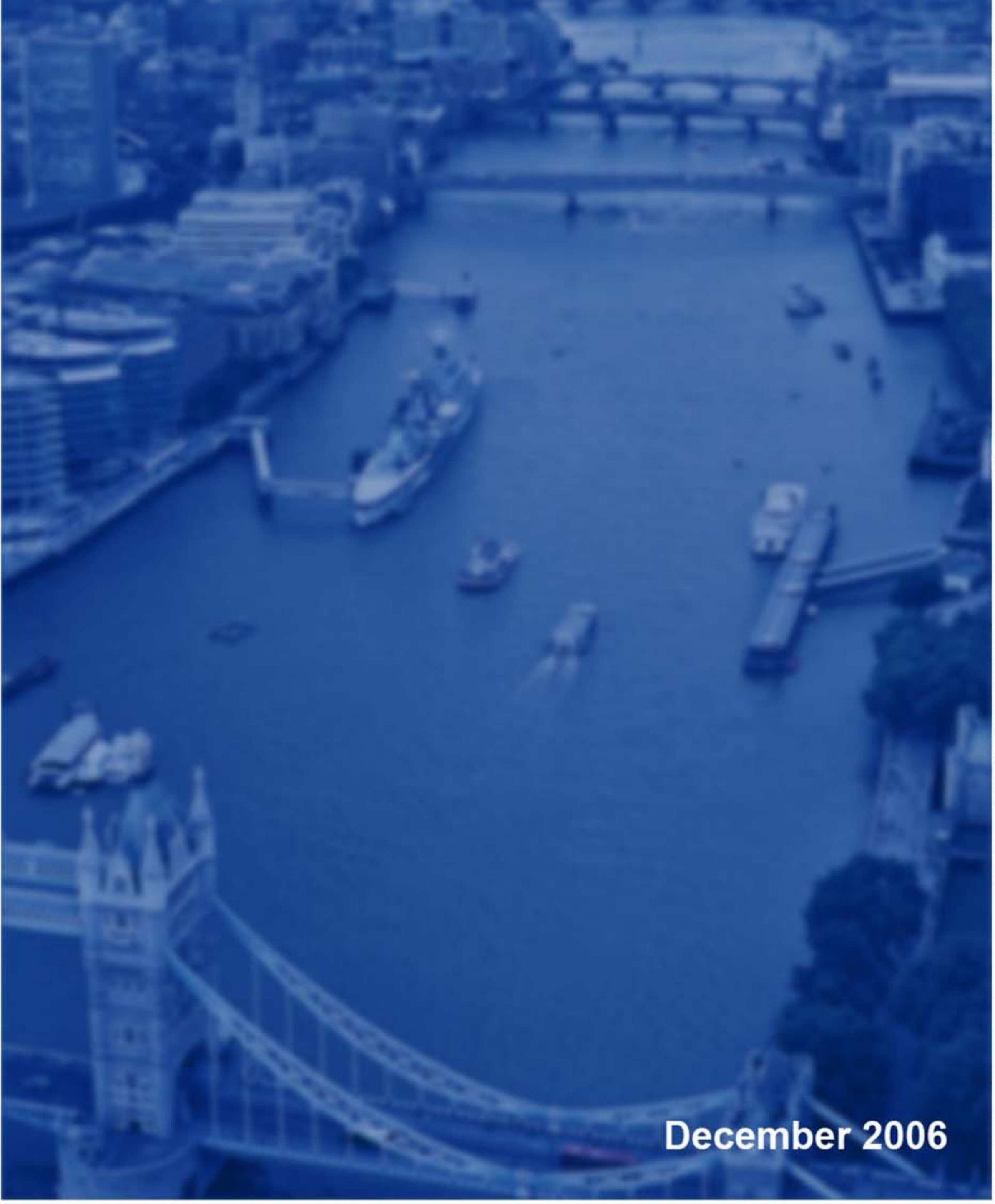
This page is intentionally blank

Tackling London's Sewer Overflows

Thames Tideway Tunnel and Treatment - Option Development

Objectives and Compliance Working Group Report,

Volume 1 - Objectives



Thames Tideway

December 2006

Thames Water

CONTENTS

1 EXECUTIVE SUMMARY

It is the Tideway STW upgrades that show the largest influence on compliance with the objective set for target dissolved oxygen level in the river.

All full-length tunnel options (1a-c) are able to meet the target river quality objective for protection of ecology (all thresholds) in conjunction with the planned Tideway STW improvements when completed (assumed 2020).

For the East/West tunnel options (Options 2a-c), modelling work has shown that these options are only marginal in meeting the target river quality objective in conjunction with the Tideway STW upgrades under current climatic conditions.

In terms of achieving aesthetic improvements, the full-length tunnel options clearly perform better than the two tunnel options which do not intercept the 17 (or 16 for Option 2c) CSOs through central London. A similar result is true in terms of reducing the elevated health risk caused by discharges of untreated storm sewage. However, since there are no controls in place on sources of pathogens (primarily, but not exclusively, the treated effluent discharges to the tidal Thames), the background health risk remains, regardless of which tunnel option is considered.

Performance of the alternative options is shown below:

	Compliance with Objectives						
Option	*DO*	*Aesthetics (%age contribution improved)*	*Health (%age contribution improved)*	*Possible Cessation of Abbey Mills PS overflow?*	*Residual spill day events (average pa)*	*%age of unsatisfactory CSOs addressed*	*%age volume of existing overflows addressed***
1a	*Y*	*100*	*100*	*No*	*3-4*	*100%*	*94%*
1b	*Y*	*100*	*100*	*No*	*9*	*100%*	*89%*
1c	*Y*	*100*	*100*	*Yes*	*3-4*	*100%*	*94%*
2a	*Y*	*62*	*63*	*Yes*	*As baseline**	*53%*	*72%*
2b	*Y*	*62*	*63*	*Yes*	*As baseline**	*53%*	*72%*
2c	*Y*	*63*	*64*	*No*	*As baseline**	*56%*	*72%*

*For Options 2a-2c the number of 'spill day events' will not change from the baseline due to the CSOs not intercepted. Those that are intercepted are reduced to 3-4 per year for comparability with options 1a & 1c

** All options intercept overflows from Abbey Mills which represent around 50% of the total volume of CSO overflows. However only those with direct link between Abbey Mills and Beckton can be engineered to eliminate residual spills into the River Lee.

The prediction of climate change impacts is highly uncertain. However, latest (UKCIP04) scenarios suggest warmer, drier summers and warmer winters. Although it is predicted that rainfall will become 'stormier' the distribution remains uncertain and total rainfall depth may not increase greatly. Higher water temperatures are expected to impact on dissolved oxygen concentrations, both directly, by reducing the solubility of oxygen, and indirectly with biodegradation (and hence de-oxygenation) happening faster. Modelling therefore focussed on summer events, the river being less sensitive under winter conditions.

When the higher water temperatures are taken into account, the compliance position appears to change as follows:

Option	Compliance (2006)	Compliance 2020	Compliance 2080
1a	Yes	Yes	No
1b	Yes	Yes	No
1c	Yes	Yes	No
2a	Yes	No	No
2b	Yes	No	No
2c	Yes	No	No

The 2080 compliance assessment has to be seen in context in that the objectives are failed even if there were a ‘perfect’ solution with no overflows at all. This is because the background quality is dictated by the continuous discharges from the STWs. It is possible, if technically challenging, to restore compliance for all periods by additional treatment upgrades. The 2020 compliance assessment illustrates that due to the greater untreated loads discharged under the option 2 variants, then compensating improvements at STWs have to be either better or carried out sooner.

2 INTRODUCTION

The Minister of State for Climate Change and the Environment wrote to Thames Water on the 27th July 2006, requesting the development of two options to tackle London's sewage overflows. In developing these options it was also requested that a number of factors were taken into account, an extract of which follows:

a) collected wastewater should receive secondary treatment or an equivalent treatment except in situations such as unusually heavy rainfall where we are required to take measures to limit the pollution from the overflows. Thames Water, with the Environment Agency, should assess and optimise the level of treatment required, and the preferred location for the provision of additional treatment….
b) Achievement of environmental objectives developed by the Thames Tideway Strategic Study, taking into account planned capacity increases and treatment improvements at Beckton, Crossness, Mogden and Riverside sewage treatment works and in-river measures. The extent to which options achieve the treatment requirements and objectives, limit pollution form the storm overflows, and represent best technical knowledge not entailing excessive cost, will enable views to be taken on which measures are appropriate to meet the requirements of the Urban Waste Water Treatment Directive;
g) Wider issues including:
    - likely requirements of the Water Framework Directive
    - climate change
    - sewer flooding
    - Flexibility and robustness

The instruction to Thames Water of 27th July did not request that new environmental objectives were developed beyond those established by the 2005 Thames Tideway Strategic Study (TTSS). Nonetheless it was clear that if the instruction was to be fully followed, a review of these objectives would be necessary for three principal reasons:

- Guidance to the engineering design teams;
- Resolving any discrepancy between TTSS and the Jacobs Babtie review;
- Providing clear outcomes (benefits) for use in the stated preference survey.

The aim, however, remained to consider environmental objectives in the context of the 27th July letter, and not to undertake a complete review of all TTSS work and option selection.

Within Thames' overall project management, a small team was assembled, the majority of whom had been involved in TTSS and were hence familiar with the issues involved. This comprised, initially, Howard Brett (TW, chair), Mark Cunningham (defra), Jon Goddard (EA), Peter Lloyd (EA), Carl Pelling (TW), and latterly, Andrew Whetnall (Consumer Council for Water, CCW). Andy Shield (TW) provided invaluable secretariat support.

This team would consider the regulatory/environmental objectives, with a sub-group to consider the discharge and river modelling and test the options for compliance with the agreed objectives. The modelling expertise was essential as an early element was to review agreed 'package' of STW improvements given the requirement for secondary treatment of the tunnel contents, as well as model refinements made since the conclusion of the TTSS.

To assist in the two key specialist areas of this review, the objectives group enlisted the services of Professor David Kay (Microbiology/health) and Dr Andrew Turnpenny (fisheries). Additional information and assistance was provided by Chris Lane (Health Protection Agency) and Jon Averns (Corporation of London).

3 URBAN WASTEWATER TREATMENT DIRECTIVE (91/271/EEC)

The Urban Wastewater Treatment Directive was transposed into legislation for England and Wales via the UWWT regulations 1994, and is accompanied by (non-statutory) guidance to aid interpretation. The Department for the Environment guidance note for dischargers and regulators was issued in July 1997.

The UWWTD is taken to be the overarching driver for action to address the intermittent discharges of storm sewage to the tidal Thames and Lee from the London sewer network connected to Beckton and Crossness sewage treatment works (STWs), and is the only relevant and clear statutory basis for reviewing sewage discharges to the tidal Thames.

The broad objective of the Directive is to protect the environment from the adverse effects of inadequately treated wastewater discharges. To do so it sets out requirements for both treatment plant (STWs) and collecting systems (sewers), and presumes a minimum of secondary treatment (article 4); specific requirements for collecting systems (sewers) are set out in Article 3 and Annex 1A and Footnote 1 of the Directive.

The key general points from these requirements are that:

a) urban wastewater (domestic and industrial sewage and rainwater run-off) should be collected and taken for treatment (normally secondary) before it is discharged;

b) the design, construction and maintenance of collecting systems is according to best technical knowledge not entailing excessive costs. Part of this consideration concerns the operation of overflows;

c) the Directive recognizes that overflows will occur, as it is not possible to construct collecting systems and treatment plants so as to treat all wastewater in every situation. It therefore requires member states to decide on measures to limit pollution from storm water overflows.

Defra considers further measures, in order to limit pollution from overflows, are needed for the London collecting systems connected to Beckton and Crossness sewage treatment works and the works themselves. This is because it has been found that some of the overflows are discharging frequently and having an adverse effect on the environment.

However, the Directive is silent as regards, for instance, the number of permissible overflows per year – that is for the Member State to consider when assessing the appropriate measures to limit pollution. To address this, three objectives were developed for the Thames Tideway by the Environment Agency and the strategic study group between 2000 and 2005.

Hence the effect of the potential measures on limiting pollution will be assessed in terms of achievement of the objectives (maintaining DO levels and protecting ecology/fish species, and reducing aesthetic impacts and health risks for recreational users) as set out below.

4 PROTECTION OF ECOLOGY

Ecological objectives for surface water bodies, including estuaries such as the Tideway, will in future be established according to the requirements of the Water Framework Directive (WFD), which has a default objective of 'good status', which will include a measure of 'good ecological status' (or, depending on the designation of the tideway as a heavily modified waterbody, 'good ecological potential'). Nonetheless, the precise standards which must be met for a water body to be at good ecological status or good ecological potential have not yet been set. Furthermore, good status might not necessarily be the objective for every water body, if for example achievement of it would involve disproportionate cost.

Currently, then, there are no statutory ecological objectives to apply, and to do so would pre-empt the deliberations of the river basin district liaison panel and public consultation regarding the river basin management plan, which is due to be drafted in 2008

The same position was recognised when the TTSS report was written, and 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.

1 Some 45 species of fish are considered resident in the tideway at some point of their life-cycle, ranging from freshwater coarse fish species in the west, through to more estuarine species, some of which are nationally rare, such as the twaite shad. Migratory species such as salmon need to be able to traverse the whole length. Additionally, the Tideway is a spawning and nursery area for commercial species such as flounder and bass. Although the resident species are, almost by definition, 'sustained' there is evidence of adverse impact on species diversity and age distribution which appears linked to episodes of poor water quality. This is in addition to the higher-profile occasions of visible fish kills. The status is therefore currently sub-optimal.

It may be inferred from this evidence that the ecology – specifically fish, both individuals and populations – is being adversely affected by low dissolved oxygen concentrations (caused by discharges of inadequately-treated urban wastewater), and it is necessary to set protective standards to avoid this adverse impact. Setting standards on this basis is consistent with the aims of both the WFD and the UWWTD.

As a generality, when dealing with the consequences of organic – and particularly sewage - pollution, the two parameters of interest are free (un-ionised) ammonia, which is directly toxic, and dissolved oxygen, the lack of which causes both behavioural changes and, in the extreme, mortality. In this specific instance, there is a large body of information which indicates that the principal cause of lethality is low dissolved oxygen concentrations. The standards to support the objective then reduce to the single parameter of dissolved oxygen.

The question of what is meant by 'protection' dictates how the dissolved oxygen standards are derived, given the various elements which make up 'protection', for instance:

- Avoidance of mortality
- Sustainable fish populations
- Prevention of adverse behavioural impacts (specifically, preventing upstream migration)
- Restoration of 'natural' dissolved oxygen concentrations

will all have differing requirements. Furthermore there are spatial (given the length of the tideway, impacts may/will be localised) and temporal (e.g. climate change effects) issues that also must be considered.

In developing a suite of dissolved oxygen (DO) standards, the Thames Tideway Strategic Study (TTSS) commissioned Fawley Aquatic Research Laboratories (FARL) to conduct a range of lethal and sub-lethal tests on representative fish species (that is, fish species either known to be currently present, historically recorded or would be expected to be present, perhaps in greater numbers, if conditions were improved)

As might be expected, the various fish species exhibited a range of tolerances to diminishing DO concentrations; from widespread mortality at or below 1.5 mg/l, to the most sensitive species showing significant mortality at 3 mg/l and behavioural impacts at less than 4 mg/l. (for full report see TTSS and appendices)

As these results reinforced an interim suite of standards derived empirically, the standards finally adopted for TTSS were as follows:

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

These standards establish a suite of conditions that are not alternatives, but complementary, and reflect combinations of intensity and exposure. For instance, if in any 1 year a concentration of less than 4mg/l was recorded for 30 tides, this would be acceptable provided that the concentration wasn't less than 3mg/l for more than 3 tides, or less than 2 mg/l for more than 1 tide, and so on.

As such these standards encompass both chronic and acute water quality issues, but recognise that extreme (but rare) events may still occur that cause fish kills.

In a subsequent assessment, Jacobs Babtie challenged the need for the most stringent standard (4 mg/l) on the basis that a sustainable fishery could be maintained provided that concentrations remained above 3 mg/l. This offers a very different level of 'protection' inasmuch that it implies that, for the most sensitive species, significant (i.e. >10%) mortality is acceptable, as is the impairment of breeding by prevention of migration.

Also subsequent to the TTSS report has been the UK technical advisory group ("UKTAG") recommendations for default DO concentrations for WFD application. Although expressed on a different basis, these suggest a minimum DO approaching 5mg/l. We have not used this for design but should be seen as a background context when considering the relative merits of 3 or 4 mg/l.

The discussion centred on the uncertainty of the meaning of achieving a 'sustainable' fishery – could not significant fish mortalities be accommodated and acceptable within a sustainable context?

The principal author of the FARL report and acknowledged fishery expert, Dr Andrew Turnpenny, who also contributed to the Jacobs Babtie report, has been approached. In summary, his opinion suggests:

- 3 mg/l is the minimum to achieve a sustainable fishery
- At 3 mg/l there will be mortalities and sub-lethal effects on sensitive species (such as salmon and smelt)
- A target of 4 mg/l would provide better protection for sensitive species and will help achieve a wider species diversity

- Species such as salmon are already close to their physiological limits, due to the interaction between temperature and Oxygen. More oxygen is required at higher temperatures, whilst simultaneously the solubility of oxygen decreases. Warmer water temperatures, an expected impact of climate change, will exacerbate this. A limit of 4 mg/l instead of 3 mg/l will assist in offering additional physiological headroom.
- Adoption of 4 mg/l is more secure given the prospective WFD requirements.

The issue then is perhaps about the degree of protection to offer to species such as salmon, which have a limited opportunity for upstream migration and continuing poor water quality will prevent any breeding in that year. Bearing in mind that for many years now, the 'return of the salmon' has been the showcase for how rivers can be restored, the existence of bodies such as the Salmon Trust and the continuing efforts to encourage a self-sustaining population, it should be remembered that the poor water quality is not a natural phenomenon, but one caused by wastewater discharges. Furthermore, 'salmon' should be seen as a surrogate for other sensitive species.

After discussion with the fishery expert, Dr Turnpenny, the majority view of the group was that the TTSS standards should remain as a defensible compromise, as these would help limit occurrences when: i) significant numbers of fish are killed; ii) more than 10% overall of a fish (species) population is killed and this could effect sustainability; iii) areas of low DO are caused which prevent or inhibit fish migration.

As regards consideration of the two principal options, compliance can be assessed against each of the standards adopted, and if there is a differential between an objective of 3mg/l compared to one of 4 mg/l, then this will be evident; a related point is that it is the STW performance that largely dictates achievement of either 3 or 4 mg/l, and improvements have already been identified and agreed to meet the standard of 4mg/l. (Although it should be noted that as part of the work of the modelling team, a revised set of STW improvements to achieve the same environmental benefit has been established) The STW improvements are expected to be in place between 2012 and 2014, the precise delivery dates having to be reviewed following the changed scope of works. Nonetheless, the improved condition in the tideway anticipated as a result of these works enhancements is the baseline for the comparison of both tunnel options.

The STW modelling suggests that the river approaches closely (but still fails) the agreed objectives even without any changes to the intermittent discharges. However, regular large-scale discharges of untreated sewage and rainwater will continue to reduce the DO levels in the river.

WFD and consequences of adopting differing standards

After a review of the initial river model results, the view was taken that the TTSS standards should apply for the purposes of this report, rather than the proposed, and hence uncertain, WFD standards. This reflects four issues:

- That the proposed WFD standards are best suited to managing continuous discharges (the associated 'intermittent' standard is met with all options);
- The major influence on the 'chronic' standard of 4 mg/l is the performance of the STWs, and the planned upgrading largely achieves this standard;
- The choice between the two options under consideration is relatively insensitive to the choice of DO standard;
- It is considered that the achievement of tighter DO standards will not be related to tunnel sizing, but is likely to be a feature of STW performance;

However, to provide a more complete picture, it was agreed that the various solutions would be tested against the potential WFD DO standards, even if the solutions were not designed to achieve these standards.

In summary, the TTSS objective was adopted, in that it would assist the development of a more balanced and diverse fish ecology and better protect the more sensitive species already present :

To limit ecological damage by complying with the DO standards specified in the table above

5 AESTHETIC IMPACTS

5.1 VISUAL

The aesthetic impact of storm sewage discharges takes several forms. There are the relatively persistent plastics and paper, and the organic faecal material, both of which may be seen floating in the river or deposited on the foreshore (although the latter may disperse fairly quickly). There is also the grey, greasy slick which accompanies any discharge. According to one survey, carried out several years ago, sewage litter – probably, in that instance, the persistent plastics etc. – represents about 10% of all litter items on the foreshore. Another estimate is that some 10,000 tonnes of sewage solids are discharged each year.

Whatever the precise quantity, there is little doubt that public complaint does arise, particularly where there are accumulations on the foreshore.

There are no specific quality standards for aesthetic pollution which are applicable to the Tideway. The implementing guidance to the UWWT regulations refers to screening as a requirement for storm overflows considered to be 'unsatisfactory' (i.e. causing significant visual or aesthetic impact). However there are caveats to this, and the earlier TTSS demonstrated that screening of individual discharges was in any case not practicable. Furthermore, even where effective screens have been installed (such as the Abbey Mills pumping station) this has little impact on either the greasy appearance or the colour of the discharge, which may still cause the discharge to be aesthetically unacceptable.

5.2 ODOUR

The group considered whether 'odour' - in this context, the odour arising from the intermittent discharges to the tideway – warranted separate identification as an objective. However, whilst there were clear instances of public complaint as regards treatment works (see other sections of this report regarding the consequences for STW design and planning) there was little measurable evidence to suggest that the intermittent discharges gave rise to odour complaint, and indeed, if they did, what an objective might look like. The majority view was that whilst odour ought to be an issue, it was only likely to be so where there were accumulations of debris and hence other aesthetic criteria would apply – preventing the debris would avoid an odour problem. Hence this became subsumed into the aesthetic impact objective.

The objective adopted for TTSS [for visual aesthetic impacts generally], and re-endorsed here, was

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

As this objective is descriptive, it was necessary to derive a measure to establish the degree of reduction achieved. On behalf of the group, the Environment Agency developed a protocol which weighted the location (visibility) and size of discharges such that the various options could be tested. This protocol - which similarly considered health issues - is attached as appendix 1.

5.3 ABBEY MILLS PUMPING STATION AND RIVER LEE

The discharge from Abbey Mills Pumping Station has a major impact on the River Lee. Whilst the discharge is screened, there remain concerns that the aesthetic impact, both in terms of the 2012 Olympic Games and the broader regeneration aims, is unacceptable.

Although not a primary objective of the study, the continuing concerns expressed regarding this discharge and the possible reputational impacts has led to an implicit secondary objective, to eliminate (if possible) discharges from this immediate location. It is recognised that to do so may, in the short term, result in diversion of flows elsewhere with perhaps limited remediation.

6 HEALTH IMPACTS.

Determining a 'health' objective - and the related benefit, for use in the stated preference survey - proved particularly challenging, due to the lack of robust data. There are a few undisputed facts:

- *The tideway is widely used for rowing and other recreational activity;*
- *It contains a high proportion of treated, but not disinfected, effluent at all times, and so immersion could not be recommended due to the associated hazard;*
- *Discharges of untreated sewage will increase the pathogen load.*

However, it is not possible to establish the existing disease burden for those currently participating in recreation, nor to estimate with any precision how this might change following sewage discharges. Both the objective (and any benefit) are, by necessity, descriptive.

The Thames tideway is not a designated bathing water and, as such, there are no nationally-agreed microbiological quality standards to be applied.

It is recognised that an estimated 3000-5000 people per week use the tideway for recreation, mainly rowing. The health risk to these people is a combination of hazard (crudely, the presence of pathogens in the water), the mode of exposure which provides the potential route for infection (principally ingestion), the numbers of pathogens in the water, and the dose likely to cause illness (which may be low, e.g. Campylobater). The health risk assessment which underpins the recent WHO (2003) *Guidelines for Safe Recreational Water Environments* has been carried out on, and for, bathing waters and assumes head immersion (and by implication a risk of water ingestion via the nose or mouth). There has been some previous research on other recreational uses such as rowing, canoeing and sailing which 'may', in some cases, carry a lower risk of ingestion[1].
Monitoring has demonstrated that bacteriological counts of indicator organisms found in the areas of the Thames where the intensity of users is high (i.e. around the clubs), even under dry conditions, generally exceed World Health Organisation 'recommended' levels for bathing. This is almost certainly due to the large volume (and proportion) of treated, but not disinfected, sewage effluent present in the Tideway.

The advice of Professor David Kay, an acknowledged expert in recreational waters and associated risk assessment, is that the indicator count under 'dry' conditions is as would be expected where a considerable proportion of the river's volume is treated sewage effluent. Previous research, in a comparable river used at the national water sports centre (NCC) at Holme Pierrepoint, suggested very significant reported illness attack rates amongst recreational slalom canoeists[2,3]. A different study, however, identified no change of illness attack rates where non-immersion recreation was practised.

---

[1]Kay, D. and Hanbury, R (Eds) *Bathing Waters Recreation and Management: Vol II Fresh Waters* Ellis Horwood. Chichester, 242p.

Fewtrell, L. Kay, D. Newman, G. Salmon, R. and Wyer, M.D. (1993) Results of epidemiological pilot investigations' Chapter 6 In Kay, D. and Hanbury, R. (eds) Recreational Water Quality Management Vol II Fresh Waters, Ellis Horwood, Chichester UK. pp 75-107.

Fewtrell, L. Kay, D. Salmon, R. Wyer, M D. Newman, G. and, G (1994) The health effects of low-contact water activities in fresh and estuarine waters. *Journal of the Institution of Water and Environmental Management 8*, 97-101.

[2]Fewtrell, L. Godfree, A F. Jones, F. Kay, D. Salmon, R. and Wyer, M D (1992) Results of the first epidemiological pilot investigation into the possible health effects of slalom canoeing on two fresh waters of contrasting quality. *The Lancet 339*, 1587-1589.

[3]Lee, JV. Dawson, R. Ward, S . Surman, S B. and Neal, K R. (1997) Bacteriophages are a better indicator of illness rates than bacteria amongst users of a white water course fed by a lowland river. *Water Science and Technology* **35:** 165-170.

Routine bacteriological monitoring shows that under wet weather conditions, i.e. when the intermittent discharges may be expected to have operated, the concentration of indicator organisms is increased by perhaps 20 fold (HPA and EA data) over dry weather conditions. Professor Kay was asked how this might impact on health risk (for example for canoeists performing activities involving an immersion risk), but he was unable to respond definitively, since faecal indicator counts at these times in the Tideway significantly exceeded the indicator concentrations covered by robust dose/response relationships which are currently accepted. There appears to be no directly relevant peer reviewed literature in this area covering the very high faecal indicator concentrations experienced in the Tideway, but, clearly, illness rates could be expected to be very high, i.e. exceed those predicted where there are lower levels of faecal contamination indicators. Nonetheless, this gives no indication to any changed risk for any group of activities which have no risk of immersion in water.

In view of the sparse evidence-base available to the policy community covering these highly polluted conditions, the Corporation of London commissioned the Health Protection Agency (HPA) to conduct a health questionnaire survey of rowers using the tideway. This has yet to report fully, but early indications suggest that, within the respondents, i.e. rowers in the Kew-Putney area, which is the most heavily used reach for rowing, the occurrence of intestinal illness in those taking part in the study, and therefore likely to report illness, was lower than that of the general population. This may be due to awareness of the study; better hygiene awareness and, perhaps, acquired immunity from regular exposure. It is also likely that as a cohort of river users, rowers will have a higher frequency of exposure (to splashed water or accidental immersion) and may comprise a fitter more healthy group of individuals thus precluding any credible statistical comparison between this group and members of the general public. Most of these illnesses reported however were, according to information received, associated with immersion and, hence, are broadly consistent with literature findings.

The HPA study reinforces the view that any water-based activities on the Tideway which involve a risk of immersion and/or ingestion will result in a high risk to the health of those so exposed. It also confirmed the presence of pathogens in the Thames Tideway. . One significant contribution has been to identify the fact that indicator organisms in the tideway remain elevated for between 3 and 5 days after a discharge event[3]. This may be due to the high turbidity of the Tideway which will tend to protect microbes from the effects of sunlight (i.e. which contains bactericidal ultraviolet radiation) which produces die-off[4].

The TTSS adopted a concept of ‘elevated health risk days’ which sought to link the elevated (but unspecified) health risk to a frequency of discharge (60 times per year) and a die-off period of 2 days. This simple calculation gave 120 days of elevated health risk.

It is now clear that the baseline health risk in periods of dry weather, i.e. periods where the counts are at their lowest, is already high, but although the risk of infection is elevated under wet conditions, it is not possible to quantify this increased risk, even following immersion, However the interim results of the study suggest that this increased hazard may persist for longer than previously assumed.

In the absence of empirically-based evidence, it is not possible to empirically identify the risk to recreational users. Nonetheless, there is sufficient evidence to suggest that the risk to immersion users of the Tideway is generally high and will be greater following intermittent sewage discharges.

---

[3] i.e. much longer than the 2 days previously assumed.
[4] Kay, D., Stapleton, C. M., Wyer, M. D., McDonald, A. T., Crowther, J., Paul, N., Jones, K., Francis, C., Watkins, J., Humphrey, N., Lin, B., Yang, L., Falconer, R. A. and Gardner, S. (2005). Decay of intestinal enterococci concentrations in high energy estuarine and coastal waters: towards real-time T_{90} values for modelling faecal indicators in recreational waters. *Water Research* 39, 655-667.

In this instance a different objective to the TTSS was adopted, as follows:

To help protect river users by substantially reducing the elevated health risk due to intermittent sewage discharges.

As with aesthetic considerations, this is a descriptive objective and again the Agency developed a protocol, based on the location and size of discharge to weight the impacts of the various intermittent discharges. This assessment is attached as appendix 1.

7 SEWER FLOODING

It is assumed that the provision of a tunnel connection will allow the free discharge of gravity overflows into the tunnel at any state of tide; this should, in theory, manifest as a reduced flooding risk for a number of properties. Although this would be best tested by comprehensive modelling, in the time available a desk exercise was carried out, which, based on the elevation of drained areas, suggested the benefit was actually quite small – perhaps a reduced risk for some 150 properties for the full-length tunnel options, and perhaps 100 properties for the East/West two tunnel options. A further check, based on Thames' flooding history database – and therefore including only properties where flooding has been reported to Thames Water – suggested even fewer properties affected, although the database is generally believed to under-represent the extent of flooding.
On this basis it does not seem to be a specific objective to differentiate between options, although it should be reflected in the benefits assessment.

8 CLIMATE CHANGE

The impact of predicted climate change on the performance of each solution has been considered up to the 2020's and 2080's. Previous climate change sensitivity testing undertaken in 2004 for the TTSS studies, showed that predicted increases in river temperature were by far the biggest factor affecting the DO objectives in the Tideway. Increased temperature both increases reaction rates, so accelerating biodegradation (and hence de-oxygenation, and renders the oxygen less soluble in water.

Changing rainfall patterns were also considered for the climate change analysis up to 2080's. This scenario included further temperature increases as well as sea level rise predictions and a factoring of the storm events to include more intense, larger summer storms but on a less frequent basis. These two effects tended to cancel each other out, although the impact of the changed rainfall was to improve compliance due to fewer discharges in summer.

Assessment of winter rainfall has never been as simple and there appears more variability in climate change predictions – the earlier view of warmer, wetter winters (implying a greater total rainfall) has been replaced with a scenario where the annual rainfall is not greatly increased in total from that current. As the impact of intermittent discharges is much less under winter conditions, modelling has focussed on the summer conditions and the known factor of higher river temperatures.

9 LINK WITH COST BENEFIT GROUP

The early considerations of the group, and the initial outputs, were concerned with providing the Cost Benefit group with the required information to enable design of the stated preference study, and, specifically, in describing the benefits which would be delivered by the various options.

Three related areas were tackled:

- Benefits description for showcards;
- Background text/descriptions to support and expand on the showcard contents;
- Text for use within the Cognitive Testing questionnaire.

All three areas demand a compromise between accuracy – so as not to mislead respondents – and brevity, as respondents would not be expected to have sufficient time to fully read and understand the technical detail. The final texts were the result of iterations between the objectives and cost benefit groups, and informed by feedback from the initial focus group surveys.

9.1 SHOWCARDS

These were the briefest descriptions. To achieve a measure that could be easily conceptualised inevitably compromised the underlying science. Nonetheless, it was important that these descriptions were as close as possible to the benefit delivered by the schemes. Several scenarios were considered:

- Current status/impacts
- 2014 status (i.e. post STW improvements)
- Option 1 benefits (large diameter tunnel)
- Option 1 benefits (smaller diameter tunnel)
- Option 2 benefits

The objectives as regards ecology were particularly challenging and the broad thrust of ecological protection (assessed in terms of meeting dissolved oxygen standards) had to be expressed in terms of 'fish kills'. This led to difficulties in differentiating between options, since although the 'current' status would identify perhaps 8 events per year, by 2014 this was expected to have declined to perhaps 1 or 2 at most, leaving little room for differentiation between options.

As regards both aesthetics and health, the Environment Agency methodology was applied and 'rounded', such that the relative improvements for both were described as two-thirds (67%) for the option 2, option 1 delivering 100%.

See: Cost Benefit Report, EFTEC, TTSP annexes 2 & 5

9.2 BACKGROUND INFORMATION AND COGNITIVE TESTING QUESTIONNAIRE

These items were similarly derived through iteration between the groups. As they were 'early' deliverables, they anticipated the final shape of the objectives, but proved sufficiently close not to adversely impact on the validity of the survey work.

See: Cost Benefit Report, EFTEC, TTSP annexes 2,3 & 5

10 APPENDICES

The assessment methodology, as developed by the Environment Agency, for 'aesthetics' and 'health risks' is attached as Appendix 1.

It is recognised that the document should not seen as a formal 'health risk assessment', but does allow a view to be taken of the relative contributions of the intermittent discharges to pathogen loading and location, and hence to likely hazard.

APPENDIX I

A Methodology for Assessing the Impact of Individual CSOs on the Aesthetics and Health Risk Objectives

1. Background

A paper entitled "An Assessment of the Frequency of Operation and Environmental Impact of the Tideway CSOs" was presented to the Tideway Strategy Steering Group in June 2004. The paper identified those CSOs that caused environmental damage, and provided information regarding their impact on the three objectives relating to ecology, aesthetics and health risk. The paper has been up-dated a number of times, but does not provide the level of detail required to carry out a comparison between the options that are now being evaluated.

A new methodology has therefore been produced which will enable a more comprehensive comparison to be made between the benefits of the options that are currently being considered. This paper provides details of the proposed methodology.

2. Health Risk

The extent to which an individual CSO impacts on the health risk objective is related to:

- The location of the CSO relative to the areas of the river where recreational activity occurs
- The frequency of the discharge
- The size of the discharge

2.1 Recreational Reaches of the River

Different parts of the river are used by different numbers of recreational users. To allow for these differences, the river has been divided into three reaches with different weighting factors that relate to the number of people using each of the reaches.

Table 1 Health Risk Weighting Factors for River Reaches

RIVER REACH	WEIGHTING FACTOR
1 Upstream of Vauxhall	1
2 Vauxhall to Tower bridge	0.1
3 Downstream of Tower Bridge	0.4

The weighting factors are proportional to the number of recreational users in each reach, as derived from information supplied by user groups.

2.2 Location

In order to assess the impact of the discharge, it is necessary to calculate the proportion of time that the discharge will affect each of the three reaches. This is a complicated process due to tidal movement, but can be calculated by the following method.

The river is divided into a series of different bodies of water - referred to as zones - which oscillate back and forth with the tide. The zones are numbered, starting at Teddington, from 2 to 26, and are subdivided into upper (U) and lower (L). Superimposed on the tidal action is a slow net seaward movement, which is not of great significance and can be ignored for the purposes of this exercise.

The first component of the calculation is to determine the proportion of time that the CSO will be discharging into each zone; and the second stage is to calculate the proportion of time that each zone will be contained within the three separate recreational reaches.

The following is an example of how the calculation is made. A section of the river, zones 5L to 11U is shown below. At low water, Western Pumping Station is discharging to zone 6U. As the tide floods, the zones will flow past Western from right to left. At high water, Western will be discharging into zone 10L, and as the tide ebbs, the zones will move past Western from left to right, until 6U reaches Western at low water. Using information relating to tidal movement and velocities, it is possible to calculate the proportion of time that each zone will receive a discharge from Western.

Fig 1 Tidal Movement of Zones in Relation to Discharge Locations

Western P/S

Kew London Br

Flood tide

2	3U	3L	4U	4L	5U	5L	6U	6L	7U	7L	8U	8L	9U	9L

Length of River Showing Position of Zones in Relation to Western Pumping Station at Low Water

Western P/S

Ebb tide

7U	7L	8U	8L	9U	9L	10 U	10L	11 U	11L	12 U	12L	13 U	13L	14 U

Length of River Showing Position of Zones in Relation to Western Pumping Station at High Water

The next stage of the calculation is to determine the proportion of time that each zone is within the three different reaches. A section of river showing the location of the zones in different reaches is shown below. It can be seen that at low water, zone 11U is situated in reach 3, but will move upriver on the flood tide, moving through reach 2 and arriving in reach1 at high water. Zone 6L, although moving up and down river with the tide, will always remain in reach1; whereas zone 13L will always remain in reach 3.

Fig 2 Tidal Movement of Zones in Relation to Recreational Reaches

Flood tide

1. U/S Vauxhall				**2.** Vauxhall to Tower Br				**3.** D/S Tower Br						
5U	5L	6U	6L	7U	7L	8U	8L	9U	9L	10 U	10L	11 U	11L	12 U

Location of Zones in Different Reaches at Low Water

Ebb tide

1. U/S Vauxhall				**2.** Vauxhall to Tower Br				**3.** D/S Tower Br						
9L	10 U	10L	11 U	11L	12 U	12L	13 U	13L	14 U	14L	15 U	15L	16 U	16L

Location of Zones in Different Reaches at High Water

Using these calculations for each CSO and each zone, it is possible to derive a proportion of time that a particular CSO will have an effect on each recreational reach. For example, the table below shows the effect of Western Pumping Station on each reach.

Table 2 Effect of Western P/S on Zones and Recreational Reaches

	ZONES									
	6U	6L	7U	7L	8U	8L	9U	9L	10U	10L
Proportion of time that Western discharges to zone	0.14	0.12	0.10	0.10	0.08	0.10	0.08	0.08	0.12	0.08
Proportion of time that zone is in reach 1	1.00	1.00	0.84	0.78	0.68	0.54	0.44	0.36	0.28	0.16
Proportion of time that zone is in reach 2	0.00	0.18	0.28	0.38	0.46	0.56	0.50	0.44	0.46	0.48
Proportion of time that zone is in reach 3	0.00	0.00	0.00	0.00	0.00	0.14	0.28	0.38	0.48	0.56
Proportion of time that zone is affected by Western and is within reach 1	0.14	0.12	0.08	0.08	0.05	0.05	0.04	0.03	0.03	0.01
Proportion of time that zone is affected by Western and is within reach 2	0.00	0.02	0.03	0.04	0.04	0.06	0.04	0.04	0.06	0.04
Proportion of time that zone is affected by Western and is within reach 3	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.06	0.04
Total proportion of time that Western affects reaches	Reach 1	0.64								
	Reach 2	0.34								
	Reach 3	0.16								

It should be noted that because each zone is over 3 km in length, they will often straddle between reaches, which means that one zone can be in two reaches at the same time. This explains why the total proportion of time for all three reaches exceeds 1.

2.3 Frequency of Discharge

For each CSO, a frequency of discharge in days per year is allocated. This figure is derived from the sewer model outputs.

2.4 Size of Discharge

The extent to which an individual CSO has an impact on health risk is not proportional to the volume discharged. This is due to the formation of contaminated slicks, which often form on the surface of the river, and do not become completely mixed for a few tides. A relatively small discharge can therefore create a high degree of risk, depending on the location of discharge. Despite this fact, however, it is considered that the size of the discharge should be taken account of in the overall assessment. CSOs have therefore been grouped into different bands according to their size, and have been allocated a flow factor based on the band. The factor used ranges from 0.1 to 2.0.

2.5 Overall Health Risk Assessment

The overall assessment of each individual CSO on the health risk objective is obtained by multiplying all of the component factors together.

Examples are given below in table 3 for Western Pumping Station, Regent St and Holloway CSOs.

Western P/S is a very large, frequently discharging CSO. It is highly visible and discharges into the lower end of the most sensitive recreational reach. Regent Street is a smaller, less frequent discharge that is situated on the Victoria Embankment in a highly visible location. It discharges into a sensitive area for aesthetics but not into the main recreational reach. Holloway is a fairly large, frequently occurring discharge, which is more remote from the most sensitive reaches.

In table 3, the data shown in rows 1, 3 and 5 are obtained from the calculations described in table 2. Rows 2, 4 and 6 multiply these figures by the weighting factors shown in table 1. Row 7 is the sum of the value for all reaches.
Row 10 is the assessment vale for the individual CSO, which is obtained by multiplying together, rows 7 (reach total), 8 (frequency) and 10 (size).
Row 12 is the percentage of the individual CSO against the total for all CSOs.

Table 3 Overall Health Risk Impact for Three CSOs

Row No		CSO		
		Western P/S	Regent St	Holloway
1	Proportion of time in Reach 1	0.64	0.42	0.10
2	x user weighting for Reach 1	0.64	0.42	0.10
3	Proportion of time in Reach 2	0.34	0.43	0.28
4	x user weighting for Reach 2	0.04	0.04	0.03
5	Proportion of time in Reach 3	0.16	0.32	0.69
6	x user weighting for Reach 3	0.07	0.13	0.28
7	Total for all Reaches	0.75	0.59	0.41
8	Frequency factor	60	20	50
9	Flow factor	0.8	0.3	0.7
10	Total assessment value	35.68	3.55	14.26
11	% of all CSOs	7.08	0.71	

3. Aesthetics

The extent to which an individual CSO impacts on the aesthetics objective is related to:

- The location of the CSO in relation to its visibility and its effect on sensitive areas of the river
- The frequency of the discharge
- The size of the discharge

3.1 Location

The two factors, which are of relevance to the location of the CSO, are:

- The physical location with regard to visibility, ease of access of the public to the discharge point, and the numbers of people in the immediate vicinity.
- The effect, due to tidal movement, on the sensitive reaches of the river

The first factor requires an individual assessment to be made of each CSO and a factor to be allocated. CSOs have been grouped in different categories of visibility and sensitivity of location. Factors from 0.1 to 1.0 have been allocated to these groups. As an example, Putney Br, being highly visible and accessible to large numbers of people is allocated a factor of 1.0; whereas Queen St, being less visible from the land, but accessible and noticeable by river users, is allocated a factor of 0.6. Some of the more-remote CSOs below Tower Br have been given factors of 0.1.

The second component with regard to location is similar to the principle used for assessing health risk. However, in the case of aesthetics, a more simple distinction is made between reaches of the river. Aesthetic pollution in the river and on the foreshore is much more noticeable above Tower Bridge, so the river is only divided into two reaches with the weightings shown in table 4.

Table 4 Aesthetics Weighting Factors for River Reaches

River Reach	Weighting Factor
1 Upstream of Tower Bridge	1
2 Downstream of Tower Bridge	0.2

The proportion of time that a CSO discharges into a particular zone, and the proportion of time that the zone is within the different reaches is calculated by the same method as described in the previous section.

3.2 Frequency of Discharge

CSOs are allocated a frequency factor as described in the previous section.

3.3 Size of Discharge

The CSO is allocated a size factor as described in the previous section. The flow factor is not used, however, in relation to the visibility aspect of the CSO. This is because the aesthetic impact of a highly visible CSO discharge remains similar, even for small volume discharges. The effect of a discharge on the aesthetic water quality of a river reach, does, however, relate to the total quantity of sewage that is discharged.

3.4 Overall Aesthetics Assessment

Table 5, below, provides an example of how the assessment is calculated for three individual CSOs

Table 5 Aesthetics Assessment for 3 CSOs

Row No		CSO		
		Western P/S	Regent St	Holloway
1	Proportion of time that CSO affects river above Tower Br	0.89	0.76	0.35
2	Proportion of time that CSO affects river below Tower Br	0.11	0.24	0.65
3	Visibility factor	0.9	0.9	0.5
4	Frequency factor	60	20	50
5	Size factor	0.8	0.3	0.7
6	Assessment for effect on river reaches	43.7	4.8	16.7
7	Assessment of visibility effect	54	18	25
8	Overall assessment	97.7	22.8	41.7
9	% of total CSO aesthetic impact	6.4	1.5	2.7

Data in rows 1 and 2 have been calculated using the methods described in section 2.
Row 3 gives the visibility factor as described in section 3.
Rows 4 and 5 use the same factors that were used for the health risk assessment.
Row 6 is obtained by multiplying rows 1 and 2 by the river reach weightings; and muliplying the sum of these by rows 4 and 5.
Row 7 is row 3 multiplied by row 4.
Row 8 is the sum of rows 6 and 7.
Row 9 is the percentage of the individual CSO against the total assessment for all CSOs.

This page is intentionally blank

Thames Water Utilities Limited
Clearwater Court, Vastern Road, Reading RG1 8DB

DCO-DT-000-ZZZZZ-080202