Thames Tideway Strategic Study

Cost-benefit Working Group Report

February 2005

Thames Tideway

MAYOR OF LONDON

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ENVIRONMENT AGENCY

Thames Water

RWE Group

Thames Tideway Strategic Study
Cost Benefit Working Group Report

Final Report
February 2005

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0. Executive Summary

The Thames Tideway Strategic Study was set up as a three-year project with the following objectives:

- assess the environmental impact of intermittent discharges of storm sewage on the Thames Tideway;
- identify objectives for improvement in terms of water quality and ecology;
- determine potential solutions, having regard to costs and benefits.

The Thames Tideway Strategic Study Cost Benefit Working Group was established in January 2002 and acted as one of three working groups (together with the Objectives and Solutions Groups) reporting to an overarching Steering Group. The remit of the group was to identify and evaluate the costs and benefits associated with the Tideway Solutions developed by the Solutions Working Group, and then to present a relative cost-benefit assessment of the different options. Three main studies were commissioned to allow each impact to be translated as far as possible into cost terms to allow financial comparison:

1. **Stated Preference Study** undertaken by Eftec (field work by MORI) with the objective of identifying and valuing individuals' willingness to pay for the non-market benefits resulting from the implementation of the Tideway solution options. Following on from this study, Cognitive Testing Analysis was also conducted in August 2004 to review people's understanding of the Stated Preference questionnaire.

2. **Environmental Costs Study** by Montgomery Watson Harza (MWH) to evaluate the non-market environmental costs attributable to each of the Tideway solution options. A desk based Congestion Costs Study was also undertaken as part of this to estimate the financial costs associated with the potential traffic disruption caused by engineering work.

3. **Market Evaluation Study** carried out by Eftec to identify the potential market benefits arising from the Tideway Solutions identified.

The Solutions Group estimated the financial costs of the Tideway Solutions independently of the above studies. Subsequent Cost Benefit Analysis by Eftec including sensitivity testing and switching analysis, which brought together the conclusions from all the above studies and compared it to the financial costs to allow comparison of the different Tideway solution options.

Results of the **Stated Preference Survey** indicated that respondents were willing to pay in the region of £59 per annum for the improvements to the Thames Tideway, namely reduced litter, health risk and fish kills. The survey recorded evidence of a significant 'non use' element to the value of improvements.

The **Environmental Costs Study** concluded that overall, the most significant environmental cost was the category of global warming caused by the substantial levels of energy use required by all the options during construction and operation. All options were identified as having significant environmental externality costs, over and above the costs, which could be against good engineering design.

The **Market Valuation Survey** found that there would be few identifiable market benefits associated with the improvements brought about by the Tideway Strategy. Where benefits were identified they were difficult to quantify or express in monetary terms. Water quality does not appear to be the primary constraint on the majority of the activities examined.

The **Cost Benefit Analysis (CBA)** results revealed that Options A(low)/A(medium), combined with the STW upgrades, gives the highest net benefits. The subsequent sensitivity testing and switching analysis confirmed these results and enabled some of the uncertainties

relating to the science and economic analysis to be addressed. The results also demonstrated that the cost and benefit estimates would have to change significantly to change the conclusions that the net benefits are positive.

The high cost of the proposed solutions and the non-market nature of the benefits associated with these led some members of the working group to seek greater confidence in the results of the studies. In response to this an Academic Panel was invited to a workshop to discuss the need and potential for further studies, one of which being a Cognitive Testing study. The members of the panel all stated at the workshop how impressed they were with the way the Stated Preference Study had been undertaken and agreed it was a robust piece of work, one to be commended.

A final cost benefit assessment was undertaken using the refined version of option A (ref) which involved technical changes to the option and to some of the parameters of the CBA, including a refined baseline, discounting procedure and project lifetime. This analysis continued to demonstrate substantial net benefits arising from the implementation of this option.

1. Background and Introduction

The Thames Tideway Strategic Study Cost Benefit Working Group was established in January 2002. The remit of the group was to identify and evaluate the costs and benefits associated with the Tideway Solutions developed by the Solutions Working Group, and then to present a relative cost-benefit assessment of the different options.

The original terms of reference for the group were as follows;

- Contribute a range of environmental economic expertise to the study;
- Review available methodologies for relative cost benefit assessment and recommend an appropriate approach for the study;
- Draft a technical specification for undertaking a relative cost/benefit analysis of the proposed solutions;
- Review tenders for undertaking the above;
- Make technical comment on progress reports, where necessary;
- Review draft reports;
- Agree final conclusions and sign off.

The working group includes representatives from:

Thames Water	Yvette de Garis (Chair) Suzanne Burgoyne
Ofwat	Giordano Colarullo (Environmental Economist)
Environment Agency	Jon Goddard Rob Curry (Environmental Economist)
Defra	Anita Payne (Environmental Economist)
GLA (formerly Atkins and Southern Water)	Paul McMahon (Environmental Economist – left the group in May 2004)
Eftec	Ece Ozdemiroglu (Environmental Economist)
Hyder Consulting (formerly Thames Water)	Ben Nithsdale
BRE	Mark Gaterell (left the group at the end of 2002)

Throughout the course of the study there has been great uncertainty over the driver for a solution to the discharge of untreated sewage from Combined Sewer Overflows (CSO). When the study was originally started it was uncertain whether the Urban Wastewater Treatment Directive constituted a statutory driver for the development of a solution. Justification of the choice of solution through cost benefit studies became more important as the principal means by which to demonstrate that the benefits of implementing a solution outweigh the financial costs. However, the most recent view *(reference Ministerial Guidance)* is that a CSO solution is a statutory requirement under the Urban and Waste Water Treatment Directive. As a consequence the balance of costs and benefits is currently a less important decision making concern than meeting the statutory objectives at least cost.

2. Decision Framework

The Thames Tideway Strategic Study is a project being managed by Thames Water to identify the objectives for the Tideway in terms of water quality and ecology, and to determine potential solutions for their achievement. As part of this study three working groups were set up: Objectives, Solutions and Cost Benefit Groups that report to an overarching Steering Group.

The Solutions and Objectives Working Groups provided quantitative information on the adverse and beneficial impacts arising from each of the identified solutions. The Cost Benefit Working Group initially commissioned three studies to allow each impact to be translated as far as possible into cost terms so as to allow financial comparison.

It was felt that the complexity of the Tideway Strategy and the multiplicity of its impacts, both positive and negative, meant that a single study investigating all impacts would be cognitively impractical and, if approached through a stated preference study, too much for respondents to handle. Consequently in order to fully determine all the relevant costs and benefits three main studies were commissioned, the results of which could be drawn together for the final Cost Benefit Analysis, these were:

1. **Stated Preference Study / Questionnaire : Eftec (field work by MORI)**
   This was the largest of the studies with the objective of identifying and valuing individuals' willingness to pay for the benefits that will result from the implementation of the Tideway options. [It should be noted that Eftec stepped out of the working group for the period when the discussions on appointing consultants were taking place.] Following this study, further work took place in the form of:
   - Cognitive Testing Analysis in August 2004 to review people's understanding of the Stated Preference questionnaire.

2. **Environmental Costs Study : Montgomery Watson Harza**:
   This was a smaller scale project with the aim of assigning economic costs to the environmental impacts caused by the implementation of the Tideway Options. As part of this the following study was also undertaken:
   - Cascade Consulting: Congestion Costs Study - a desk based study to estimate the financial costs associated with the potential traffic disruption caused by engineering work.

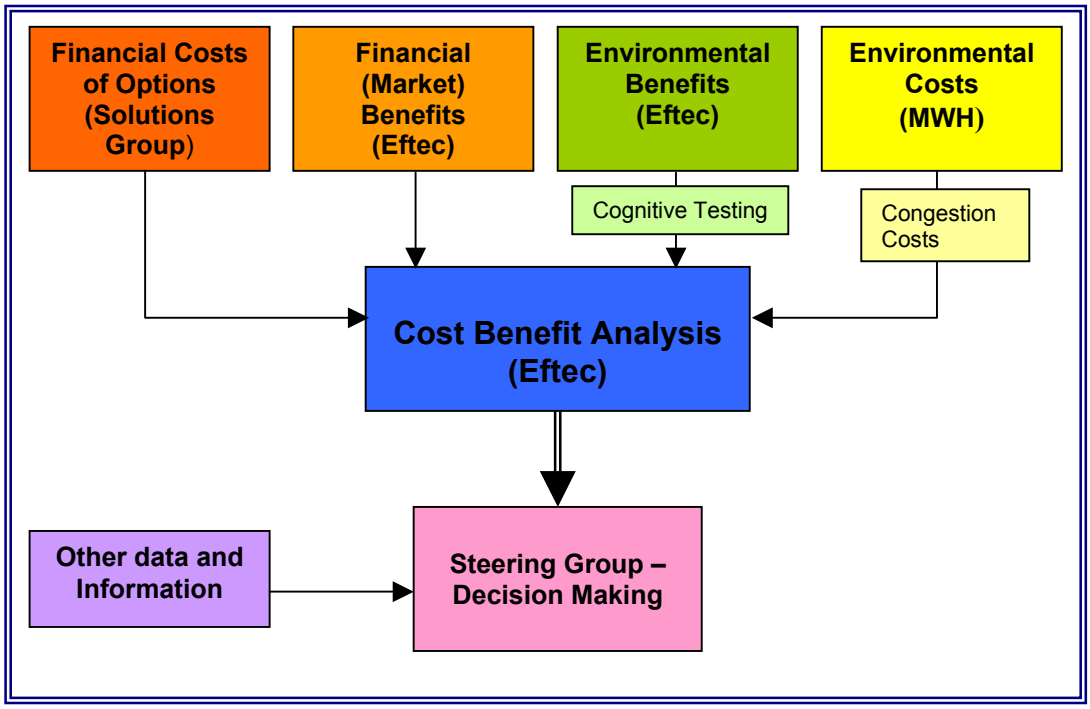
3. **Market Evaluation Study : Eftec**
   A further small project was undertaken with the aim of identifying the potential market benefits resulting from the implementation of the Tideway Strategy.

Independently of these studies the financial costs of the options were estimated by the Solutions group. Subsequent Cost Benefit Analysis, by Eftec, brought together the conclusions from all the above studies and compared it to the financial costs.

Environmental costs that could not be expressed in monetary terms could not be included explicitly in this analysis.

Figure 1 illustrates the studies commissioned by the Cost Benefit Group and the financial cost estimates and how these feed into the decision making process.

Figure 1: Cost Benefit studies commissioned and decision making process



3. Cost and Benefits Studies

3.1 Stated Preference Study

The working group agreed that the unique nature of the Thames Tideway necessitated an original economic valuation study using stated preference techniques. Designed by Eftec, the main objective of the Stated Preference (SP) Study has been to identify the non-market benefits associated with the Tideway solution options and to monetise these benefits as far as possible. Full details of the study are reported in Appendix A.

The specific tasks of the SP Study were to:

- Identify people's preferences for / against the impacts of the potential solutions on the attributes of the River Thames, in this instance sewage litter, human health risk and fish population.;
- Establish the economic value of any marginal change in these attributes;
- Determine the implied ranking of these attributes among the relevant population.
- Gather information on the general attitudes towards and the opinion about the River Thames and the solutions within the Tideway Strategy.

Stated Preference techniques are a form of economic valuation which construct hypothetical markets through surveys establishing people's Willingness to Pay (WTP) to secure an improvement or avoid degradation in the quality and quantity of goods or services. This is a particularly useful technique as it allows an economic value to be placed on environmental goods and services not reflected in actual markets. Two groups of techniques exist: Contingent Valuation and Choice Modelling.

The main valuation technique used in this study was the Choice Experiment, one of a family of Choice Modelling techniques. The Choice Experiment was used in order to cover as many of the potential improvements associated with different options as possible. During the initial stages of the specification of the options there was uncertainty regarding the environmental benefits that would be delivered. It was therefore necessary to have the benefits information in a format that could be used for a range of options, delivering a range of benefits. In a choice experiment design the respondents are asked to choose their most preferred scenario from a number of scenarios outlining potential improvements to each attribute (in this case the environmental impacts of combined sewer overflows (CSOs) and an associated cost. By including the current situation in the list of scenarios, respondents are given the option of not paying anything and foregoing the improvements.

This technique can test a large set of scenarios and the scenarios presented do not need to exactly match the options planned at the time or could be developed later so long as the level of impact assigned to each attribute reflects actual or potential levels. Given the uncertainty that surrounded the Tideway options, their impacts and costs, the ability of the choice experiment technique to cover a large set of possible improvements was seen as a compelling advantage.

In addition, a Contingent Valuation question was also employed as a back up for comparison with the Choice Experiment results. The contingent valuation question asked respondents if they were willing to pay a given increase in their water bills to finance an option that would eliminate all of the environmental impacts of CSO in the Tideway. The set of amounts used in this question were the same as that used in the choice experiment. Each respondent was given one such amount and the amounts were randomly changed between respondents. The resulting average WTP estimate gives the maximum non-market benefit of eliminating the CSO impacts. Even if complete elimination is not possible in practice, designs that come close to it are possible and this benefit estimate can be seen as the ceiling value for spending.

The process of the questionnaire design incorporated focus groups, pilot surveys and stakeholder and working group consultations. The draft and final questionnaires were peer reviewed by Professor Ken Willis of The University of Newcastle upon Tyne.

The fieldwork for the final questionnaire was carried out by MORI in the form of face-to-face surveys to 1,214 Thames Water customers. This covered both users and non-users of the Thames Tideway during October and November 2002. The user population referred to those who use the River Thames in general, and the Tideway in particular, for recreational purposes. The survey was undertaken within the Thames Water wastewater service area only, stretching as far west as Banbury, Oxfordshire. The questionnaire was targeted purely at Thames Water customers since these are the people who would pay for any solution through increased bills.

Consideration was given to undertaking a survey beyond the Thames Water wastewater service area, along with the potential need for a booster sample to specifically identify the valuations of improvements by users of the Thames Tideway. Benefits accruing to people outside the TW area, if proved to exist, could not be captured as actual payments as there is currently no mechanism for the financing of a project of one water company by the customers of another. Given this context, the working group concluded that a survey outside the TW area (just to demonstrate the existence or otherwise of their WTP) was not a high priority. Attempts to establish a distance decay function for WTP, in order to find the distance from the Thames at which WTP falls to zero, failed to generate results that could further inform the potential size of any such benefits – even though is showed even those people who do not use or see the River regularly or at all, still hold positive WTP values (see below). These wider benefits are therefore excluded from the analysis but would be included in a measure of the total social benefits of Tideway improvements. A river-user booster sample was also not pursued since there is again no separate mechanism to capture the higher WTP of users.

Based on the useable answers obtained from the questionnaire the following willingness to pay information can be derived:

Table 1: WTP Results	**(£/Household/year)**
Choice Modelling	
a) Sewage Litter (per % point of total litter)	1.8 (1.4 – 2.2)
b) Health Risk (per day of increased health risk)	0.4 (0.3 – 0.4)
c) Fish Population (per potential fish kill)	1.5 (0.7 – 2.4)
Aggregate WTP for best improvement scenario	
(baseline = 8 fish kills) = (a)*10+(b)*120+(c)*8	76.4 (66.7 – 86.1)
(baseline = fish kills) = (a)*10+(b)*120+(c)*4	70.4 (62.7 – 78.2)
No. of Observations (No. of respondents)	8,311 (1,039)
Contingent valuation	58.9 (51.9 – 66.0)

* Figures in brackets represent the confidence intervals for each of the attributes)

No discernable pattern or statistically significant difference emerges in the two models estimated with different fish kill baselines. This was also the case for the Contingent Valuation results. It seems that changing the baseline does not significantly affect preferences. Hence, for most purposes the data relating to the two baselines can be combined.

While the total willingness to pay might seem high, there is evidence of a significant non use element to the value of the improvements to the Thames Tideway. Non-users, defined as those who never see the Thames, were nonetheless willing to pay on average about £25 per household per year for elimination of the impacts of the CSOs, which aggregated over all non-

users amounts to more than half of the total WTP for the improvements. In addition, 64% of all respondents that were willing to pay for improvements stated non-use motivations for doing so. This is not a surprise given the historic and symbolic importance of the river. Cognitive testing work was carried out in August 2004 to address issues such as this and more detail is given about this work in Section 4.3.

The contingent valuation question results showed that on average respondents were willing to pay about £59 per year for the full improvement scenario and this compares favourably with the choice experiment results – with overlapping confidence intervals. This relationship indicates consistency in the results between the two approaches and adds credibility to the validity of the survey. However, it is accepted that the similarity in the results obtained may simply be a function of drawing the responses to both types of questions from the same respondents.

Although there are no directly comparable valuation studies of the types of benefits assessed here comparison with similar studies showed that the magnitude of the willingness to pay estimates obtained from this study is comparable to the results of other WTP surveys undertaken to assess related criteria. This is elaborated on in section 5.2.2 of the Stated Preference Study Report, Appendix A.

The results of the survey should not be compared with those derived from the MORI survey (The Periodic Review 2004 – Research in to Customers' Views) for the following reasons. Firstly, the MORI survey respondents were not told what the extra money would be spent on, but simply told 'many reasons'. In contrast, in the Tideway Stated Preference Study the current situation and potential future interventions were described in great detail. It was also made clear that the money respondents stated as their Willingness To Pay (WTP) would be used entirely to finance the reduction in the environmental impacts. Secondly, only four options were given to respondents of the MORI questionnaire in terms of how much extra individuals would be happy to pay on water bills, and these were (i) pay nothing, (ii) pay up to £2 more per year, (iii) pay up to £5 more per year or (iv) pay more than £5 more per year. The Tideway Stated Preference study provided respondents with a large number of options with the associated (randomly distributed) long list of (larger) WTP bids (£), all based on careful focus group testing and pilot studies.

Finally, the MORI survey was designed to give an overview of customer preferences but was not designed to elicit the value people hold for improvement to the Thames resulting from the Thames Tideway project. However the MORI survey did confirm customer priorities as, 'maintenance of the quality of river waters' and 'protection of important areas of wildlife and plants', two areas that would be directly addressed by the Tideway Strategy options.

A number of uncertainties were highlighted through the stated preference survey, described in detail in the study report. These uncertainties notwithstanding, the Stated Preference Survey report was peer-reviewed by Professor Ken Willis from Newcastle University, who concluded that:

> **"*The research in this study conforms to general principles and good practice guidelines for undertaking choice modelling and contingent valuation studies, laid out in the DTLR (2002) Economic Valuation with Stated Preference Techniques appraisal guidance manual. The research has been rigorously conducted to a high professional standard. Thus the results will, as far as possible, be accurate and reliable."***

3.2 Market Valuation Study

The Market Valuation study was undertaken by Richard Dubourg, working for Eftec, to assess the benefits of the Tideway Strategy Options on those goods and services which currently have a market value (e.g. commercial boats, recreational clubs, on river and waterside property etc.), and to calculate an increase in market value as a result of the improvements made to the Thames Tideway. This study complements, but does not overlap with the Stated Preference Study which focussed on the non market benefits only.

The study found that there would be few identifiable market benefits associated with the improvements brought about by the Tideway Strategy. Where benefits were identified they were difficult to quantify or express in monetary terms. The key issue highlighted in the report is that water quality does not appear to be the primary constraint on the majority of the activities examined. The only activity where market benefits have been quantified is the use of the Thames bubblers which will be required less if water quality in the Thames Tideway improves (see Section 4). The full report can be found in Appendix B.

3.3 Environmental Costs Studies

This study was carried out by Montgomery Watson Harza (MWH) to provide a valuation on the environmental costs associated with the different solutions in the Thames Tideway. The assessment of the environmental costs of the seven engineering options was based on benefits transfer derived from a review of the work already undertaken by Thames Water, the Environment Agency, English Nature, English Heritage, EC Harris and Defra. The environmental cost of an option, in this study, can be defined as a measurement in either monetary, quantitative or qualitative terms associated with a negative impact on the environment caused by the engineering solution. In August 2003 MWH were asked to carry out a further piece of work examining the environmental costs of the AMP4 STW (Sewage Treatment Work) Upgrades and option H+. Copies of the reports can be found in Appendix C.

Due to a lack of quantitative data some of the environmental costs identified could not be expressed in monetary terms, and as a result are not included in the final cost benefit analysis. The categories omitted are ecology, archaeology and cultural heritage, playing fields, and open spaces, other material resources not covered and bank side recreation. The disruption effects on traffic of closing or restricting flow on main roads and railways are also not explicitly included, although a sensitivity analysis of their potential impact has been undertaken.

Overall the most significant of all the environmental costs is the category of global warming caused by the substantial levels of energy use required by all the options during construction and operation. All options were identified as having significant environmental externality costs, over and above the costs which could be against good engineering design.

3.4 Congestion Costs

Cascade Consulting undertook a study to assess the congestion costs associated with road closures at the site works for each of the Tideway Solutions. Cascade adopted the methodology developed by Peter Bretts Associates, the assumptions used are outlined in Annex 2.4 of Eftec's Cost Benefit Report, see Appendix H.

3.5 Financial Costs

The financial costs of the options were put together by the Solutions Group in conjunction with external consultants. Studies were undertaken by Halcrow, EC Harris and Faber Maunsell to estimate the appropriate costs for each of the solutions. The cost calculations were on a detailed element-by-element basis by consideration of the resources and materials required and the programmed duration of activities. The exception to this is specialist contract work where quantities have been priced from experience of other recent similar work.

4. Cost Benefit Analysis

4.1 Objectives, Framework, Inputs and Results

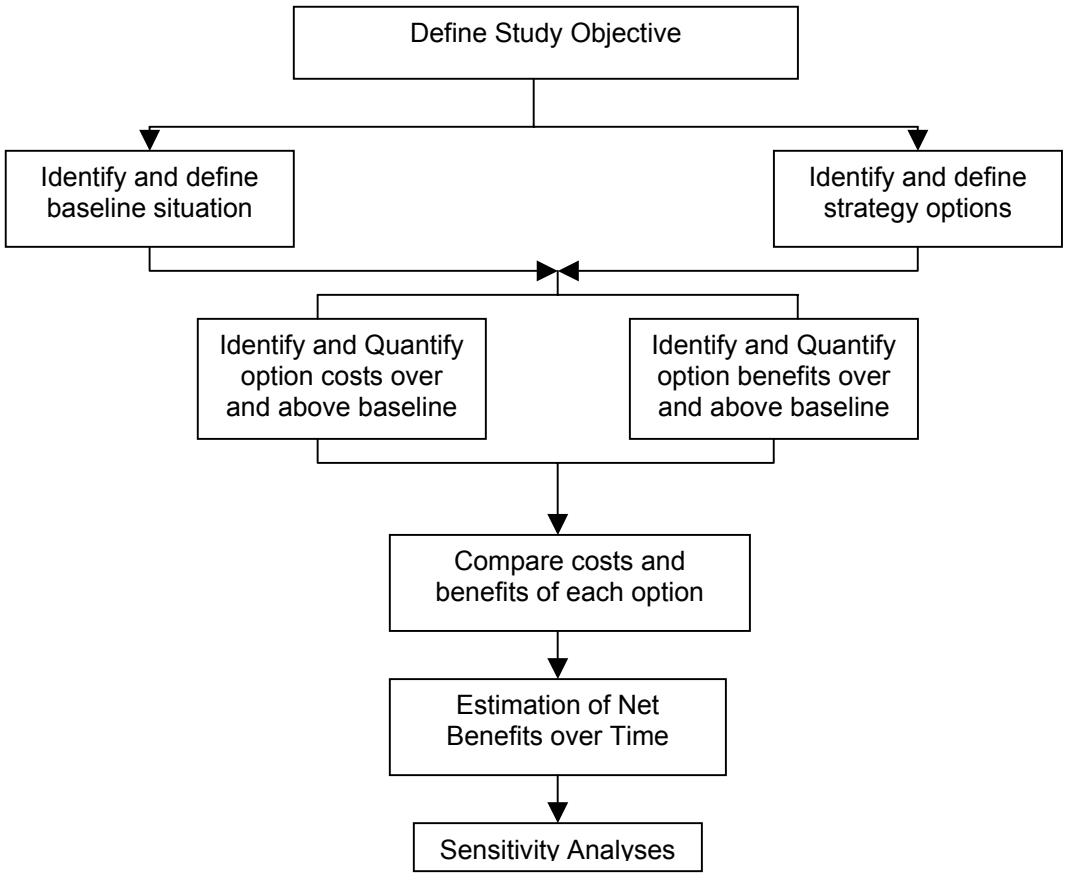
The objective of the process is to identify the predicted change in society's wellbeing due to the implementation of the different CSO and Composite options.
The Cost Benefit Analysis (CBA) draws together the information gathered in the three studies described in Section 3, along with information on the financial costs of the Solutions and allows comparison of the different solutions, see Appendix H.

The objectives of the CBA were to:

- Set up a consistent and comprehensive framework for the comparison of all assessed costs and benefits of all solutions proposed in the Tideway Strategy;
- Undertake the cost benefit analysis using this framework;
- Test the results using sensitivity analysis; and
- Advise on the preferred option only so far as a cost benefit analysis can do this.

The process of the Cost Benefit Analysis is outlined in Figure 2 below.

Figure 2: The Cost Benefit Analysis Process



The performance of any option is judged on whether the net benefits of a given option are positive or negative. The net benefits are calculated as follows;

Benefits of a given option = net benefits of option = (benefits – costs of option with respect to baseline)

where all components are expressed in the unit of money. Results are expressed in terms of their Net Present Value (NPV), i.e. they are discounted to reflect the principle that costs and benefits in the present are considered more important than those in the future. NPV is used at a policy or project level to identify the optimal solution out of a set of mutually exclusive options. A positive NPV indicates that an option is economically viable (benefits exceed costs). Benefit-Cost ratios were also calculated and are reported in Eftec (2004a) Appendix H. However, NPV is the preferred decision rule to be used when the objective of the appraisal is to find the option that leads to the highest net benefit to society, as required in this case.

The rest of this Section summarises the information inputs and assumptions regarding the stages of CBA outlined in Figure 2. Main points in this summary are highlighted in bold for easy tracking through the text. The **costs and benefits** included in the assessment are summarised in Table 2.

Table 2: Costs and Benefits of the Tideway Strategy

Environmental Benefits (market) *reduction in the following impacts due to reduced CSOs* ▪ Avoided operating cost of Thames bubblers	Environmental Benefits (non-market) *reduction in the following impacts due to reduced CSOs* ▪ sewage litter ▪ effect on fish populations (potential fish kills) ▪ elevated health risks
Financial Costs (market) *due to the construction and operation of options* ▪ capital expenditure ▪ operating expenditure	Environmental Costs (non-market) *due to the construction and operation of options* ▪ energy impacts ▪ sewage litter disposal ▪ obstructions to in-stream recreation ▪ construction spoil and operational waste transport (congestion, air pollution and noise associated with HGV transport) ▪ sand & gravel ▪ concrete mix

CBA was undertaken for two types of **Options**: (1) CSO Only Options and (2) 'Composite Options' that combine CSO options and STW (sewage treatment works) Upgrades. The STW upgrades were included within the remit of the study when it became clear that STW discharges during wet weather had a significant influence on Tideway quality.

STW upgrades are those that have been assessed as part of the L1 schemes CBA, reported in the June 2004 Report to Government. The CBA input data for the upgrades had to be acquired in a number of ways. In terms of the benefits, the data already collated in the Stated Preference Study for the CSO solutions has also been used for the STW Upgrades. This is considered to be a defensible procedure because the STW upgrades lead to the same impacts as the CSO solutions albeit through a different mechanism, and affect the same population, i.e. Thames Water customers. Environmental costs for the STW upgrades were derived from a second study, Appendix D. Financial costs were provided by Thames Water.

In this study the affected population is defined as Thames Water's customers since this is the population who would ultimately pay through their water bills, should any of the solutions be implemented. Clearly, by restricting the assessment to the population served by Thames Water (i.e. the people who would pay for any improvements) the benefits may be underestimated as mentioned in Section 3.1 above.

In order to undertake the Cost Benefit Analysis as defined in Figure 2, it is necessary to define the existing situation in environmental and economic terms so that changes from the baseline situation due to the different options can be estimated.

The economic baseline is defined in the Market Valuation Study, Eftec, 2002, Appendix B. Only two aspects were identified where water quality played a major role. These were recreation (which the Cost Benefit working group agreed was covered sufficiently by the SP study) and the use of the Thames bubblers. The two Thames bubblers were deployed around 60 times in 2002 for a total period of around 1,000 hours. The residual use of the bubblers under each option depends on the impact of the option on the dissolved oxygen (DO) concentrations. Therefore, it is assumed that a given option reduces the need to use the Thames bubblers at the same level as it reduces potential fish kills since these are also dependent on DO levels. The derivation of fish kill reductions is described below and the predicted reduction in bubbler use given in Table 3.

The environmental baseline is defined as the current conditions (without the Tideway Strategy) of environmental parameters that are impacted upon by the Tideway Strategy options. In terms of Fish Population, the observed number of **potential fish kills** per year, as used in the Stated Preference survey, is eight. However, these are driven by a number of factors, not all related to CSO discharges. Therefore mathematical modelling was used to estimate the number of fish kills arising from CSO discharges alone. The resulting estimate was 2.7 kills per year and is the baseline used for comparison of the performance of the CSO only solutions. The STW upgrades, however, will influence all types of fish kills so the performance of the composite CSO and STW upgrade options is judged against the actual baseline of 8 fish kills per year.

Mathematical modelling by The Objectives Group was utilised to estimate the residual number of fish kills remaining after implementation of a given solution. The results of the modelling are reported in Table 3. The methodology for calculating the data outlined in Table 3 can be found in Appendix E.

The risk to human health when in contact with the polluted river is described as the number of elevated health risk days. The value for each of the CSO Options was calculated based on a number of assumptions, determined by the Solutions Group. Broadly the baseline comprises the average number of spills a year (estimated at 60), each spill elevating risk to human health for 2 days and hence resulting in 120 elevated health risk days a year. In calculating the number of health risk days the Tideway was subdivided into three reaches representing the varying level of recreational activity and hence risk. Reaches with a higher level of recreation were given a greater weighting. Consequently the number of spills per region per option is taken into account when calculating the number of elevated health risk days per option. The residual number of spills predicted with a given solution was then used to estimate the reduction in health risks associated with each solution. The methodology for calculating the number of Health Risk days is outlined in Appendix F and the results are reported in Table 3.

The proportion of total litter that is derived from sewage is estimated to be 10%. The level of sewage litter reaching the Tideway under each solution is calculated, by the Solutions Group, as a percentage of the sewage volume (assuming that the litter is equally distributed throughout the discharge) the methodology is described in Appendix G. The results are reported in Table 3.

Table 3: Environmental Benefits of Tideway Strategy Options (per year)				
Options	**Sewage litter (% of general litter)**	**Potential fish kills***	**Elevated health risk days**	**No. of times Thames bubblers are deployed***
Baseline	10	2.7 (8)	120	60
A (Max)	0	2.2 (0.2)	0	49 (1)
A(Med)	0.3	2.2 (0.2)	1	49 (1)
A(Low)	1.9	2.2 (0.2)	6	49 (1)
B(Max)	0	2.3 (0.2)	27	51 (1)
C(Max)	0	2.6 (0.4)	120	58 (3)
C(Med)	0.3	2.6 (0.4)	120	58 (3)
C(Low)	1.9	2.6 (0.4)	120	58 (3)
H	5.2	2.2 (0.2)	89	49 (1)
H+	2.1	2.2 (0.2)	89	49 (1)
STW Upgrade	10	0.36	120	3

* The numbers in brackets show the potential fish kills and bubbler use for the composite options (CSO and STW upgrades) The exception to this is the last row of the table which shows the environmental impacts with STW upgrades only.

In order to complete the Cost Benefit Analysis a number of assumptions were made, some of which were explored further through sensitivity analyses. The best estimate results that are derived from sensitivity analysis are presented in Table 4.

Table 4: Summary of CBA report NPV results for all options assessing all WTP results and impacts		
Options	Range of NPV £bn	All WTP – all impacts £bn
		Best estimate
A (Max)	-0.88 – 3.82	3.82
A(max)+ STW	-0.51 – 4.43	4.43
A(Med)	-0.08 – 4.58	4.58
A(med) + STW	0.29 – 5.18	5.18
A(Low)	0.05 – 4.48	4.48
A(low) + STW	0.39 – 5.06	5.06
B(Max)	-0.90 – 2.80	2.80
B(max) + STW)	-0.54 – 3.40	3.40
C(Max)	-2.76 – -2.08	-2.08
C(max) + STW	-2.58 – -1.47	-1.47
C(Med)	-1.03 – -0.37	-0.37
C(Med) + STW	-0.84 – 0.24	0.24
C(Low)	-0.48 – 0.07	0.07
C(low) + STW	-0.29 – 0.68	0.68
H	0.03 – 1.59	1.45
H + STW	0.89 – 2.45	2.04
H+	0.53 – 2.15	1.88
H+ + STW	1.29 – 3.23	2.64
STW ONLY	0.40 – 1.14	0.81

Key	
	Highest NPV value
	All NPV Values above zero
	Negative NPV Values

Source: Thames Tideway – Cost Benefit Analysis, Eftec, October 03. Table 7.7, page 37.

4.2 Sensitivity Analysis

Sensitivity, in the context of the CBA, refers to the variation in output (NPV) with respect to changes in the value of the analysis inputs (environmental impacts, WTP estimates etc). In a broader sense, sensitivity can refer to how conclusions (e.g. ranking of the CSO and composite options) may change if analysis, data or assessment assumptions are changed.

Different approaches to sensitivity analysis have been used in this CBA:

- Monte Carlo analysis where the uncertainty and variability in estimates of exposure to risk are characterised quantitatively. This approach has been used to examine the uncertainty around WTP estimates and affected population.

- Trying different WTP estimates for different options to reflect different times at which benefits will be generated even if WTP starts in year 1 ("mix – WTP" results in Table 4). The Stated Preference study asked one part of the sample their WTP if the solutions came into effect in 3-6 years and another part if this happened in 10-20 years. The differences between the two time periods (the shorter being more beneficial) were significant at 5% significance level.

- The Cost Benefit Analysis was also rerun excluding health risks to test the importance of this benefit category (not reported in Table 4) and assuming WTP starts in the first year of operation rather than year 1 of the strategy ("later benefits" results in Table 4). Although not all reported here the analysis was also run for discount rates of 6% and 10%.

- The options that consistently appeared at the top of the ranking were investigated further using more detailed cost profiles. These results are reported in Table 5.

The second column of Table 4 shows the range of NPV values from the best estimate Cost Benefit Analysis and the sensitivity analysis.. The preferred option, with the greatest NPV is highlighted in green and, the options that pass the NPV test but have a lower absolute net present value than the preferred option are highlighted in yellow. Those options that fail the NPV test, i.e. score a negative value, are highlighted red and cost benefit analysis suggests they should be rejected.

Full details of the sensitivity analysis are reported in Appendix H, but key points are as follows:

- The closeness of the CBA results for Options A (medium) and A (low) is also seen in the Monte Carlo Analysis which shows that the two options have almost the same NPV.

- Composite options consistently rank higher than CSO only options; and

- Option C (CSO only or Composite) fails the NPV test in most sensitivity analyses and when it passes it does so with the poorest score compared to other options.

As an additional test 'switching analysis' has also been performed. This analysis shows by how much costs would have to increase and by how much benefits would have to decrease before any of the options achieved an NPV of zero (i.e. benefits and costs are equal). The results are summarised in Table 5. These results show that based on the best estimates (all WTP, all impacts), especially for the most highly ranked options, there is substantial room for the costs to increase and/or the benefits decrease before the options approach failure of the NPV test.

Table 5: Switching Analysis Results						
	Financial Costs (£bn)	Environmental Costs (£bn)	Environmental Benefits (£bn)	NPV (£bn)	% increase in PV of costs	% decrease in PV of benefits
CSO ONLY OPTIONS						
A (Max)	2.4	0.06	6.3	**3.82**	**156**	**61**
A(Med)	1.54	0.06	6.2	**4.58**	**288**	**74**
A(Low)	1.17	0.07	5.7	**4.48**	**360**	**78**
B(Max)	2.43	0.03	5.3	**2.8**	**115**	**54**
C(Low)	1.35	0.02	1.4	**0.07**	**2**	**2**
H	0.6	0.02	2	**1.45**	**223**	**69**
H+	1.16	0.03	3	**1.88**	**152**	**60**
COMPOSITE OPTIONS						
A (Max)	2.83	0.1	7.4	**4.43**	**153**	**60**
A(Med)	1.99	0.1	7.3	**5.18**	**146**	**59**
A(Low)	1.65	0.1	6.8	**5.06**	**289**	**74**
B(Max)	2.89	0.07	6.4	**3.4**	**116**	**54**
C(Med)	2.55	0.06	2.8	**0.24**	**7**	**7**
C(Low)	1.82	0.06	2.6	**0.68**	**38**	**28**
H	1.07	0.05	3.2	**2.04**	**186**	**65**
H+	1.65	0.05	4.3	**2.64**	**153**	**60**
STW	0.49	0.02	1.3	**0.8**	**155**	**61**

The sensitivity of the results to assumptions on cost was also investigated for the top ranking options, A (medium), A (low), H and H+, both CSO only and Composite Options. For these options the analysis was repeated with the following more detailed cost information;

1. allocation of capital expenditure over design and planning and construction and commissioning stages. This has the effect of postponing the majority of construction and commissioning costs and hence reducing the present value of costs;

2. addition of capital replacement expenditures , for a sub-set of the scheme assets, over the lifetime of options. This has the effect of increasing the overall financial costs (including their present value);

3. no changes to operating costs; and

4. further uncertainty is taken account of in the capital costs of A (medium) and A (low) in the Monte Carlo analysis. The lower bound of cost represents a reduction in contingency to 10% and the upper bound a value of 2.7 times the lower bound as advised by the Solutions Group.

Table 6 compares the results of this more detailed analysis with the results in Table 4. The options with the highest NPV are again shaded in green.

Table 6: Net Present Value using detailed cost profiles (£ billion, 3.5% discount rate)						
Options	Simplified financial cost profiles			Detailed financial cost profiles		
	NPV (all WTP all impacts)	NPV (Monte Carlo)	NPV (later benefits)	NPV (all WTP all impacts)	NPV (Monte Carlo)	NPV (later benefits)
A(Med)	4.58	2.73	2.23	4.91	2.63	0.99
A(med) + STW	5.18	3.01	2.42	5.52	2.76	0.92
A(Low)	4.48	2.77	2.30	4.71	2.75	1.16
A(low) + STW	5.06	3.02	2.47	5.34	2.88	1.04
H	1.45	0.03	0.90	1.58	-0.02	0.45
H + STW	2.04	1.09	1.20	2.18	0.93	0.46
H+	1.88	0.95	1.18	2.18	0.95	0.60
H+ + STW	2.64	1.33	1.65	2.96	1.22	0.72
STW Upgrades only	0.80	0.40	0.55	0.84	0.29	0.50

Using the detailed cost profiles in 'all WTP – all impacts' and 'Monte Carlo Analysis' runs postpones the costs but does not change the benefits (which still start in year 1). Therefore, the result is that with detailed financial cost profiles, NPV is higher than with simplified financial cost profiles. For the 'later benefits' run, however, the result is the opposite: using detailed profiles gives lower NPV for all option. This is because, in this run, not only the costs are postponed into the future but also benefits which now occur much further into the future than costs due to longer planning and periods. This change in the late benefits version of the NPV results in a change in the ranking of the options from Composite A (low) to CSO Only A (low).

Finally, consideration was given to the potential influence of non-monetised environmental costs highlighted by MWH (March 2003). If these impacts could have been quantified, their inclusion in the cost benefit analysis would have decreased the NPVs of all options to the degree that each option generates these costs.

4.3 Congestion Costs

There was some concern that costs arising from congestion during construction might be substantial. The level of detail available for the different solutions is insufficient to enable the direct calculation of option specific congestion costs. However, in order to investigate the significance of this environmental cost a hypothetical calculation was undertaken. An annual cost of £50 million was assumed over the construction period, based on calculations undertaken using PBA methodology (based on the email from Josh Fothergill to Yvette de Garis, 25 September 2003 – see Eftec (2004) Appendix H) but assumes even higher congestion costs.

At the 'best estimate' NPV calculations, adding these costs to all options doesn't alter the rankings. Further, adding the congestion costs to the calculation and excluding health impacts did not cause option H / H+ to fail the NPV test. From this quick test it is concluded that, although adding congestion costs to environmental costs does cause a significant increase from the original estimates, the overall conclusions remain the same.

Despite the various sensitivity analyses mentioned above, there are likely to be v=some factors that may lead to under or over estimation of the NPV. For example, the following factors may mean we have *underestimated* the NPV:

- it is likely that WTP for environmental improvements of this kind will be increasing over time with the result of increasing aggregate benefits. While the magnitude of this increase is not known, there could be several reasons for this including increases in income; increasing awareness of environmental issues and increasing scarcity of good water quality generally available. Here, however, WTP over time is assumed to remain constant as a 'conservative' assumption;

- the affected population is limited to the Thames Water customers, while it is possible that those outside this area (at least within the commuter belt of London and perhaps even beyond), may hold positive WTP for a successful Tideway Strategy;

- it is also likely that the affected population will increase over time leading to increasing benefits even if WTP per household is assumed to remain constant. As a conservative assumption, the population size is also assumed to remain constant over time; and

- in the main CBA run, financial costs of options start from year 1 and allocated equally across the construction period of the option. However, it is likely that the bulk of the construction costs will start much later (allowing for design and planning phases before actual construction). Related to this, operating costs are also likely to occur much later than assumed in the main run. The combined effect of these is a lower Present Value of financial costs (and indeed the related environmental costs) than those calculated in the main run.

The following factors, on the other hand, may mean we have *overestimated* the NPV:

- those environmental costs that could not be expressed in monetary terms are excluded from the CBA (see below). Therefore, strictly, their inclusion (either quantitatively or notionally) in the analysis would result in an increase in the Present Value of costs and (all else remaining the same) a decline in the NPV.

    - Ecological impact – Insufficient data (MWH, 2003a and b)
    - Visual Impact – ranked as High, Medium, Low (MWH, 2003a and b)
    - Hydrological Impact – assessed with depth of tunnel (MWH, 2003a and b)
    - Archeology and Cultural Heritage – Insufficient data (MWH, 2003a and b)
    - Bank-side recreation – Insufficient data (MWH, 2003a and b)
    - Noise and Vibration - ranked as High, Medium, Low (MWH, 2003a and b)
    - Air quality and odour - ranked as High, Medium, Low (MWH, 2003a and b)
    - Playing fields, open spaces – no suitable measurement found (MWH, 2003a and b)
    - Congestion costs due to closing main roads and railways during construction – not included in the environmental cost assessments

  However, it is unlikely that this change will be significant given that the majority of the significant impacts are already expressed in monetary terms and

- the main run of the CBA assumes that environmental benefits start to accrue from year 1 of the project. As mentioned above, benefits starting from year 1 of operation will reduce the present value of benefits and hence (all else remaining the same) reduce the NPV.

- The project lifetime was assumed to be 50 years for the 2003 runs of the CBA and 60 years for the new A(low) in Section 8. However, it could be argued that especially tunnel options would have a lifetime into perpetuity so long as maintenance work is carried out sufficiently. Introducing these somewhat arbitrary project lifetimes is likely to underestimate the net benefits of the tunnel options as we can assume that future flows of benefits are likely to exceed the flows of operating, maintenance and replacement expenditures.

5. Additional Studies

5.1 Academic Panel

As the proposed solutions are high cost schemes (in the order of £2bn) and the majority of the benefits arising from their implementation comprised primarily non-market benefits, key regulators, Ofwat and Defra sought further confidence in the results of the CBA.

A workshop was convened on 18th December 2003 to discuss and agree what further studies could, and should, be undertaken to give further confidence in the study outputs. An academic expert panel were invited to the workshop and these experts have remained involved in the study as expert advisers since that time. The Academic Panel consisted of Professors David Pearce (UCL), Ken Willis (University of Newcastle upon Tyne) and Ian Bateman (UEA). The members of the panel all stated at the workshop how impressed they were with the way the Stated Preference study had been undertaken and agreed it was a robust piece of work, one to be commended.

Among the topics of discussion at the 18th December meeting were:

- Issues about the stated preference study such as respondents' understanding of the survey questions, details of the valuation scenario and the context of valuation and the benefits over time;
- The role of Cost Benefit Analysis in decision making in general and in the case of the Tideway Strategy in particular; and
- Further work needs, content and timing.

These discussions highlighted four possible avenues of further work;

1. Further analysis of the existing stated preference data;
2. Expost testing of the existing stated preference survey to test how well the questionnaire was understood by respondents and how this understanding affected their responses;
3. A new survey to reflect the new decision making context that the CSO solution was not a statutory requirement and had to be demonstrated to be Best Technical Knowledge not Entailing Excessive Cost (BTKNEEC) and putting in the context of rising water bills and to address any other issues arising out of the first study which led to the results being questioned; and
4. Revisions to the CBA report.

Subsequent discussions between the CBA working group and the Academic Panel concluded that it was not clear what further analysis on the existing stated preference dataset would provide and that effort should be focussed on the other items of work. Cognitive testing was selected as the preferred means of ex-post testing and a programme of work agreed to complete this study in time for inclusion in this report. Publication of the Ministerial guidance for the 2004 Periodic Review of Prices confirmed that a CSO solution for the Thames Tideway was a statutory requirement, thus the decision making context reverted to that appropriate for the existing survey and a further stated preference survey was not required. Revisions to the original CBA have been completed and the impacts of these changes reported in Section 11 of the CBA report.

5.2 Cognitive Testing

The purpose of undertaking further analysis of the stated preference study was to examine how well the original questionnaire was understood by respondents and how this understanding affected their responses. Three techniques are available to ascertain this information: focus groups, laboratory tests and cognitive testing.

Having assessed the pros and cons of each of the techniques, cognitive testing was seen to be the most appropriate to adopt, for two reasons. Firstly this technique is more conducive to discussing the type of questions being asked in this study. The number and detail of the issues surrounding the understanding of the questionnaire are more easily addressed in a one to one situation. Secondly, during a cognitive testing interview respondents are not susceptible to the influence of dominant behaviour that can sometimes be exhibited in focus groups.

The original Stated Preference questionnaire had four sections: (A) attitudes and uses; (B) health; (C) valuation and (D) follow up questions and demographics. It was agreed only to devise briefing questions for Sections B and C, to be asked following the respondent's completion of these sections of the questionnaire. The questions focus on addressing respondents' understanding of the overall context and the uncertainty that may exist surrounding the responses to attribute information, subdivided into the categories: general, litter, health risk days and fish kills.

MORI were commissioned to undertake the fieldwork with eftec designing the debriefing questions in collaboration with the Academic Panel. It was thought appropriate to carry out the research in two stages. The first stage, in April 2004, comprised a briefing session, twelve interviews at three locations and a debriefing session. A two week break then followed to give the working group the opportunity to examine the results and decide if the types of responses being obtained were useful or if the briefing questions being asked needed to be changed. The second stage of the research was then undertaken in May 2004, following the same pattern as stage one. Eftec produced a report (2004c) outlining the findings of the research, Appendix I of this report.

The cognitive testing showed that the respondents understood the 'story' the questionnaire was trying to tell regarding the current situation with the CSOs and the potential solutions. The testing also clarified that respondents understood that the improvements being discussed would result in a rise in water bills to fund the chosen solution. It should be noted that the sample size for this study was relatively small, 24 people, and the results are not, therefore, statistically significant. However, the very nature of this type of study means a larger sample size would not necessarily lead to different results and consequently 24 was considered to be an adequate number.

5.3 Cost Benefit Assessment Update

CBA Update involved three main changes to the first version of the CBA report in October 2003:

- Editorial changes to the report;
- Addition of the list of factors that may mean we have under or over estimated NPV (these are reported above in Section 4.2); and
- CBA of a revised version of Option A (ref) which involved technical changes to the option as well as changes to the key parameters (baseline, discounting procedure and project lifetime) of the CBA. These meant that the impact data for potential fish kills were changed significantly.

The preceding work described in this and the Solutions Group reports has shown CSO Option A(low) to be the option with the greatest potential of implementation. Since these original analyses, the design of this option has been further refined and the compliance test procedure, from which the impact on fish populations is derived, has been enhanced. Ofwat

has also made provision for funding of the proposed improvements at the STWs so that these can now be considered to be part of the baseline for assessment. In addition some changes have been agreed to some of the assumptions adopted in the CBA. Details of the changes made to this run of the CBA are described in full in Eftec (2004), Appendix H. The revised fish kill data is reported below in Table 7.

Table 7: Revised potential fish kills for Option A low		
Model run	Fish kills	Reduction from observed baseline
	Per year (breaches/34)	(per year)
Observed baseline	8	n/a
Baseline after introduction of STW improvements.	1.53	6.47
Option A low optimised	0	8

Table 8 presents the cost and benefit estimates for this option.

Table 8: Revised Cost Benefit Analysis for Option A(low)				
Version of option and CBA	PV Benefits (£ billion)	PV Costs (£ billion)	NPV (£ billion)	BCR (ratio)
A(low) (3.5% discount rate)	5.7	1.2	4.5	5
A(low) & STW (3.5% discount rate)	6.8	1.7	5.1	4
Revised A(low) (hyperbolic rate)	8	1.3	6.7	6

The results in Table 8 show that the above mentioned changes lead to even better results for A (ref) in terms of NPV and BCR: while costs increase by a small margin, benefits increase (due to changing estimates for potential fish kills) by a larger amount.

Switching Analysis was also repeated for A (ref). This showed that benefits would have to be reduced by about 85% or costs increased by 500% before NPV equals zero (i.e. costs and benefits are equalised and nothing is gained or lost through implementing the project).

6. Conclusions

- The CBA results suggest A(low)/A(medium) composite options would give the greatest net benefits to society.

- For A (medium) and A (low) benefits would have to decrease by 74% and 78% or cost increase by 288% and 360% respectively for the NPV to reduce to zero and fail the NPV test.

- The updated CBA results show that the optimised option A (ref) continues to demonstrate a positive net present value with the updated specification and the STW work assumed as part of the baseline since it is now accepted to be a statutory requirement.

- It is recognised that there are uncertainties related to both the science and economic analysis. Where possible we have addressed these uncertainties e.g. with sensitivity analysis and cognitive testing.

- The results of the sensitivity analysis shows that in almost all cases the estimated benefits of the preferred options outweigh the estimated costs.

- The remaining uncertainties have been clearly stated and should be taken into consideration alongside the results of the CBA.

- Not all of the environmental costs and benefits assessed could be quantified in monetary terms, but they still need to be taken into account within the decision making process.

- During the early stages of the cost benefit studies detailed specifications of the schemes and their associated costs and benefits were not known. Consequently assumptions had to made to enable the calculation of costs and benefits. As the options are refined and more information becomes available these assumptions may be improved and the estimated costs and benefits may change as a result.

- Irrespective of the actual balance of costs and benefits the stated preference study has shown that respondents attached significant value to the proposed improvements that would be delivered by the Thames Tideway Strategy.

- The CBA group believes that the results of the study provide a valuable input into the decision making process.

Ofwat, after considering the cognitive testing results and original study results, is not yet satisfied that

- respondents understood the specific issues addressed by the scheme. In particular Ofwat doubts their capability to appreciate marginal changes to the river attributes. Whilst respondents seem to understand that there are environmental issues affecting the Thames, they do not seem to fully appreciate the scope of these issues.
- The impacts on water bills were sufficiently clear for respondents to consider them in deciding on their willingness to pay

In the light of the above considerations Ofwat wishes to see the results of a new study that presents the deliverable improvement as a package and asks for respondents' willingness to pay for this package. Furthermore this new study should clarify the context of this scheme. It may be that rises in Thames Water's water bills in order to meet the costs of delivering other improvements to the environment and to their services are significant and may affect customers' decisions. A new study would allow respondents to consider this when deciding their WTP.

Appendix

Appendix A: Stated Preference Study, Eftec, 2002

Appendix B: Market Valuation Study, Eftec, 2002

Appendix C: Environmental Costs Study, MWH, 2002

Appendix D: Environmental Costs of STW Upgrades, MWH, 2004

Appendix E: Fish Mortality Date Calculation Methodology

Appendix F: Methodology for calculating the number of Health Risk Days

Appendix G: Methodology for the Calculation of Litter Reductions

Appendix H: Cost Benefit Analysis, Eftec, 2004

Appendix I: Ex-post Testing of the Tideway Stated Preference Study, Eftec, 2004