Thames Tideway Strategic Study

Supplementary Report to Government

November 2005

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References

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Glossary

Abbreviations used in this report

CSO	Combined Sewer Overflow
DO	Dissolved Oxygen
AMP4	(Underground) Asset Management Plan No. 4 1.04.05 - 31.03.10
STW	Sewage Treatment Works
DWF	dry weather flow
UWWTD	Urban Waste Water Treatment Directive
WFD	Water Framework Directive
CTRL	The Channel Tunnel Rail Link Project
BTKNEEC	Best Technical Knowledge Not Entailing Excessive Cost
BOD	Biological Oxygen Demand
OD	Outside Diameter
ID	Inside Diameter
TBM	Tunnel Boring Machine
NATM	the New Austrian Tunnelling Method
NOS	the Northern Outfall Sewer
SuDS	Sustainable Urban Drainage
Mm^3	Million cubic metres
CFD	Computational Fluid Dynamics

0. Executive Summary

0.1. Background

In June 2004, in advance of the publication (in February 2005) of the main reports from the Thames Tideway Strategic Study, a preliminary interim Report to Government was submitted to Ministers outlining the likely content of the main reports. The response from the Department for Environment, Food and Rural Affairs (Defra), and further consideration by the Steering Group resulted in terms of reference (Appendix A) and this Supplementary Report. In summary this comprises further investigation of the proposed long-term tunnel solution and of alternative measures including temporary or interim works and some smaller scale tunnel and/or treatment options to deal with the discharge of storm water from Combined Sewer Overflows (CSOs) into the Thames Tideway.

It should be realised that only the preferred tunnel option A(ref) meets all the objectives within the main Tideway study agreed by the Steering Group. The alternative options achieve various levels of benefit short of this optimum from limited to substantial. This report attempts to compare and rank these in terms of estimated costs and benefits.

In view of the success of the London Olympic bid a number of sub-options focussed on the CSOs on the river Lee close to the games site have also now been considered.

To put the alternative measures into context it has been necessary to highlight a number of features relating to the nature of London's drainage system and the overflows into the Thames that impose limitations on the options available to achieve the objectives (see Appendix B). The work reveals that in order to achieve the stated objectives significant additional storage and flexibility of operation is necessary. It is clear that works of a minor nature, although these may be worthwhile, are unlikely to achieve significant improvements on the scale of the target objectives.

The conclusions and recommendations in this report are based on the reports of previous work carried out as part of the Tideway study and its supporting documentation, and a number of investigations undertaken between summer 2004 and the middle of 2005.

0.2. Findings

0.2.1. Interim Measures

A number of additional, interim, measures are currently being assessed and some are to be implemented by Thames Water. Although they may be of limited benefit, they are an immediate attempt to reduce or manage the most harmful effects of the overflow discharges, by managing the levels of dissolved oxygen (DO) and removing some of the visible sewage solids from the river.

It is presumed that the existing ameliorative measures, being the provision of two oxygenation barges and some fixed-point hydrogen peroxide dosing plants, will continue as current.
Interim improvement measures are:

- Pending confirmation advice from the Agency, providing a new hydrogen peroxide chemical dosing plant at Crossness STW (sewage treatment works) and reviewing the performance and capacity of up-river peroxide installations to assist in protecting the upper reaches
- Provision of two specialised river craft with screening plant to remove litter including visible/floating sewage solids
- Installation of two additional water quality monitoring stations to ensure optimal use of re-oxygenation measures
- Provision of advice to recreational river users

These measures have some merit pending a more complete longer-term solution but their impact on sewage derived litter and DO is likely to be small and would do little for the ambient background level of health risk in the Thames. Allowing the river to be polluted and then applying remedial measures is not considered, by the EA, to be a satisfactory long-term solution in principle. Their value is that they can be implemented quickly, are targeted to reduce or limit pollution, and are relatively inexpensive. They also show that the bodies responsible for the Tideway are taking some action. The measures are already part of Thames Water's capital programme for delivery by 2010.

0.2.2. Smaller Scale Measures

The smaller scale measures generally attempt to provide improvements in the Tideway for lower levels of investment, to a shorter timescale and therefore with earlier benefits, than the preferred option A(ref), in the main reports. They either: a) incorporate a lower storage capacity; b) intercept and convey for treatment overflows from fewer CSOs; c) or involve a lower level process , such as primary treatment, or screening. The measures are summarised below and in table 0.4 and are described and evaluated in more detail below (see 1.3).

a) Smaller Storage Tunnel

Several smaller tunnel options including a review of option H (see main reports 0205 - Ref 3), and H+, two new options dealing with the CSOs on the river Lee close to the site of the Olympic games, and a larger composite option H++ have also been considered (see 1.3.1). They provide various levels of benefit and an attempt has been made to compare these with one another and the earlier options evaluated by the Solutions Group. None fully meets the objectives developed by the Steering Group, and all appear to be less cost-effective overall than the preferred option A(ref), especially if extending them to fully meet the objectives were to be carried out later. All would still allow some level of pollution throughout the length of the river due to tidal effects although some reaches would be improved compared with the current situation.

b) Treatment Plant at Abbey Mills

Storm flows pumped to the river Lee at Abbey Mills represent a significant proportion (about 50%) of the total overflows into the Tideway and discharges could receive enhanced primary treatment to reduce polluting load. This could only be by filtration as bacteriological processes cannot treat intermittent flows, and the limited reduction in BOD load afforded by the treatment plant would not fully achieve the DO objectives. A measure of storage would be required to balance flows to facilitate operation of the plant. Overflows (e.g. during unusual storms) would still occur but pollution is expected to be limited through the application of enhanced primary treatment to most of the overflow discharge.

Such plant would present a serious operational challenge and successful automated functionality could be hard to achieve. This might necessitate manual intervention at the site, which would have significant resource and cost implications.

The estimate of approximately £400M would be more expensive than connecting Abbey Mills flows to the preferred main tunnel option A(ref).

c) Screening Plant where Feasible

It has been established that building screening plant at most CSO locations is not practical (ref. 5). There are a few sites where it could be technically possible to install screening plant. The five most viable sites could be screened at a cost estimated to be over £600M, which is higher than the smaller partial tunnel solutions of option H. Provision of such screening plant could remove screenable solids from some 16% of the total discharge from all the Tideway CSOs. The other CSOs would continue to discharge and tidal effects would carry sewage to other parts of the river largely masking any improvement. Screening a limited number of overflows would partially address only one of the objectives (i.e. the removal of sewage-derived litter). There would be little or no improvement in the levels DO or of public health risk.

Screening large gravity CSOs presents major operational challenges not least because no forward flow is available during storm events creating major storage problems. Pumping through the screens would generally be required to avoid increased flood risk. Experience suggests that this would cause much screenable sewage solid matter to pass through the screens leaving plumes of organic pollution slicks. Of all the technical processes, which have been evaluated through the study, major automated mechanical screening plants on remote sites have now been shown to be limited in their effectiveness and in central London would be disproportionately so costly that more effective and beneficial storage arrangements could be provided at a cost comparable to the equivalent level of screening.

d) Dispersed Storage Units

Providing storage in a dispersed or fragmented manner throughout the sewerage system has the advantage of providing some early benefits but this is outweighed by a longer overall delivery timescale and greater cost. It would be considerably more disruptive and at least five times the volume of storage would have to be provided to cater for the range of storm events because of the spatial distribution of rainfall and the response times of the system. The budget cost is likely to be more than £10bn.

e) Application of Sustainable Drainage Systems (SuDS)

Because London's catchments are densely urbanised, widespread retrofitting of SuDS techniques would be disruptive, costly and technically difficult as insufficient land is available. Due to system constraints, open storage features would not hold clean rainwater but combined storm sewage. The few installations of this type that do exist are already subject to public complaints. To prevent this would entail a large degree of separation to be carried out in conjunction with the attenuation tanks. Implementing SuDS via redevelopment would take decades to have significant impact on CSO discharges.

f) Separation of Sewerage system

As the root cause of the CSO pollution problem is surface water combined with foul sewage flows, separating the two is an obvious potential option for consideration. This could be achieved by having the existing sewers deal only with surface water and installing a completely new foul system. Disruption would be enormous involving construction work in potentially every road in London and the modification of the drainage system for virtually every property. The minimum cost would be £12bn at current rates and an overall cost of £20bn could be possible. Such works would need to be phased over several decades.

g) Trade Effluent Control of Fats and Grease

The accumulation and discharge of fats and grease from the CSOs is a minor, though visible and objectionable, component of pollution. Apart from some specific, managed industrial sources most grease and fat in central London comes from domestic premises not covered by trade effluent regulations. Even total removal of fats and grease from the system would only offer a minor reduction in pollution. Control at source may be of some benefit as a small-scale measure to reduce the aesthetically objectionable matter discharged pending a more complete solution.

DOMESTIC OPTIONS

h) Removal of Sewage Litter at Source (Bag-it and Bin-it)

Since 28 July 2005 the Thames Water website has provided information on how to be a "sewer blockage buster". However, water industry experience of bag and bin it campaigns shows little success in significantly reducing sewage-derived litter. To be of some merit a positive and sustained public response would be needed to enable it to be considered as part of a more complete solution. Previous experience shows that such a response is unlikely and also this option would have no effect in reducing the impact on DO and public health risk.

i) Water Butts

This option offers a minor potential contribution to reducing the amount of rainwater run-off entering the sewerage system. These small tanks only catch rainwater from roofs and could never achieve more than a vary small reduction in discharge even if fitted universally. Currently Thames Water encourages the use of water butts, but to store water and avoid shortages. Used this way butts probably would be full and thus useless when rain fell.

j) Other Domestic Options

Grass roofs, composting toilets and reed-beds with domestic small-scale sewage treatment and reuse of grey water in theory might help, but most of the surface water that causes the significant overflows in London comes from ground level paved areas like roads. There is no certainty that such features would be adopted or maintained, and in any case, Thames Water would remain responsible for providing effectual drainage.

0.2.3. Integrated Options and Phased implementation

The partial options individually have notably less impact than the preferred option A(ref). Although combined options such as H+ and H++ give a higher level of benefit than option H, this is achieved at significantly greater cost. At first sight using some smaller scale options such as source control and SuDs, localised screening or treatment and even a domestic element in optimum localities could produce an “Integrated” solution in order to increase the chances of success by not depending on a centralised facility.

However, the research done to date has produced several powerful arguments against this approach.

Screening the Thames Tideway CSOs locally has been shown to be likely to be impracticable and have limited effect. All the substantial benefits identified from remediation so far are associated with storage options. The two key factors in providing such options are: the location of the storage and the return of flows to treatment.

Centralised storage serves all events anywhere in the catchment. If dispersed, a much larger volumes of storage would have to be provided to achieve the same effect. Although a number of smaller tanks distributed through the network could be built in a shorter timeframe to provide some minor benefits early, a total solution using this method would cost much more and take much longer to deliver overall. The volume required in this way could rise to 8 million m^3 and the spatial distribution of rainfall means that for most localised storm events much of this would not be utilised.

Modelling shows that attenuation in the whole network means that a given volume of storage provided locally to reduce run-off would not be passed on as an equivalent reduction in discharge from the CSOs and cost savings by making the tunnel slightly smaller are also likely to be quite small (see 2.6.1).

There is little surplus capacity anywhere in the system. Unless flows are returned for treatment near the east London STWs, the lack of network capacity would merely cause overflows elsewhere.

These factors strongly support the provision of a centralised storage solution with an outfall near the east London STW facilities.

The smaller scale measures could be phased as a series of partial solutions and delivered incrementally to build up the level of benefits achievable. As this is attempted the cost quickly escalates. It is considered that any combination of smaller scale options equal in value to the proposed tunnel option A(ref) would not achieve comparable improvements.

Any smaller measures applied to only part of the Tideway, for example option H, may be undermined by the tidal nature of the Thames. Since partial solutions do not catch all the CSOs, which have been assessed as having an environmental impact, overflows would continue and impacts may occur elsewhere in the river because of the 15km tidal excursion. This may be particularly noticeable in the summer if a major storm follows a long dry spell and a large load of sewage solids overflows into the Thames especially at periods of low flow. The west London option(s) could limit the effects of this from reaching the upper part of the Tideway.

The preferred option A(ref) could be implemented in phases. There are two options for phased implementation: sequentially and in parallel.

i) The tunnel could be constructed sequentially in sections to spread the cost over a longer period. A three-stage implementation increases the cost by just over £250M and could delay overall completion to 2030 or even later (see 1.4.3).

ii) The sections of the tunnel could be constructed in parallel. There would be additional costs of approximately £70M but delivery could be brought forward by over a year.

This approach could help to reduce the concerns over the length of time taken for complete implementation and could also be applied to the combined options (see 1.4.4).

The order of construction could be influenced by the 2012 Olympic games and options 1 and 2 are suitable modifications to the method of implementing the Tideway storage solution considered to prioritise improvements to the river Lee close to the games' site. Although 50% of the estimated annual total discharge would be dealt with, the impact of these options alone on the public health objective for the whole Tideway is likely to be limited, the impact on the Lee would be significant and greatly improve water quality in and around the site of the games, and in the Thames around the junction with the River Lee. Such options could form the first part of a complete Tideway solution to be completed later.

To achieve this partial solution in time for the games would entail an early start in 2006. Given the known difficulties of obtaining necessary planning approvals this approach has to be considered as a high-risk strategy, and it will be difficult to guarantee delivery to the required timescale.

0.2.4. Update on Continued Investigations

a) STW Upgrades

Certain issues and risks around the likely ability of the works upgrades to cope with returned flows and increased sludge have been reviewed. The project risk register and contingency sums have been modified to provide more reliability that these risks can be accommodated and cost variations met for a range of potential forecast values.

b) Impact of Non-Connected CSOs

Prioritisation of the CSOs by the EA reduced the number to be intercepted from the active 57 to the 36 with highest priority. The remaining 21 cannot be practically screened and the design, compliance testing and forecasts of improved water quality all indicate no action is required as they do not operate frequently or cause an adverse ecological impact.

c) Average Annual Volumes Discharged

In February 2005 the Steering Group Report stated that the average annual discharges of storm sewage into the Tideway were typically 20 million m^3. Recently published figures have been much larger but these include STW discharges omitted from the earlier figure. Updated modelling has also shown the earlier figure to be an underestimate. Thus a more accurate figure for the total annual overflow discharges is nearer 50 million m^3. It is estimated that 32 million m^3 is discharged from the CSOs, and 20 million m^3 from the sewage treatment works. Work is in hand at

Beckton, Crossness and Mogden to significantly reduce overflow discharges from the works. The revised estimate has no bearing on the calculations for the size and forecast performance of the preferred option A(ref) where figures for actual rainfall events were used. The modelled design figures are not influenced by observed discharges and remain unchanged.

d) Similar Projects Elsewhere

A number of other projects worldwide have been considered and it is evident that interception, storage and return to treatment solutions have been adopted in a number of other places both in the UK and internationally. Screening and dedicated storm treatment installations are not much used. Storage is sometimes combined with a range of other measures such as rainfall rerouting, real time control, and SuDs. The main Tideway investigations have shown the limitations of using such techniques in Central London.

0.2.5. Current Tunnel Proposal Aspects

Clarification of several issues associated with the preferred storage tunnel option A(ref) was requested. Many of these issues had already been investigated and were contained in the detail of existing reports or were under continuing investigation. These matters are discussed in more detail in section 2 and are summarised below:

a) Sustainability and Environmental Issues

The newly proposed pumping station and treatment plants would consume approximately 11GWhrs of energy per year. To offset this energy requirement three potential options for the utilisation of renewable energy have been identified, as described in 2.1. These are wind generators, bio fuels and sludge incineration. Dependent upon optimisation of the existing Sludge Powered Generators (SPG) it should be possible to exceed the energy sustainability requirement of 10%.

Disposal of the tunnel spoil could have environmental implications should landfill be unavoidable. However the vast majority of the material will have a significant reuse value as described in 2.1.2. The key issue is timing, synchronising with other significant projects that may require or be able to utilise the surplus material to be disposed of. The proposed Thames Gateway development and flood improvements give reason to be optimistic. Possible contamination of the aquifer is potentially more serious either during construction or from leakage from stored storm water during operation. These risks can be largely avoided as described in 2.1.2.

b) Interception Shafts

Further investigations have shown that the interception shafts represent a lower area of risk than previously thought although they present a range of potential challenges both above and below ground. Many unavoidable shaft locations are sensitive and the depth presents a number of technical issues for which specialised techniques have been included and the cost estimate and contingency suitably updated. All the interception shaft sites have been studied and outline plans and layouts prepared. All were found to be feasible although for several sites alternatives were prepared should problems arise. Three of the shafts need to be sunk in the river and the PLA have agreed to this in principle.

c) Construction Overrun

The potential costs associated with construction overrun should problems be encountered are covered by the contingency sum allowed. The average cost of delay would be approximately £1m per month to cover site establishment and management. Obviously there may be other costs related to the resolution of the encountered problem.

d) Risk Assessment

The risk assessment process and allocation of contingency is described in 2.2 and the current register is included in Appendix G. All risk items are subject to review to mitigate their impact, but in particular the top five have been directly addressed. A key example of this being site availability for the main shafts. The recommendation is that these sites be acquired at an early stage. An allowance for this has been made in the Project Plan for Outline design included in 4.1 to cover the acquisitions of options to purchase together with completion of acquisition following planning application.

e) Update of the Cost Estimate

All estimated costs were based on the second quarter of 2002 in line with submissions for Asset Management Programme 4 (AMP4) and updated to 2004. Review of the construction indices show an increase of 11.56% to the third quarter of 2004 as described in 2.4. Applying this factor increases the budget cost for the preferred storage tunnel option A(ref) from £1,527m to £1,699m

f) Reliability of the Cost Estimate

More detailed analysis has shown that the cost estimate compares favourably with similar sized tunnelling projects like the Channel Tunnel Rail Link (CTRL). Several items of risk have now been more reliably costed and the estimate increased. This is balanced by a commensurate reduction in the contingency sum which now stands at a little over 24% overall with a statistical certainty of 75% of avoiding cost overrun. The scale of the project shows that the total cost is relatively insensitive to variations in the volume of storage provided and the unit cost improves significantly as the total volume increases.

g) Land acquisition and planning issues

The issues associated with land acquisition, planning applications and the EIA (Environmental Impact Assessment) have been continually reviewed and updated throughout the study as described in 2.5 and summarised in Appendix F. The main issue could be delays due to the planning approval process. The outline programme includes an allowance of 18 months for a public inquiry if called for. One of the key mitigating measures is to acquire the sites for the main shafts by private treaty and avoid compulsory purchase, which might entail a public inquiry. Early acquisition of these sites is a key requirement and requires funding.

h) Traffic congestion issues

As described in 2.6, it is proposed to service construction of the main storage tunnel by river barge to minimise impact on traffic congestion. The main traffic impact will arise from the construction of the CSO interception structures. The high level review of impact on traffic congestion has been calculated with regard to street works and HGV movements. The impact of traffic congestion has been calculated to be £18M, but by adopting an alternative arrangement for the works at Vauxhall Bridge and Savoy Street it may be possible to further reduce this amount.

i) Combined Use Tunnels

Consideration has been given to combining the sewer tunnel with other major transportation tunnels to maximise economy but none of these has so far proved a realistic option.

0.3. Conclusions and Recommendations

0.3.1. Interim Measures

Implementation of the interim measures should be completed by 2010, and the completion of the STW improvements will be in 2012 and 2014. The effectiveness of new peroxide dosing station at Mogden has been monitored through 2005, and investigation of opportunities for effective additional facilities elsewhere along the Tideway will complete shortly.

0.3.2. Smaller Scale Measures

None of the smaller scale measures on their own provides significant benefits. Some proposed combinations of measures could provide significant targeted storage and flexibility of operation, which could go some way towards achieving the objectives. However, for these the cost approaches or exceeds that of the preferred option A(ref) for less overall benefit.

The river Lee option 2 is considered, in engineering terms, to be the most effective way to improve the state of the river Lee before the Olympic games in 2012. This scheme would also be able to form the first part of the preferred option A(ref). However, construction would have to start in 2006 to be ready in time, and this approach carries considerable risk.

Localised screening plant should generally be avoided as having notably minimal impact and presenting a major operational challenge, which would also apply to a primary treatment facility at Abbey Mills or Heathwall.

The incremental provision of some of the smaller measures could achieve some early benefits pending completion of the preferred option A(ref).

0.3.3. Phased Implementation

Phasing implementation of the preferred option A(ref) to spread the cost of delivery over a longer period would increase costs by over £200M overall and could delay completion to 2025 or later.

Constructing either the preferred option A(ref) or a combination option in parallel phases is recommended and would enable shorter delivery timescales without excessive extra costs.

0.3.4. Outline Design

The Project Plan for progressing the preferred option A (ref) through the next stage of outline design, planning application, EIA and land acquisition is detailed in 4.2 at a cost of £63M.

It is recommended that approval to progress pre-planning work for the preferred option A(ref) be given as soon as possible. It is recommended that funding to progress the project through design, planning and land acquisition be allocated as soon as the decision on the way forward is made.

Consideration should be given to prioritising the eastern section of the chosen option to facilitate environmental improvements in the river Lee.

The recommended outline design stage is a necessary precursor to most of the smaller scale measures as well as option A(ref). Further opportunities to review the strategy and approve or reject continuation before major funds were committed could be:

- at the end of the first year before planning applications are submitted by which time the outline design would be completed and the planning application and EIA issues will be clearer.
- prior to any expenditure for land acquisition
- at the end of year 5, by which time the EIA and public inquiry should be complete and planning approvals granted.

Any delay in the approval from now on would put back the completion date of the preferred option A(ref) or any scheme with significant storage capacity.

Table 0.4 summarises the estimated costs and benefits for both the earlier options and the smaller scale measures considered in this report:

Supplementary Report Table 0.4 - Options Comparison

Note - These figures are best estimates as at October 2005

Options - Costs at 2004 Prices	95 Storage Volume 000m3	Total Capital Costs £M	Operating Costs £M/year	Total Score Points	Impact: Achievement of TTSS objectives %tage Improvement DO	Litter	Public Health	Compliance	Unit Costs: £/m3 Storage	£M / point	£M/1% Improvement DO	Litter	Public Health	Residual Spills No./Year	m3 / year	%tage of Total Litter Remaining	Remaining No of fish Kills	Bubblers Deployed No times	Remaining No of Elevated Risk Days	NPV (CBA)	Construction period Yrs	Delivery Date	Comments: Advantages	Disadvantages
A(ref)	1500	1,698	6.446	300	100	100	100		1132	6	17	17	17	1.5		1.9	2.2(0.2)	0???	6	6.70		2020	Fully Compliant	Refined Option Base for Comparisons
A (Max)	4200	3,095	6.93	300	100	100	100		737	10						0	2.2 (0.2)	49 (1)	0	3.82	10			
A(Med)	2100	1,974	3.49	300	100	100	100		940	7						0.3	2.2 (0.2)	49 (1)	1	4.58	9			
6m - Full Length A(low)	1070	1,431	1.89	191	60	81	50		1337	7	24	18	29			1.9	2.2 (0.2)	49 (1)	6	4.48	9	2020	Lower Capital Cost	Non-Compliant - Unit Costs High
B(Max)		2,945	9.68	180	30	100	50			16						0	2.3 (0.2)	51 (1)	27	2.8	10	2017	Lower Capital Cost	Non-Compliant - Unit Costs High
C(Max)		4,085	10.33	105	0	100	5			39						0	2.6 (0.4)	58 (3)	120	-2.08	9	2017	Lower Capital Cost	Non-Compliant - Unit Costs High
C(Med)		2,417	5.33	100	0	97	3			24						0.3	2.6 (0.4)	58 (3)	120	-0.37	9			Non-Compliant - Unit Costs High
C(Low)		1,628	2.29	82	0	81	1			20						1.9	2.6 (0.4)	58 (3)	120	0.07	9			
H (9m dia) - Old Version	757	722	1.24	108	50	48	10		955	7	14	15	72			5.2	2.2 (0.2)	49 (1)	89	1.45	6		Helps Upper Reaches	
H (7.2m dia) - Old Version	518	558	1.24	82.57	35	40	8		1076	7	16	14	70			5.2	2.2 (0.2)	49 (1)	89		6		Helps Upper Reaches	
A(ref)	1500	1,698	6.45	300	100	100	100		1132	6	17	17	17	1.5		1.9	2.2(0.2)	0???	6	6.70		2020	Fully Compliant	Refined Option Base for Comparisons
H++ West 10.6m - East 9.7m	1531	1,528		166	75	75	16		998	9												2011	Helps Olympics and Upper Reaches	
H++ West 9.0m - East 8.3m	1125	1,363		159	72	72	15		1212													2011		
H++ West 7.2m - East 7.4m	800	1,217		148	67	67	14		1521													2011		
H++ West 6m - East 6.3m	565	1,140		138	63	63	13		2018													2011		
River Lee Option 1 (8.5m dia)	728	888		98	49	49	0		1220	9												2012	Helps Olympics	
River Lee Option 2 (9.7m dia)	728	781		98	49	49	0		1073	8												2011	Helps Olympics	
H+ (10.6m dia)	803	1,626	1.24	159	57	86	16		2025	10						2.1	2.2 (0.2)	49 (1)	89	1.88	6		Helps Upper Reaches	
H+ (9m dia)	579	1,549		156	56	85	15																	
H+ (7.2m dia)	370	1,424		150	53	83	14																	
H+ (6m dia)	259	1,378		145	52	81	13																	
H (10.6m dia)	803	747		70	27	27	16																	
H (9m dia)	579	603		67	26	26	15																	
H (7.2m dia)	370	480		62	24	24	14																	
H (6m dia)	259	424		57	22	22	13																	
Crossness Dosing		1.0		0	0	0	0			n/a	n/a	n/a	n/a	60								2005	Quick	Interim Only
Skimmer Craft		6		0	0	0	0			n/a	n/a	n/a	n/a	60								2006	Fairly quick	Interim Only
Treatment at Abbey Mills		399		16	5	10	1			25	80	40	399	60								2010		Non-Compliant
Screening Plants where		600		11.1	0.1	10	1			54	6000	60	600	60								2012		Non-Compliant
Dispersed Storage	7500	16,000		300	100	100	100		2133	53	160	160	160	10								2025	Incremental Implementation	High Total Cost High Unit Cost
SuDS	7500	16,000		225	75	75	75		2133	71	213	213	213									2030	Incremental Sustainable	High Total Cost High Unit Cost Still Polluting
Separation		20,000		275	90	95	90			73	222	211	222	60								2030	Incremental Sustainable	Similar number of discharge events but less pollution
Removal at Source (Bag &				0	0	0	0	0						60								?		No realistic figures
Water Butts 1 at 0.2m3	400	300		3	1	1	1		750	100	300	300	300	50								?	Possible	Non-Compliant
Water Butts 20 (4m3 storage per property)	8000	6,000		45	15	15	15		750	133	400	400	400	5									Unlikely to be possible	Impossible to realise Still Non-Compliant

Colour Codes

Compliance: Best … Worst | Figures: Good | Assessed | Interim Measures

Note: Because of the way the Public Health benefits have been calculated, the figures for options H, H+ and H++ are likely to be underestimates (see 1.3.1.1)

1. Alternative Options

1.1. Introduction

1.1.1. Constraints

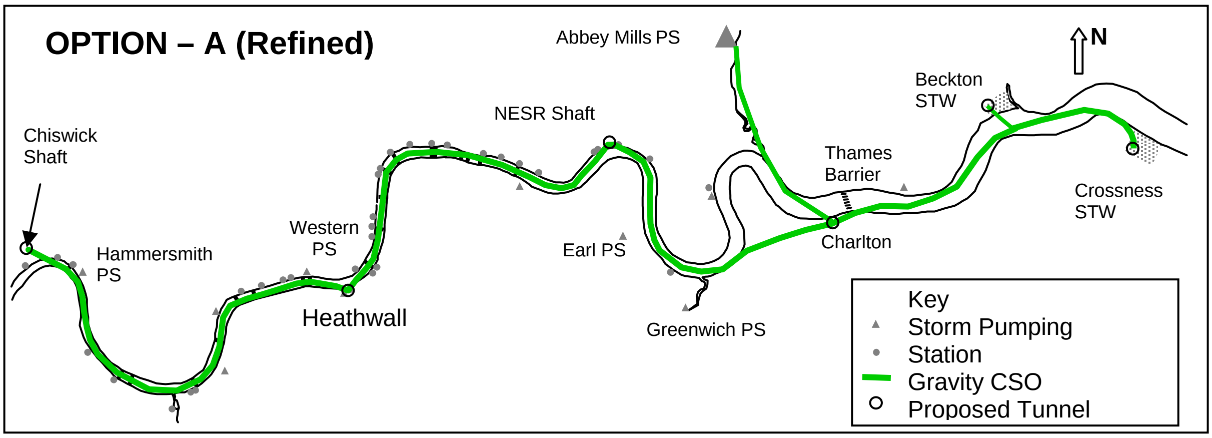
The Thames Tideway Strategic Study has revealed that the nature of London's sewerage system imposes limits on the options available to reduce or control polluting discharges. These include:

1. Catchment size: The area is approximately 557 sq km, rainfall intensity and duration is variable leading to different flow patterns and the amount and significance of CSO discharges.
2. System complexity: The system incorporates 12,000km of sewer with over 600 cross connections and overflows. There are 57 active CSOs on the Tideway and an assessment by the EA shows that 36 of these have the greatest impact.
3. Tidal effects: high tide currently restricts discharge from the gravity CSOs and causes risk of sewage flooding to property.
4. System capacity: The intercepting sewers flow at about two thirds capacity in dry weather. There is little surplus capacity for wet weather flows.
5. London is highly developed restricting the land available for sewage treatment related operations. Even underground space is restricted by service and transport facilities.

(Note: a more comprehensive and detailed list and description is included in Appendix B: Constraints)

1.1.2. The Preferred Option A(ref)

Earlier investigations (ref. 3) of partial or smaller options show that works of a modest nature do not achieve a significant reduction in pollution. The scale and complexity is such that any solution, which fully achieves the objectives, must incorporate significant capacity and flexibility. This led to the proposed main storage tunnel option now designated A(ref).



The proposed tunnel would be 34.5km long and, in order to provide the desired storage volume of 1.5 million m^3, would have a diameter of 7.2m. There would be a new storm sewage treatment plant at Crossness, which would supplement the existing full treatment process at times when the works are overloaded and could not receive flows from the tunnel. These would be pumped out at a rate of up to $10m^3/s$ by a new deep pumping station to be built at the works.

1.1.3. Request for further Work

In September 2004 following submission of the Report to Government a request was received from Defra for further investigation of the proposed long-term tunnel solution (Section 2) and alternative activities including interim measures and some smaller scale tunnel and/or treatment options.

Two different groups of alternative options have been considered: Interim Measures and Smaller Scale Measures.

1.2. Interim Measures

Currently a number of activities ameliorate the impact of CSO discharges in the Tideway. These include the use of oxygenating craft, which are deployed after many discharge events and also the injection of hydrogen peroxide from fixed stations along the river. Also skimmer craft, operated by the Port of London Authority (PLA) are able to remove quantities of floating debris from the water surface. The proposed interim measures seek to extend these activities as follows:

- **a)** Provision of a Peroxide dosing plant at Crossness STW to mitigate the effect of low DO levels in the middle reaches and review the capacity of up-river peroxide installations to assist in protecting the upper reaches.
- **b)** Installation of two additional monitoring stations to ensure optimal use of peroxide.
- **c)** Provision and operation of specialised craft to remove visible/floating sewage solids.
- **d)** Provision of comprehensive advice on health risk to river users.

(Note: These are now obligations under AMP 4)

a) Peroxide dosing plant at Crossness

Two existing plants at Barnes and Chelsea are used to inject hydrogen peroxide into the river as a source of oxygen to alleviate the deoxygenating effects of some CSO discharges. An additional installation at Mogden STW has recently been commissioned as part of the outputs required by the Office of Water Services (Ofwat) under AMP3 and will be used to boost DO levels in the upper reaches of the Tideway when discharges from the CSOs or Mogden storm tanks threaten this part of the river.

In the past, the use of hydrogen peroxide has been partially successful in preventing large-scale fish mortalities and consideration is being given to supplementing the existing installations. The use of peroxide is only effective at dealing with the deoxygenating effects of the CSOs and makes no contribution to meeting the aesthetic or health risk objectives.

Hydrogen peroxide is a very reactive and aggressive chemical. Under certain conditions it can be toxic to aquatic life and a safety hazard to river users. It cannot therefore be used in a widespread and uncontrolled manner. Clearly this imposes limitations on the extent to which the existing installations can be expanded and this is currently being reviewed.

Consideration is being given to the provision of a new installation possibly sited at the Crossness STW, to deal with DO problems in the middle reaches; and a review is being undertaken of the optimum quantity of peroxide that needs to be stored to deal with problems in the upper reaches.

b) Installation of two additional water quality monitoring stations

Two new stations may be needed for additional effective real-time monitoring of the proposed Mogden peroxide plant to optimise dosing of the river in the Richmond to Brentford area. This should make it possible to minimise any drop in DO more effectively than before.

c) Provision and Operation of specialised craft to remove visible/floating sewage solids

A large amount of general litter ends up in the river. This includes naturally occurring foliage, leaves and weeds up to large pieces of driftwood, and much human derived waste of all sorts from shopping trolleys, household rubbish and debris thrown from river traffic. It is estimated that litter from the CSOs accounts for some 10% of the overall total. Much of the floating litter (perhaps 60%) is deposited at the strand line when the tide recedes, and much of the sewage-derived matter will sink to the bed, sometimes to be exposed on the foreshore at low tide.

Skimmer boats for the removal of general litter and weed growth are already in use, operated by the Port of London Authority (PLA). These operate on the river and help with other efforts to clean parts of the foreshore made by a number of voluntary agencies and the local authorities. The existing river craft are somewhat restricted in the way they can collect litter by a number of factors: tidal movements, their draught so that in shallow tidal water they have limited ability to collect litter from the strand line, operating only in daylight hours and the maximum charge of rubbish before unloading becomes necessary. Currently each boat can clear about 20 tonnes of litter on a good day.

In proposing new craft whose objective is to clear sewage debris it is fairly obvious that these will be unable to avoid large items of debris and will thus inevitably be dual function in operation, collecting material both as above and incorporating fine screening for the smaller sewage solids, paper and plastics. Current proposals are that the new craft will have a specialised prototype barge based operating platform for the above method of collection pushed by an interlocking powered vessel of the same design as those in use by the PLA. It should be no more than 6m wide and with the maximum allowable draught of 1.5m. The screen width would be maximised at about 4m and would incorporate rotors or conveyors to draw water in to coarse and medium preliminary screens and a third 6mm band screen filtering something over $2m^3/s$ of river water. Operational experience at STWs suggests such screens will require pressure washing. The plant on board will need to be able to compact and store the screenings in suitable containers for transfer to PLA barges, which are already stationed at many points along the Tideway, or off-loading at refuse-transfer wharves

The prototype craft will be commissioned and observed in operation for a period so that the design of any further craft may be refined and improved. They will probably be moored at Greenwich and are expected to be available for operational use for as much as 180 days per year. Deployment for several days at a time is allowed for, when called out the boat(s) would, where the depth of water is sufficient, be positioned and remain in the slicks of discharged sewage moving with the tide. They would skim off surface floating debris and draw in subsurface material to depth of about a metre.

Assuming this length of operation some of the most conspicuous sewage derived material could be removed, improving the aesthetic appearance of the river. It is hoped that some of the litter, which has been deposited and re-floated from the foreshore, may be collected. It is anticipated that the new craft will be able to supplement the existing debris collection efforts and make a notable difference to the slicks of sewage so often seen after rainfall events. Study suggests that a small reduction in sewage solid material and general litter could be achieved, though the operation would probably be expensive and inefficient in terms of percentage of total solids removed.

The estimate for the two craft is approximately £6M including the pusher boat.

The current programme is for the craft to be commissioned and in operation towards the end of 2006. Whether these will have a useful impact could then be established and further craft deployed in the light of the knowledge gained.

d) Provision of Advice to Recreational River Users

The problems of microbiological contamination are thoroughly discussed in ref. 2. The options available to take forward this issue are under consideration by various bodies represented on the Steering Group.

Table 1.2 - Summary table for the Interim measures

Measure		Estimated Improvement			Comments
		DO	**Litter**	**Public Health**	
1a	Peroxide installation at Crossness	<1%	Nil	Nil	mitigate low DO in the middle reaches
1b	Review capacity of up-river peroxide installations	-	-	-	assist in protecting upper reaches
2	Installation of two additional monitoring stations	Trace	Nil	Nil	optimise use of peroxide
3	Provision and operation of specialised craft to remove sewage solids	Nil	<1%	Nil	Remove visible floating sewage solids
4	Provide Public Health Advice regime	-	-	-	Education, awareness to reduce potential risks

It is clear that on their own such measures will have a small actual impact on Tideway pollution. However, they may be useful as part of a package of remedial measures.

1.3. Smaller Scale Measures

Smaller scale measures have been considered that may provide some worthwhile benefit and could also form part of the long-term solution. These typically involve alternative methods such as storage involving lower levels of intervention and treatment than the preferred option A(ref), or local screening or treatment plants. Less flow would be intercepted so some polluting flow would still discharge to the river. Other options include upper catchment rainfall intervention or separation of the system, and even some domestic ideas, which could involve public participation. Some would be able to be incorporated later into a more complete scheme by forming part of initial phases of implementation. Several options, for example screening plant at Acton or Hammersmith PS or treatment plant at Heathwall, would become partially or wholly redundant if a full-length tunnel were to be implemented later, and only provide limited benefit and partial compliance with the objectives for a limited duration.

The smaller measures considered include:

1. Smaller storage tunnels including “river Lee” options for the Olympics
2. Treatment plant at Abbey Mills
3. Screening plant where feasible
4. Dispersed storage units (distributed across London)
5. Local application of Sustainable Drainage Systems (SuDS)
6. Separation of the sewerage system (in whole or in part)
7. Trade effluent control of fats and grease

and a number of Domestic Options:

8. Removal or Reduction of Sewage Litter at Source
9. Water Butts
10. Some Other Domestic Ideas

COST BENEFIT

The earlier proposed solutions were subjected to a cost benefit analysis, which cannot easily be repeated for the newly considered measures. Even if this could be done it would be unsatisfactory given that, apart from the preferred option A(ref), none of these includes the flows from Abbey Mills PS, which are now known to be significant.

To provide a basis for cost benefit comparisons (see table 0.4 above) the smaller scale measures have been compared with the preferred option A(ref) in the three main areas for improvement: reduction in sewage-derived Litter, improved Levels of DO and reduction of the number of Elevated Health Risk Days. It is assumed that the preferred option A(ref) scores 100% in each of these categories and each of the new measures has been assessed by making reasonable assumptions about the discharges: numbers, locations and quantities, and by making broad comparisons with elements of the earlier solutions which were studied in detail and reliable data obtained. An attempt has been made to include benefit scores for the Interim measures but these are small in comparison to those for the measures below.

1.3.1. Smaller Storage Tunnels

In contrast to the preferred option A(ref) this could be either a smaller diameter tunnel over a similar length, or similar diameter tunnels over shorter lengths. The most sensitive reaches of the tidal Thames are in the west, e.g. in terms of recreational use, but research has shown that a successful storage option would best be able to deliver return flows near to the works in east London.

A full length but smaller diameter tunnel sees storage volumes fall significantly as diameter decreases and below 6m it is considered that such a tunnel would not fill in a hydraulically stable manner. Economies of construction show that as the tunnel diameter decreases the unit cost of storage volume constructed increases substantially. A 5m tunnel would give half of the effective storage of the proposed 7.2m but would be much more than half the capital cost (see 2.6).

Driving the interconnecting tunnels from the interception shafts will be prevented if the diameter is reduced below about 6m. Below 4m in diameter the main tunnel would not be able to receive side connections without reception shafts constructed in the middle of the river.

In order to assess the benefits of the smaller tunnels a number of assumptions have been made. The reduction of sewage solids discharged is assumed proportional to the volume intercepted by storage options compared with A(ref) for both Litter and DO. This is rather simplistic and ignores the characteristics of the first flush whose duration, from actual observations, can be quite long. Often a series of sequential first flushes are observed due to the wide range of times of concentration for flow to reach CSOs from different parts of the catchment. Also tidal movements may carry solids discharged from unintercepted CSOs e.g. following a significant overflow discharge, along the Tideway so that they may have an impact on any reach of the river served by a partial option. The discharge figures used in estimating the intercepted flow volumes and option benefits are derived from the Compliance Test Procedure (CTP), which involved modelling some 154 real storm events for which good recent data was available (see Appx I). For Health Risk Days a degree of judgement has been used in estimating the level of improvement on the current total of 120 annually. The total volume discharge from the CSOs annually is assumed to be 32 million m^3 as explained below (see 1.5.3)

1.3.1.1. Review of Option H

A shorter storage tunnel between Hammersmith and Heathwall was previously considered in detail as Option H (see diagram and refer Solutions group report Vol 1). A 9m diameter tunnel would intercept approximately 25% of the total spill flow to the Thames/River Lee and provide some measure of protection to the western and most sensitive reaches of the river. The CSOs downstream of Heathwall would still discharge and tidal movements could carry pollution to the sensitive upstream reaches and so environmental impact is still likely to occur.

Two levels of intervention have now been considered using two smaller tunnels and two larger ones and the costs and benefits assessed. The smaller tunnels would provide less storage and return the flow into the sewerage system at the maximum rate allowable in the vicinity of Heathwall. If it should be necessary for operational reasons to exceed this rate a limited surplus capacity could be provided which would be screened before returning to the river at Heathwall. This lower level of intervention would be achieved utilising the land currently available at Heathwall and the screening plant would be the largest size that could be accommodated on the site. The higher level of intervention would entail need to acquire a larger site at Heathwall involving land purchase and more involved planning approvals so that a primary treatment plant could be located at Heathwall to deal with larger volumes of stored flow and higher pump-out rates.

Under Option H flow from 18 CSOs (EA report category 1 & 2) is intercepted, stored and subsequently returned to the sewerage system. For larger events, bypass flows would be screened and in the largest options, storm treatment plant would be provided. Option H could be built as the first phase of the preferred option A(ref) though this has the disadvantage that it later results in a number of stranded and thus redundant assets (see 1.4.2).

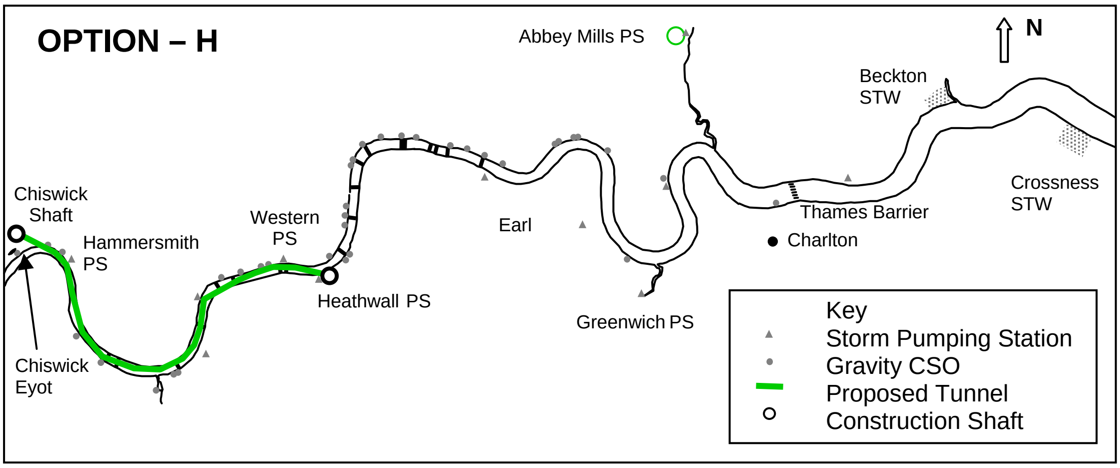


Figure 1.3.1.1

A number of different tunnel diameters have been considered:

Tunnel Diameter (m)	Storage Volume (m^3)	Typical Bypasses (pa)	Maximum Pump-out rate (m^3/s)	Comments
6.0	259,000	6 - 7	1.5	Maximum return rate to sewerage system Any excess flows screened and discharged to river
7.2	370,000	4 - 5	2.1	
9.0	579,000	2 - 3	3.4	Storm treatment plant required
10.6	803,000	1	4.6	

Table 1.3.1.1.a

The capacity of the existing interceptor sewers in the vicinity of Heathwall PS to accept return flows without causing overflow to the river is limited. There would be little opportunity to pump out the tunnel whilst filling. Modelling shows the spare capacity of the Low Level 1 (South), which passes adjacent to Heathwall PS, is approximately 0.5m^3/s. By utilising the existing Cross Thames Link tunnel to Western PS it could be possible to utilise the Low Level 1 (North), which has spare capacity of approximately 1m^3/s. To make use of the other more remote interceptor sewers would require extensive tunnelling work to make the connections.

For the two smaller diameter tunnels, the intercepted and stored flow would be returned to the system at the maximum return rate possible, extended over a longer period for the larger events. Protracted duration of storage could cause problems with septicity so excess flows up to 0.6m^3/s could be passed through a small screening plant and dosed with Hydrogen Peroxide prior to discharge to river. This level of treatment could adversely impact on the river and reduces the benefit of this variation.

For the two larger tunnels, storm treatment of the excess flows would be required prior to discharge to the river. This requires extra land to hold an enhanced primary treatment plant similar to that considered at Abbey Mills (see 1.3.2) whose extra cost can be seen in the summary table below.

PERFORMANCE

For the reach of the river covered by Option H the notional reduction in pathogen discharge and thus litter and DO is assumed to be proportional to the volume intercepted. Since observed evidence for specific catchments is limited, the above simple assumptions are considered the best available.

Most of the intercepted flow would be returned to the sewerage system for full treatment. For the larger options excess flows would be discharged to the river at Heathwall after storm treatment.

The flows intercepted for the above range is summarised below:

Tunnel Diameter (m)	Storage Volume (m^3)	Typical Bypasses (pa)	Extrapolated from 154 CTP rainfall events		
			Annual m^3 intercepted	%age of total flow intercepted	Annual discharge to river (m^3)
6.0	259,000	6 – 7	7,132,000	22.3	24,868,000
7.2	370,000	4 – 5	7,700,000	24.1	24,300,000
9.0	579,000	2 – 3	8,380,000	26.2	23,620,000
10.6	803,000	1	8,702,000	27.2	23,298,000

Table 1.3.1.1.b

Tidal flows will carry pathogens discharged from CSOs in the east to this section and, though smaller discharges may have a minimal effect, the influx from significant discharges may still generate two health risk days per event. Since this influx will now be diluted it is assumed that the number of health risk days arising in the section covered by Option H would be reduced from 2 to 1 per event, that is an average of 60 per year. However when Option H is bypassed the number of health risk days is assumed to be 2 per event as before.

The reduction in health risk days and percentage improvement, based on an assumed 120 health risk days for current situation, is shown in the table below:

Tunnel Diameter (m)	Storage Volume (m^3)	Typical Bypasses (pa)	Western Section			Whole Tideway		
			Health risk days (pa)	Reduction in health risk days	%tage Improve-ment	Health risk days (pa)	Reduction in health risk days	%tage Improve -ment
6.0	259,000	6 - 7	74	46	38	105	15	12.5
7.2	370,000	4 - 5	70	50	42	103	17	14
9.0	579,000	2 - 3	66	54	45	102	18	15
10.6	803,000	1	62	58	48	101	19	16

Table 1.3.1.1.c

Given the earlier explained method used for assessing the benefits of the options there are grounds for believing that these rather understate the likely benefits of the H option. This is because significant discharges in the eastern part of the tideway will not track so far upstream in some circumstances.

COSTS

The earlier costs for Option H were based upon a 9m diameter main storage tunnel from Hammersmith to Heathwall. These have now been reviewed and updated to 2004, taking into account a number of construction issues. Contingency is based on the proportion determined by the risk assessment (24.4%) as this Option H is a cut down version of A(ref).

Summary for Option H – Estimated Cost (£M) @ 2004						
Main Tunnel Diameter (m)	Bypass (pa)	Annual Volume Intercepted (m^3)	Percentage Improvement			Cost (£M)
			Litter	DO	Health Risk	
6.0	6 - 7	7,132,000	22.3	22.3	12.5	**449**
7.2	4 - 5	7,700,000	24.1	24.1	14	**496**
9.0	2 - 3	8,380,000	26.2	26.2	15	**620**
10.7	1	8,702,000	27.2	27.2	16	**697**

Table 1.3.1.1.d

From this it can be seen that the benefits of this option are slightly below 25%, although percentage improvement of health risk likely to be underestimated, of the target level set by the objectives, at a cost of 30% - 40% of the cost of option A(ref).

1.3.1.2. Option H+

Under this option various additional facilities were considered to augment Option H and increase the level of benefit. These included:

1. Abbey Mills Storm Treatment
2. Screening Plant for Deptford PS and Charlton Storm Relief
3. Screening Plant for Earl PS

Two further items were considered for inclusion but were ultimately rejected from H+ as being uneconomical and very difficult to implement:

4. Screening Plant for North Eastern Storm Relief
5. Extension of Storage Tunnel to intercept the Brixton SR and Clapham SR sewers

After much analysis the screening plant for the North Eastern Storm Relief outfall was omitted on grounds of cost, disruption and loss of amenity as well as the general problems with screening such a large gravity CSO, which are described in more detail below (see 1.3.3).

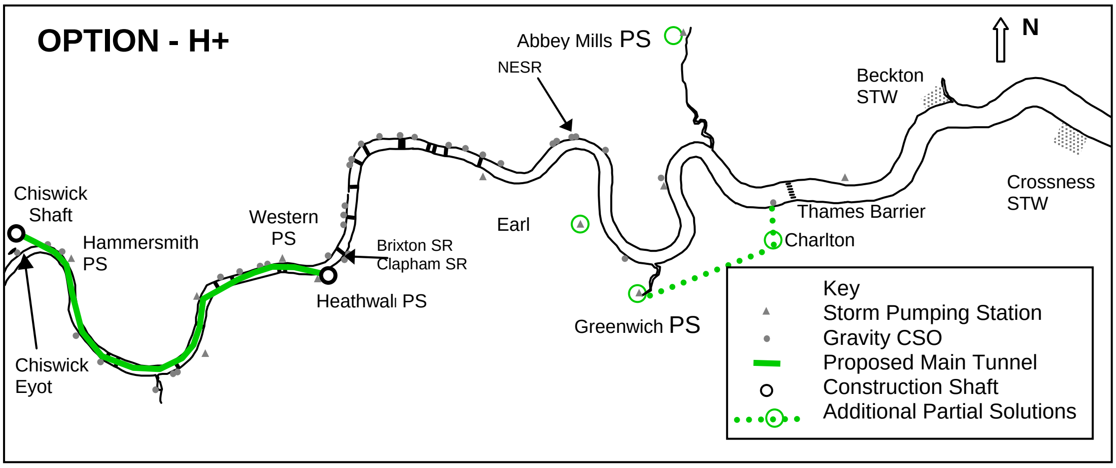


Figure 1.3.1.2

The proposed extension of the option H tunnel to intercept the Brixton and Clapham SR sewers was initially thought to be an easy win until considered in detail. These two CSOs outfall adjacent to the southern abutment of Vauxhall bridge and partly under the bridge approach making an inland shaft very hard to position and pushing the shaft location out into the river and thus presenting serious technical difficulties. In either position the shaft would be near to the Victoria line running tunnels and discussions with London Underground produced great concern with the potential impact of construction on the operation of the railway.

The best fit produced an extension to Option H tunnel whose total cost, estimated at £319M, would add the interception of less than 2% of the Tideway discharges to the option. Since this would make H+ more expensive than the preferred option A(ref) these works were omitted from H+ at this stage.

The installation of storm treatment plant at Abbey Mills to achieve a 60% BOD reduction was included and is described in detail below (see 1.3.2).

The screening plant for Deptford (Greenwich PS) and Charlton would be located at the existing Thames Water site at Charlton Chalk Pits over the SOS (southern outfall sewer). A 5m-diameter tunnel would be required to transfer the flows from Deptford to Charlton, together with an additional outfall tunnel and pumping plant to lift the transferred flows to the screening plant.

Despite the general difficulties of remote screening plants, the CSOs from Charlton and Earl PS have the advantage of land availability and existing operational installations whose maintenance regimes could be extended to allow for the new plant.

The scope for Option H+ therefore includes a storage tunnel from Hammersmith to Heathwall PS (as Option H), supplemented by enhanced primary treatment plant at Abbey Mills, screening plant for Earl PS and screening plant for Deptford PS and Charlton Storm Relief.

PERFORMANCE

The reduction in the discharge of sewage solids by screening is assumed to be proportional to the volume intercepted by the storage tunnel in line with the data for option H. However for the screening plant at Charlton and Earl PS the intercepted flow is preceded by pumping. From operating experience of the new screens at Abbey Mills it is known that the capture of sewage solids is much lower than expected. It is generally accepted that the sewage solids are macerated by the pumping action and tend to pass through the screens. Therefore screening is much less effective after pumping.

The treatment plant at Abbey Mills is assumed to reduce BOD for those discharges by 60%. This value is obtained from the published results of the pilot trial for deep bed filters. However this may be an optimistic assumption. The potential performance of this treatment plant is discussed further in 1.3.2. The reduction in BOD from screening alone is insignificant and is assumed to be negligible. Therefore the reduction in BOD is derived from the proportion intercepted by the storage tunnel plus 60% of the treated flows discharged from Abbey Mills.

Screening alone will not reduce the discharge of pathogens; therefore the provision of screening plant will not reduce the number of health risk days. As Abbey Mills discharges to the river Lee, it is assumed that treatment of these flows will not reduce the health risk days for the Thames. Overall the impact on Health risk days will be just the same as for Option H on its own.

The figures for the overall improvements achieved by option H+ are tabulated below and show an aggregate benefit of just over 50% of the full objectives.

Main Tunnel Diameter (m)	Number of Bypasses (pa)	Volume Intercepted Annually (m^3)	Percentage Improvement		
			Litter	DO	Health Risk
6.0	6 – 7	29,127,000	81.1	51.6	12.5
7.2	4 – 5	29,694,000	82.9	53.4	14
9.0	2 – 3	30,375,000	85.0	55.5	15
10.7	1	30,687,000	86.0	56.5	16

Table 1.3.1.2.a

COST

The previous estimated costs for the three extra sites have been reviewed and updated and for Abbey Mills the filtration treatment flow-through rate has been increased following subsequent advice from the Consultants who evaluated the option (see 1.3.2).

Additional Partial Solution	Cost £M @ 2004
Enhanced Primary Treatment at Abbey Mills	399
Screening plant at Earl	101
Screening plant for Deptford and Charlton, inc transfer tunnel	429
Total	**929**

Table 1.3.1.2.b

Adding these costs to the storage tunnel Hammersmith to Heathwall for the range of tunnel diameters and costs as for H gives:

Main Tunnel Diameter (m)	Estimated Cost £M @2004		
	Tunnel	Sites	Total
6.0	449	929	**1,378**
7.2	496		**1,424**
9.0	620		**1,549**
10.7	697		**1,626**

Table 1.3.1.2.c

From this it may be concluded that Option H+ offers about 50% of the target benefits for between 80% and 96% of the cost of the preferred option A(ref). The inclusion of the Brixton and Clapham CSOs would raise the estimated benefits by two percentage points making the estimated overall benefit 52% for the smallest variation, for the same cost as A(ref).

1.3.1.3. The Olympic Games

The main site chosen to hold the Olympic Games is a derelict industrial area to the north of Abbey Mills pumping station (see drawing). The site is crossed from west to east by the NOS (Northern Outfall Sewer) and from north to south by a tidal stretch of the river Lee, which, in the vicinity of the Olympic park, currently receives discharges from two outfalls: Wick Lane CSO and Abbey Mills pumping station (see fig 1.3.1.3.a and Ref 13).

The Wick Lane CSO has potentially the greater impact, as it is located centrally within the site. Recent analysis has shown that the outfall can discharge 16,000m^3 in a typical rainfall event.

Abbey Mills is the largest single CSO discharge in the whole of London and in a summer storm event can pump volumes of 500,000m^3 or more in a few hours at rates up to 45m^3/s. Such large discharges are common: the pumping station is much more sensitive to light rain than Wick Lane and its operation is also influenced by the need to manage flows arriving at Beckton STW. Operational experience suggests that the chances that the pumping station will not discharge, or can be prevented from discharging, in the two-month midsummer period are negligible. The operational risk will reduce with the completion of the ongoing refurbishment and capacity improvements at Beckton, but some discharge from Abbey Mills in this period is virtually certain. The modelling group has assessed the risk of a discharge from either outfall as virtually 100% during the period June to October and 99.5% in the period July to August (Ref 13).

Although the outfall is downstream of the Olympic site, the effects of a significant discharge could be transferred upstream to the Games' site by the tide (see fig 1.3.1.3.b).

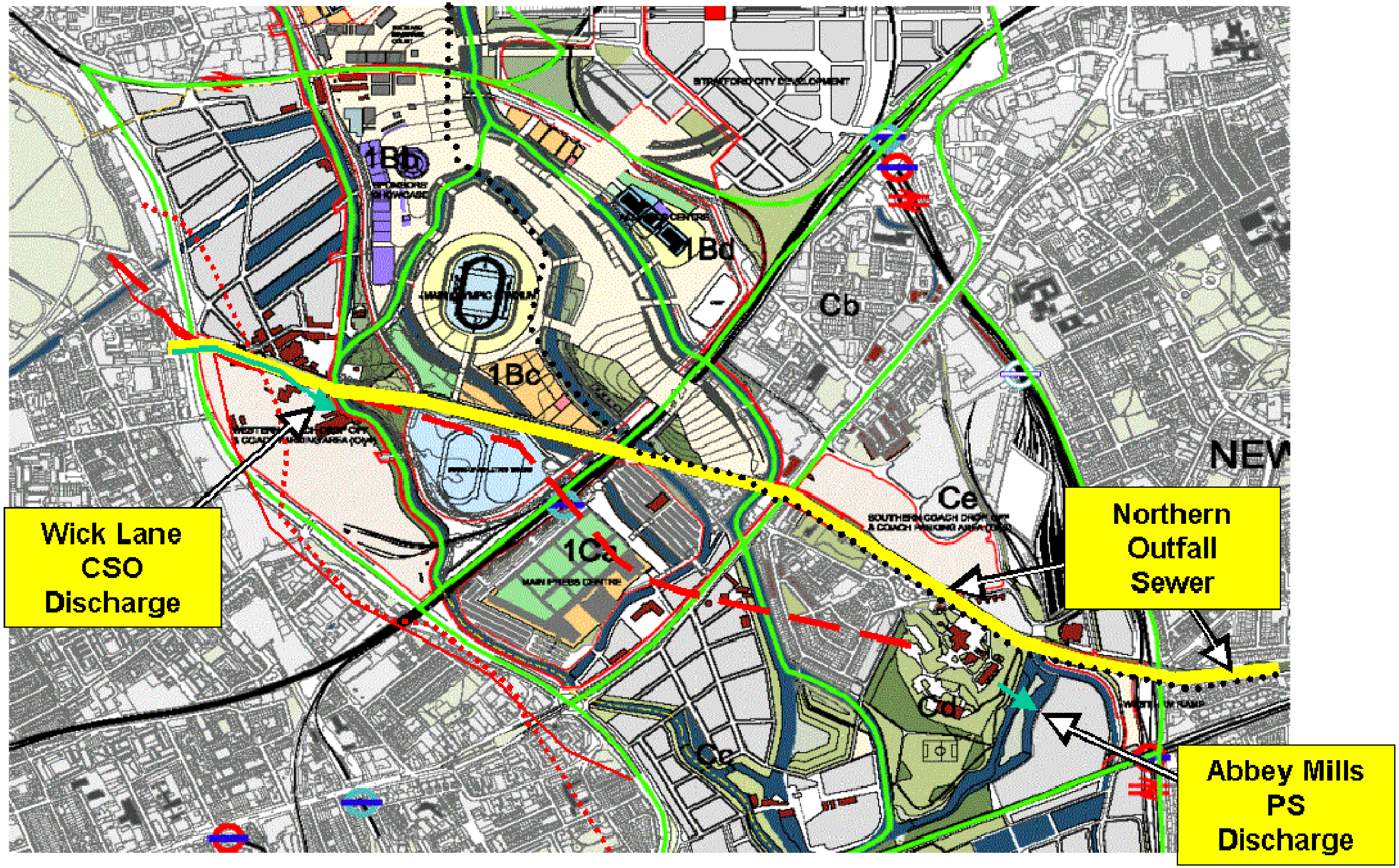


Figure 1.3.1.3.a Olympic Development Zone – Major Trunk Sewers

Northern Outfall Sewer	North London Flood Relief
Deephams to Beckton Sludge Main (Disused)	Low Level 1 Wick Lane Br
	Hackney to Abbey Mills Sewer

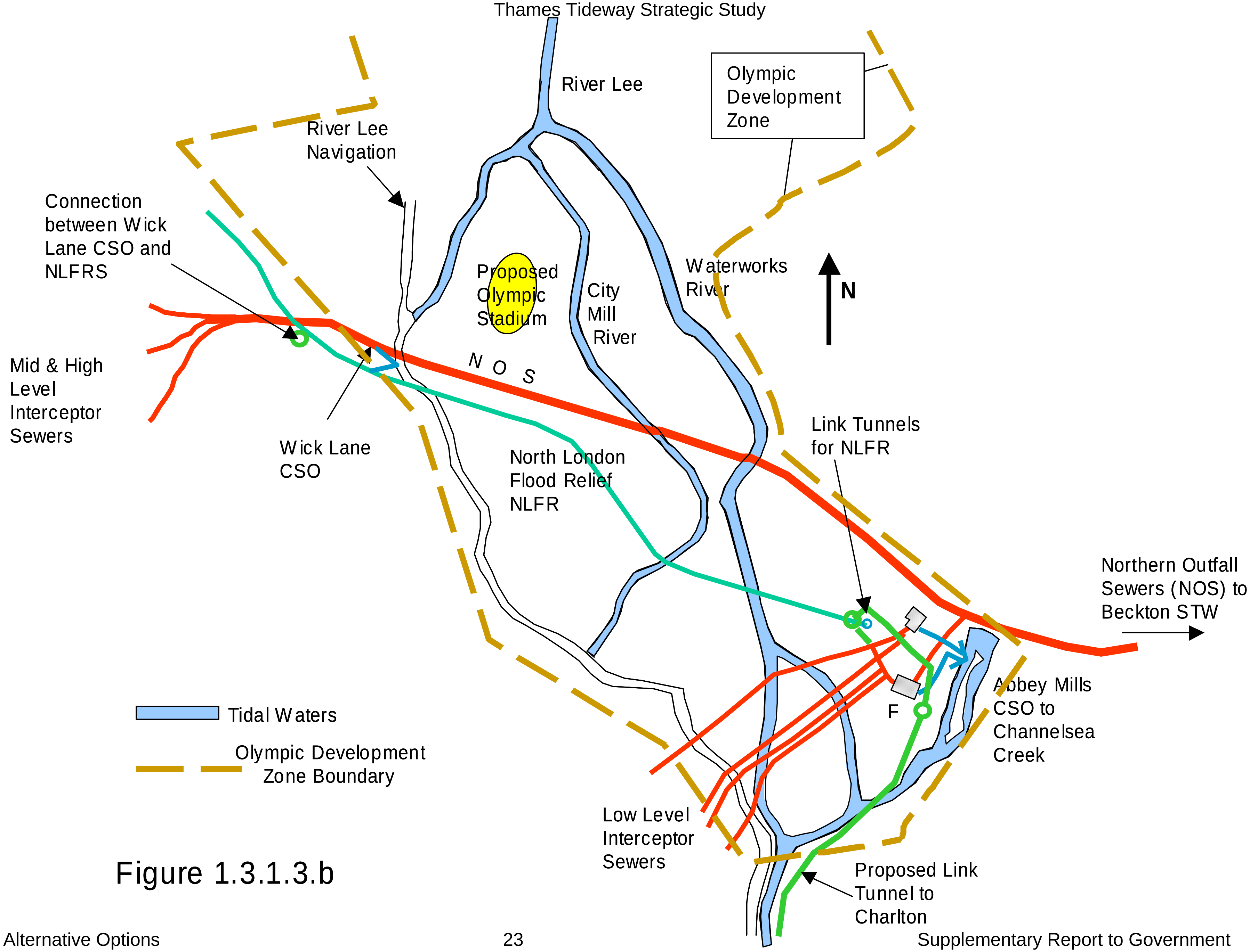


Figure 1.3.1.3.b

1.3.1.4. Mitigation Measures

1. SCREENING

The discharge from Abbey Mills already receives screening, but observations show that large quantities of organic matter continue to pass through the screen, and slicks of sewage are still evident in the Lee after discharges. The proposed further mitigation measures are therefore diversion or storage or a combination of the two. It should be appreciated that it is not possible for the measures provided to guarantee that there will be no discharge at all but the risk of this occurring can be reduced to acceptable levels compared with the existing situation.

At Wick Lane, a basic scheme for providing screening has been evaluated at an estimated outline cost of £45M. This high value reflects the specific difficulties of installing such a plant in this vicinity including land acquisition and bunker construction to avoid surrounding developments. This option is not being taken any further at this stage.

2. DIVERSION OR STORAGE

a) Wick Lane

This CSO relieves excess flow from the NOS flowing direct to Beckton STW. The overflow chamber is located at Wick Lane Depot near Old Ford and discharges via twin culverts, located directly under the NOS barrels, to the river Lee. The outfall can also receive an even larger flow from a junction with the Low Level sewer No. 1 (Wick Lane Branch) via another overflow.

Locally dedicated storage for the combined Wick Lane CSO flows would need to be about 16,000m^3 to prevent significant risk of discharge. This could be provided by a shaft 25m in diameter and 35m deep which would be difficult to locate near the outfall.

Another proposal is to intercept the flows near Wick Lane Depot and transfer them via a new tunnel 1500m long and 2.5m in diameter to Abbey Mills. A detailed assessment has not yet been carried out as other factors, which may impact on interception of this CSO have yet to be resolved.

The North London Flood Relief Sewer passes directly under the depot and a cross-connection into this sewer, which terminates at Abbey Mills, may present a solution. This would require alterations to the junction at Abbey Mills where currently the sewer is pumped out at a low rate.

The influence of these factors will determine the appropriate method for intercepting the Wick Lane CSO. In summary the basic options for interception are:

- Provision of dedicated storage tunnel or shaft for the discharge from Wick Lane CSO with return pumping to the NOS after storm events. *Estimated cost £13M.*
- Interception of discharge and transfer to Abbey Mills PS via a new dedicated tunnel. *Estimated cost: £9.5M*
- Interception to the existing North London Flood Relief Sewer, including modifications to the current pump out arrangements at Abbey Mills. *Estimated cost £6M*
- Localised interception to the North London Flood Relief sewer seems to be the most likely option. The cost of the works to divert Wick Lane to Abbey Mills is modest compared with the solution for Abbey Mills itself and could be put in hand straight away.

b) Abbey Mills

Local storage and treatment have been considered for Abbey Mills but the reduction in pollution achievable by these measures would not enable the overall Tideway objectives to be fully met. Also such works would cost more than connecting Abbey Mills to the preferred Tideway tunnel option A(ref).

Earlier modelling analysis has shown that the storage required for Abbey Mills and Wick Lane should be some 740,000m^3 to reduce the frequency of discharge to below once per year and this is regarded as an acceptably low level. Storage and transfer options dedicated to relieving the difficulties faced potentially by the Olympic park are discussed below.

3. THE STW UPGRADE WORKS

Analysis has been carried out to see what impact the upgrade works at Beckton and Crossness STWs would have on the discharges from Abbey Mills PS and Wick Lane CSO. The improvements at Crossness will have no impact on the north side of the Thames.

By increasing flows to treatment at Beckton STW, the AMP4/5 works will have a negligible effect on the frequency of storm discharge at Wick Lane.

Abbey Mills PS currently discharges storm water with events as small as 5 mm of rain. Increasing the treated flow at Beckton STW should not significantly change the frequency of operation of Abbey Mills CSO as the rate of storm discharge at the onset of pumping to the river is already much higher than the increased capacity at the STW. However, the volume discharged is expected to be reduced significantly by better flow management after storm events reducing the duration of ongoing spills.

1.3.1.5. The River Lee Options

1. OPTION 1 (Via Charlton)

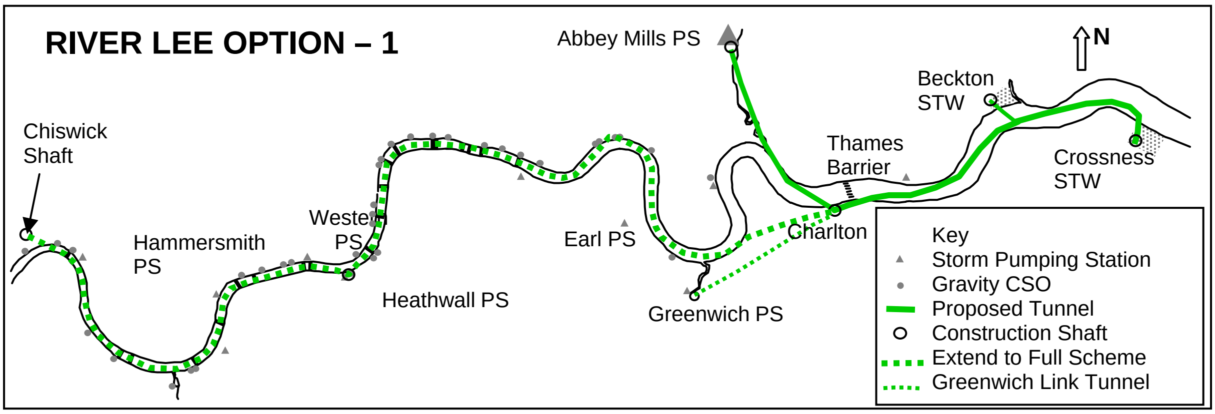


Figure 1.1.3.5.a

The above analysis has so far resulted in two main Tideway sub-options dedicated specifically to the river Lee CSOs and their impact and costs have been assessed both as independent schemes and as part of a larger option H++ or as the first phase of the preferred option A(ref).

This option represents essentially the eastern section of the storage tunnel A(ref). Three basic variations are considered as follows:

1. Tunnel diameter 7.2m as proposed for the preferred option A(ref). This would provide 432,000m^3 of storage, which, combined with 10m^3/s pump-out to storm treatment at Crossness should limit the number of bypass events to the Lee to 4 or 5 per year. Completion of the full scheme could be achieved later by extending the main 7.2m diameter storage tunnel from Chiswick to Charlton.
2. Tunnel diameters increased to 8.5m. This would provide 749,000m^3 of storage, which combined with 10m^3/s pump-out to storm treatment at Crossness should limit the number of bypass events to the Lee to just less than one per year. Completion of the full scheme could be achieved by later extending the main storage tunnel at only 6m diameter from Chiswick to Charlton.

3. Add the interception of Greenwich PS CSO via an interconnecting tunnel between Greenwich and Charlton. Increase storage to 820,000m^3 by increasing tunnel diameters to 9m. The number of bypass events to the Lee should be limited to just less than one per year. Completion of the full scheme could be later achieved by extending the main storage tunnel at only 6m in diameter from Chiswick to Charlton to provide additional storage.

These variations are summarised in the table below:

Variation	**Tunnel diameter (m)**		**Storage Volume (m^3)**	**Bypasses to Lee (pa)**	**Construction Period (months) (Ref 2)**	**Cost (£M) (Ref 3)**
	Abbey Mills To Charlton	*Charlton to Crossness*				
1	5.0	7.2	432,000	4 - 5	72	710
2	8.5	8.5	749,000	<1	76	888
3	9.0	9.0	820,000	<1	76	936

Table 1.1.3.5.a

This option will provide sufficient storage, pump-out and treatment to significantly reduce discharges to the river Lee. However the overall programme for delivery is 72 to 76 months. A start on planning and design in January 2006 would give a completion date of April 2012. This is particularly close to the proposed opening date for the Olympics. Any delay in planning, land acquisition or construction could prevent completion of this option in time for the Olympics.

2. OPTION 2 (Direct to Crossness)

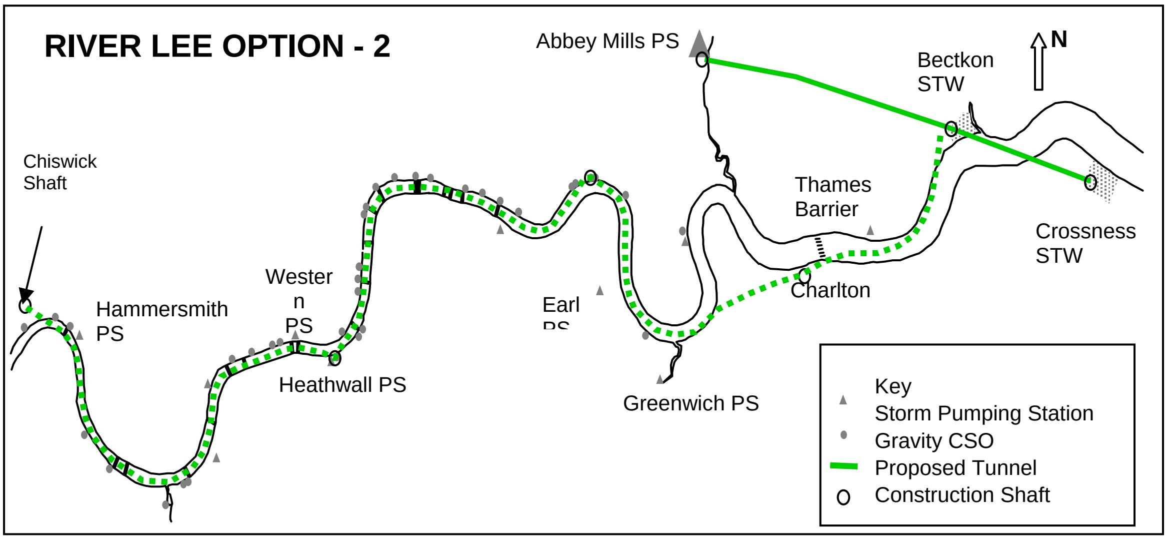


Figure 1.3.1.5.b

This option represents a storage tunnel direct from Abbey Mills to Crossness via Beckton. The tunnel is shorter in length than the previous option and needs to be 9.7m in diameter to produce the 740,000m^3 of storage required to limit bypass events to the river Lee to fewer than one per year.

Completion of the full scheme could be achieved by extending the main storage tunnel at only 6m in diameter from Chiswick to Charlton. The final connection between the Charlton shaft and the main tunnel just upstream of the Beckton shaft could be made just 3m diameter as it would be possible to withdraw the tunnel boring machine through the main tunnel. This could still facilitate the extension to the preferred option A(ref) and would significantly reduce the construction risk and cost.

In this scenario pumping plant would be required in the Charlton shaft to lift the flow during pump-out. This shaft would also have to incorporate a high level overflow to balance intercepted flows between the two main storage tunnels. These additional elements would increase the cost of the full scheme.

If 4 to 5 bypass events annually were considered acceptable, as in the first version of option 1 then the diameter of this tunnel could be reduced to 7.4m. Although this may give a slightly lower initial cost, the programme for delivery will be similar. Later completion of the full scheme would require a 6.75m diameter tunnel 27.2km long from Chiswick to Charlton. The cost of increasing the diameter from 6m to 6.75m may outweigh the initial saving.

These variations are summarised below. A detailed cost estimate and construction programme has only been produced for the 9.7m diameter tunnel. The changes to cost and programme for the smaller tunnel have been estimated in outline as an indication of the potential savings and should be confirmed during detailed design:

Diameter (m)	**Storage Volume (m^3)**	**Bypasses to Lee (pa)**	**Construction Period (months) (Ref 2)**	**Cost (£M) (Ref 3)**
9.7	749,000	<1	72	**781**
7.4	432,000	4 - 5	76	**737**

Table 1.3.1.5.b

This option will provide sufficient storage, pump-out and treatment to significantly reduce discharges to the river Lee. The overall programme for delivery is 67 months for the 9.7m diameter tunnel and a start in January 2006 would give a completion date of August 2011. This gives a better margin for completion in time for the Olympics in 2012 but is still a fairly high-risk strategy given the likelihood of delays due to planning or construction problems.

Reducing the tunnel to 7.4m in diameter would decrease the overall cost but will not reduce the implementation timescale. The cost of completing the full scheme later would also increase. As the storage volume is reduced the number of bypass events to the river Lee increases, thus there would still be a risk of a pollution event during the period of the Olympics.

3. DELIVERY TIMESCALES

It is important to stress that the above Options would present a challenge to be delivered by 2012 if normal constraints apply even if construction were approved now. Measures would have to be taken to fast track the planning approvals and EIA for the required works for the Olympics to enable completion by 2012. If normal planning procedures apply it is highly unlikely that these works would be completed in time for the games. The construction period cannot realistically be reduced to less than 5 years and the project would need to start in early 2006 to meet the deadline imposed by the Olympics.

Currently OPTION 2 would appear to be the better choice. A dedicated tunnel direct from Abbey Mills to Crossness would have a shorter construction period than the eastern section of A(ref) with forecast completion in the fall of 2011.

These Options have been assessed in order to present the most sensible method of implementing the Tideway project recognising the best way to facilitate CSO improvements to help with the preparatory work for the games. If the Olympics require a guaranteed improvement to the river Lee marine environment and the organisers are unable to fast track the planning issues, this option would presents a high risk approach to be achieved by the time the games commence.

1.3.1.6. Option H++

By combining Options H and the river Lee Option 2 a composite Option comparable to building the western and the eastern sections of the main preferred tunnel option A(ref) and has been put forward as a combined east and west London option H++.

It should be appreciated that H++ is an extension of H and not H+. The extensions for H+ would take the cost of H++ way above that of the preferred option A(ref) but still not achieve the target levels of benefit. The likely forecast costs and benefits of such a combined option can be inferred from the data in table 0.4 but a separate evaluation is not presented in this report.

Initially the eastern section of A(ref) river Lee Option 1 was considered for this second section. However the study of options that could be implemented to facilitate development of the Olympic Village and regeneration of the Lee Valley found that it was unlikely that this could be implemented in time for 2012. A larger tunnel constructed on the shorter route Abbey Mills to Beckton to Crossness could be implemented before the end of 2011. The disadvantage of this option is that flows from Greenwich and Charlton are not easy to intercept and are therefore excluded due to time constraints.

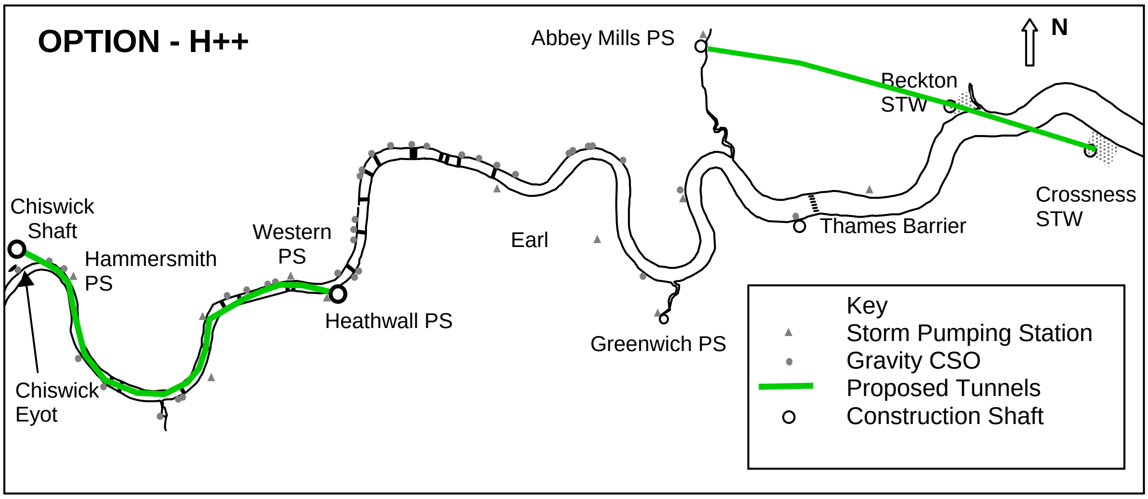


Figure 1.3.1.6

The storage volume required for the western section is detailed above (option H). The volume required for the eastern section, to intercept Abbey Mills flows only, is influenced by the capacity of pump-out and assumes that a performance similar to A(ref) is achieved as believed necessary for the river Lee options. The tunnel can be pumped out to storm treatment at Crossness during filling and for the first stage of emptying at a rate of 9.6m^3/s. The second stage of emptying is to full treatment at either Beckton or Crossness, dependent upon available capacity.

Pumping out during filling increases the number of larger events that can be captured. This aspect has been previously assessed and is reviewed below. Typically the higher volume events at Abbey Mills are of longer duration (determined from review of pumping records). The table below summarises the storage requirements for the range of volumes from the 154 CTP events:

Typical Bypasses (pa)	Event Volume (m^3)	Minimum hours pump-out (hrs)	Pump-out Volume (m^3)	Net storage volume req'd (m^3)	Tunnel Diameter (m)	Actual Volume (m^3)
6 – 7	450,000	3	144,000	306,000	6.3	312,000
4 – 5	610,000	5	180,000	430,000	7.4	430,000
2 – 3	870,000	9	324,000	546,000	8.3	541,000
<1	1,340,000	17	612,000	728,000	9.7	739,000

Table 1.3.1.6.a

PERFORMANCE

The interception performance of the east and west tunnels combined is summarised below:

Tunnel Diameter (m)		Total Storage Volume (m^3)	Typical Bypasses (pa)	Extrapolated from 154 CTP events		
West Tunnel	East Tunnel			Total Volume intercepted m^3	Fraction of Total intercepted	Total discharged to river m^3
6.0	6.3	571,000	6 - 7	20,048,000	62.6	11,952,000
7.2	7.4	800,000	4 - 5	21,433,000	67.0	10,567,000
9.0	8.3	1,120,000	2 - 3	22,994,000	71.9	9,006,000
10.6	9.7	1,542,000	<1	24,053,000	75.2	7,947,000

Table 1.3.1.6.b

As with all the versions of the smaller storage tunnels cost can be kept down by accepting more bypasses to the river. In the eastern section, it may be desirable to minimise the risk of a significant overflow discharge during the period of the Olympic Games. A compromise version is presented which allows 4-5 bypasses on the west side but retains the acceptable frequency on the Lee as below:

Tunnel Diameter (m)		Total Storage Volume (m^3)	Typical Bypasses (pa)		Extrapolated from 154 CTP events		
West Tunnel	East Tunnel		Thames West	Lee	Annual m^3 intercepted by both	Fraction of Total intercepted	Annual m^3 discharged to river
7.2	9.7	1,109,000	4 - 5	<1	23,050,000	72.0	8,950,000

Table 1.3.1.6.c

As for Option H, the reduction in the impact of both sewage derived solids and BOD is assumed to be proportional to the discharge volume intercepted.

Generally in terms of Health Risk only the impact in the Thames itself has been considered. It is thus assumed that the additional flow intercepted from Abbey Mills will not reduce the number of health risk days for the Thames. The improvement therefore can only be as calculated for Option H alone.

It is accepted, of course, that intercepting the flow from Abbey Mills will significantly reduce the pollution of the river Lee and correspondingly reduce the quantity of pathogens discharged thereto and this will be evident in the Thames itself, but this will only reduce the concentration of pathogens and not the extent of the Tideway that will be affected. Owing to the high increase in pathogens caused by even modest CSO discharges the concentration rarely falls below WHO guidelines for bathing waters even with substantial reductions from individual or partial groups of outfalls. However, as the Thames Tideway is not bathing water the objective is to protect the health of recreational users.

COSTS

The estimated costs for the Abbey Mills to Beckton to Crossness storage tunnel (the river Lee section) are detailed below. It should be noted that the screening, treatment and pumping capacity is the same for all variations. The ability to pump-out at a significant rate (approximately $10m^3/s$) decreases the storage volume required to intercept an event:

<table>
<tr><th rowspan="2">Main tunnel diameter</th><th colspan="8">River Lee Section - Estimated Cost (£M) @ 2004</th></tr>
<tr><th>Tunnel & Structures</th><th>Screens</th><th>Treatment</th><th>Pump & Power</th><th>Contingency</th><th>Resource Costs</th><th>Land Costs</th><th>Total Cost</th></tr>
<tr><td>6.3</td><td>360</td><td rowspan="4">36</td><td rowspan="4">58</td><td rowspan="4">56</td><td>124</td><td>61</td><td>20</td><td>716</td></tr>
<tr><td>7.4</td><td>376</td><td>128</td><td>63</td><td>20</td><td>737</td></tr>
<tr><td>8.3</td><td>393</td><td>132</td><td>65</td><td>20</td><td>760</td></tr>
<tr><td>9.7</td><td>408</td><td>136</td><td>67</td><td>20</td><td>781</td></tr>
</table>

Table 1.3.1.6.d

Combining these with the west Options as described gives a summary table for Option H++:

<table>
<tr><th colspan="2">Main Tunnel Diameters (m)</th><th colspan="2" rowspan="2">Bypass (pa)</th><th rowspan="2">Annual Volume Intercepted (m^3)</th><th colspan="3">Percentage Improvement</th><th rowspan="2">Cost (£M)</th></tr>
<tr><th>West</th><th>East</th><th>Litter</th><th>DO</th><th>Health Risk</th></tr>
<tr><td>6.0</td><td>6.3</td><td colspan="2">6 - 7</td><td>20,048,000</td><td>62.6</td><td>62.6</td><td>12.5</td><td>1,165</td></tr>
<tr><td>7.2</td><td>7.4</td><td colspan="2">4 - 5</td><td>21,433,000</td><td>67.0</td><td>67.0</td><td>14</td><td>1,233</td></tr>
<tr><td>7.2</td><td>9.7</td><td>4 - 5</td><td><1</td><td>23,050,000</td><td>72.0</td><td>72.0</td><td>14</td><td>1,277</td></tr>
<tr><td>9.0</td><td>8.3</td><td colspan="2">2 – 3</td><td>22,994,000</td><td>71.9</td><td>71.9</td><td>15</td><td>1,380</td></tr>
<tr><td>10.7</td><td>9.7</td><td colspan="2"><1</td><td>24,053,000</td><td>75.2</td><td>75.2</td><td>16</td><td>1,478</td></tr>
</table>

Table 1.3.1.6.e

1.3.1.7. Smaller Tunnels - Recommendation

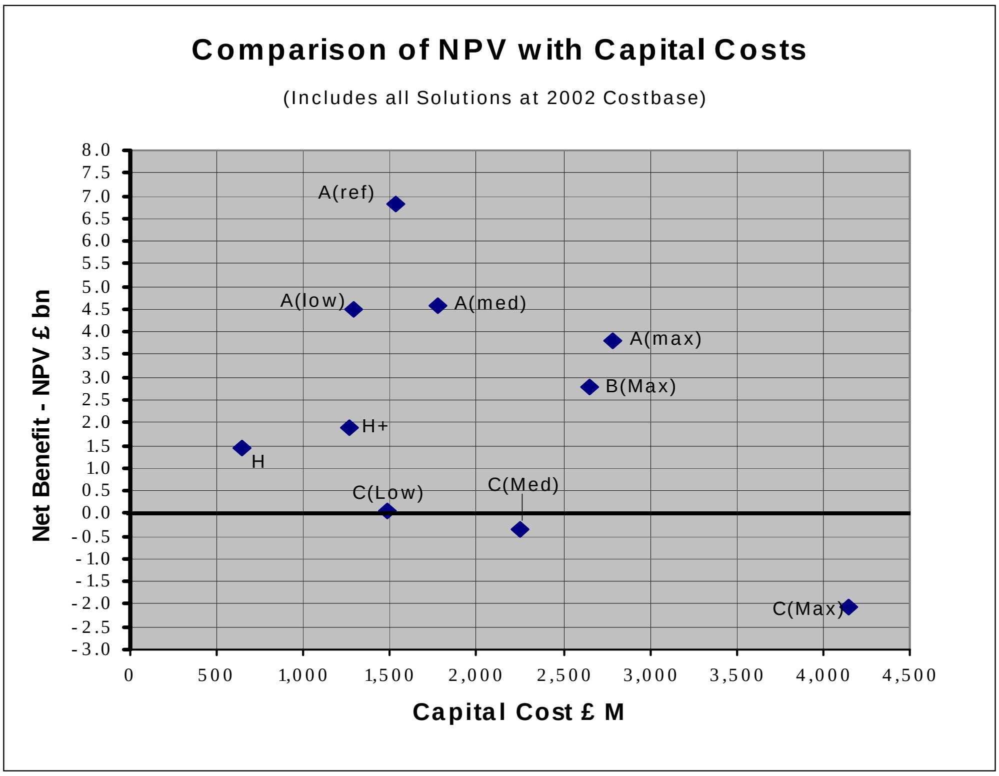
Now the Olympics are coming to London the opportunity arises to consider sewerage improvements around the site, and for London as a whole. For the desired beneficial improvements river Lee Option 2 is less costly and might prove slightly easier to implement. If approved it should be possible to ensure this can be incorporated into the preferred option A(ref), including the Charlton CSO, should this follow on later. Best value would be obtained by making this tunnel a uniform diameter over the entire route, which would be chosen to reduce the risk of discharge at Abbey Mills to acceptable levels. The critical factor is the total volume of storage. The preferred option A(ref) could be made 6m diameter from Chiswick to Charlton with an even smaller diameter tunnel from Charlton to link in either at Beckton or Crossness, which would be sufficient for drain-down requirements. Since speed is of the essence, any decision to implement this tunnel to protect the river Lee must be made now, pending any later decision over the main storage tunnel option.

1.3.1.8. Comparing the Tunnel Options

In the first phase of the main investigation the solutions put forward did not include Abbey Mills flows whose impact on the Tideway is now thought to be much greater than before. Modelling and feedback from operations suggests that Abbey Mills contributes on average half the total CSO discharge to the Tideway. The newer solutions described in this report all include Abbey Mills and Wick Lane flows and thus it is difficult to compare these with the earlier options in terms of cost and benefit. A(ref) always included the river Lee CSOs and therefore has a much larger beneficial impact than the earlier storage options as revealed by the chart below which shows the options presented graphically in terms of the NPV (net present value) from the Cost and Benefit report shown against the total capital cost (at 2002 prices).

All Options above the x-axis have a net positive benefit and represent an advance on the current situation. Clearly A(ref) is significantly better in cost benefit terms than any of the earlier options.

Table 0.4 also shows comparative figures for the smaller scale options in relation to A(ref).



1.3.2. Treatment plant at Abbey Mills

The provision of a treatment plant at Abbey Mills in the form of deep bed filtration of flows to remove fine solids has been previously considered (Ref 5) and has been further reviewed. This removes the polluting load associated with particulate matter but will not affect BOD in solution. Enhanced primary treatment should have the capability to reduce BOD load by approximately 60%. The CTP demonstrated that this process on its own is insufficient to comply with the DO standards.

The process is relatively novel for the treatment of storm sewage and it is envisaged that such plant may work successfully when receiving flows at a steady flow and loading rate, such as pump-out from a storage tank or tunnel, or a controlled STW inlet. There is however some doubt that such a plant would operate successfully when subject to such highly variable flow and loading rates, particularly when peak flow rates could be up to $45m^3/s$.

For such a high capacity plant, called upon to operate intermittently, it will be a significant operational challenge to maintain performance. It is therefore considered necessary to implement a degree of storage prior to treatment to smooth the variations in peak flow and a balancing storage tank of at least $150,000m^3$ volume is proposed. Due to the unproven reliability of the performance of such a novel installation a high degree of caution and contingency is reflected in the estimated cost. The layout of the site and the hydraulic constraints mean that it would be necessary to rebuild the existing screening plant.

Currently the Abbey Mills site is unmanned and the provision of totally automatic treatment plant with suitable reliability is likely to prove impractical. Experience shows that providing manual intervention in reaction to storm warnings would be a serious operational challenge and manning the site full-time when only storm flows require treatment would be similarly undesirable.

The revised cost estimate is tabulated below:

Treatment Plant at Abbey Mills – Estimated Cost (£M) 2004						
Structures	***Screening***	**Treatment**	**Pumping & Power**	**Contingency & Risk 30%**	**Resource Costs**	**Total Costs**
129	33	103	16	84	34	**399**

Table 1.3.2

The costs of installation are significant and exceed what would be required to connect Abbey Mills to the main storage tunnel.

1.3.3. Screening Plant Where Feasible

The provision of screening plant for all CSOs has been investigated in outline in Ref. 3 and in detail in Ref. 5. At most CSO locations providing screening plant is impractical owing to the lack of space in highly sensitive locations in central London and the extreme levels of disruption and high cost of construction. Screening plant may be possible at some sites and these were considered to augment the total screening capacity as part of option H+ (Ref. 4) and reconsidered as potential partial options in Ref. 6. The five sites most likely to be able to accommodate screening plants are at Heathwall including the SWSRS, Hammersmith, Acton, Charlton Chalk Pits and the NESRS. These sites could be screened at a cost now estimated to be over £600M, which is higher than the smaller partial tunnel solutions of option H. Such screening plant would remove sewage-derived litter from only 16% of the discharge. The other CSOs would continue to discharge and tidal effects would carry sewage to other parts of the river largely masking any improvements.

The one location where large scale screening plant has now been installed is at Abbey Mills pumping station where Thames Water land was available and special circumstances made this an ideal location. Abbey Mills is sited adjacent to the NOS in one of only a few places where a forward flow in the NOS continues during storm events thus enabling the return to the sewer of screenings wash water from the screen launder channel. At most CSO sites where there is no forward flow this wash water would either have to be stored, greatly complicating the operating procedure, or passed to the river thus minimising the reduction in pollution achieved by the screens.

Since the study began new data have been collected about storm sewage screenings from further use of the SCITTER rig and the new fine screens installation at Abbey Mills. Early estimates of average screenable solids expected to be collected on fine screens were in the range 400 mg/lt (0.4 kg/m^3) and upwards and at Acton this has been borne out with typical peak flow loadings during some events of 3000 mg/lt (3 kg/m^3) recorded by the SCITTER rig. However measurements from Abbey Mills are showing collection rates far lower than this at around 25-50 mg/lt (0.025-0.05 kg/m^3). It is now believed that this is largely due to maceration of the solids by the pumping plant located immediately upstream of the new screens. The study has shown (Options F and C) that the gravity CSOs could not be fitted with simple screens as they stand. The hydraulic head losses from passing through screens would cause operating flow levels to rise in the system upstream causing serious increased flood risk to property. Thus pursuing the screening approach would inevitably entail new pumping stations to create sufficient heads to drive flows through the new screens. The experience at Abbey Mills now suggests that this would be self-defeating, as fewer solids would be caught than with conventional screens on normal gravity CSOs in more typical catchments. Screening plant at a few sites could have a limited effect on only the litter objective and would have no impact on DO or the level of public health risk.

For these reasons, the fitting of screening only plants on the London Tideway CSOs is unlikely to achieve even minimal benefits and should not be considered for any further installations.

1.3.4. Dispersed Storage Units

Other ways of providing storage have been considered and reported in Ref.3. The principal alternative method is by dispersed discrete storage tanks, shafts and short lengths of tunnel or sewer constructed as on-line or off-line structures associated with the trunk sewer system. This approach appeared to spread the cost of implementation more widely by adopting a targeted approach. It also allows early implementation and commissioning of some storage elements. However it does have serious drawbacks:

1. Overall a much larger total volume of storage would be needed to provide a level of protection in line with the objectives. Each storage unit should be sized for the peak forecast rainfall in its own locality. Widespread heavy rain would fill all such storage units but, for the majority of events, rainfall is localised and tanks at the edges or outside of the rainfall area would be underused or empty. The storage volume required by this fragmented approach would have to be at least five to ten times that of the centralised tunnel to be effective against localised flash summer storms.
2. The unit cost of construction of storage is estimated to be higher due to the large number of site establishments and the costs of land acquisition, disruption and diversion of services.
3. As the capacity of the existing trunk sewers is limited, additional capacity would be needed to accept the return flows after storm events and this problem would get worse over time.
4. Disruption would be great as the works would be spread over London and all construction traffic would be by road. There would be little if any opportunity to use river transport.
5. Considering realistic levels of resources available and acceptable rates of potential investment the overall programme for delivery would be in excess of 30 years, so delaying provision of full protection to the river although small benefits would be noticed earlier.

Using the estimate for option E, which is the nearest in scope, the cost of providing effective storage by dispersed, discrete units would be approximately £10bn. Option E comprised large diameter storage shafts, incorporating static screens, constructed in the foreshore to minimise land acquisition costs. About 70% of the flow passed screened to the river, the 30% carrying the screenings being stored. This option provided only 30% of the storage volume of an equivalent tunnel but the cost of implementation was 25% higher, due mainly to multiple site establishment costs, pumping plant and dedicated emptying tunnels and more extensive works associated with interception (see Refs. 3 & 7).

1.3.5. Sustainable Drainage Systems (SuDS)

SuDS has been investigated to assess whether its application and that of similar “near to source” measures could play any significant part in alleviating the CSO discharges. This was considered by an expert consultant and reported in Ref. 8.

SuDs are in the vanguard of modern solutions to the problems of urban drainage. The main idea is to retain surface run-off, either in open tanks and ponds or in covered storage elements, which allow only slow draining so as to attenuate the passage of sudden large volumes of storm water. There are drawbacks to the implementation of SuDS techniques in the London area including:

1. The catchment is densely urbanised and mature and there is insufficient space to install surface facilities big enough in existing areas of parkland even if these were available.
2. Open surface storage of combined sewage is not publicly acceptable. A significant amount of separation would have to be carried out to eliminate nuisance (see appendix B).
3. The original river and land drainage systems in central London are now wholly incorporated into the sewerage system and alternative disposal routes for diverted surface water run-off are generally not available.
4. Widespread retrofitting of SuDS, like fragmented storage would be highly disruptive and costly.

SuDS techniques have obvious advantages for new development such as Thames Gateway but this particular development lies east of the central area and will have no effect on existing CSO spills to the Tideway. Applying SuDS to future redevelopment in London would make a gradual, limited improvement taking several decades to be felt. Redevelopment of one square km using full separation and complete implementation of SuDS reduces excess discharge to the river by less than 0.2% (Ref. 2).

Other Suds ideas include reducing infiltration, base potable (dry-weather) flows, in-line attenuation and permeable paving.

Modelling shows that reducing base flows by cutting water consumption or infiltration makes little difference to CSO spill volumes and microbiological contamination and the actual polluting load would not be affected.

In-sewer detention tanks suffer from many of the challenges described in 1.3.4. Similarly the potential for improving inlet control and overland flow control have been investigated and reported in Ref 8 and paragraph 6.1 of Ref. 3. These indicate that there is only limited opportunity for this application.

It is unlikely to be possible to install permeable paving on any significant scale in central London. Even if approval of the installation were not a problem, the cost would be prohibitive for little gain given the sub-soil in London is clay and has poor permeability.

1.3.6. Separation of Sewerage System

One key recommendation of the SuDS report was to reconsider separation as a long-term solution to the problem of CSO discharges caused by foul sewage combining with surface water flows. This could be achieved by converting the existing system to carry surface water only and installing a completely new system of foul sewers.

This would require the construction of some 12,000km of new sewers estimated to cost at least £6bn (average £500/m). About three million properties would need to be resewered at a further cost of £6bn. Serious disruption involving construction work in every road in inner London would entail the work being phased over a long period. The presence of the existing network would interfere greatly with the new work with a high risk of miss-connections that might take decades to resolve. Separation is discussed in more detail in Ref. 3 and reviewed in Ref. 2. The above estimates indicate only minimum costs and re-sewering every property may in fact cost much more. For First-Time Sewerage projects the average connection charge per property is £5,000, not always including the full cost of the drainage works. Costs for new foul sewers are based on small diameter pipes, which are less complex to construct in suburban areas. In the metropolis deeper installations and existing services increase costs and entail more pumping. A new separate foul system could cost close to £20bn so separation is unlikely to be acceptable as a complete solution. Several attempts at separation in particular parts of London have been tried in the past, including eastern Ealing in the 1970s and the London Docklands Development area in the Isle of Dogs in the 1990s. These attempts were eventually found to be impractical and abandoned.

1.3.7. Trade effluent control of fats and grease

Some unsatisfactory CSOs are known to trap large quantities of oil, fat and grease arising from the numbers of restaurants and domestic dwellings in London. Restraint at source might reduce this problem but private houses are beyond the jurisdiction of trade effluent control. This has traditionally been an operational problem and the water industry's concerns have focused on reducing blockages rather than the pollution impact of contaminated discharges.

In London, there is a particular problem along the Victoria Embankment where several sewers pass southward under the Circle and District railway line in small, permanently submerged, pipes. Without free open surface flow, large quantities of floating matter including fat are trapped in manholes on the north side until flushed out in storm conditions. Raising the railway running tunnels to clear the soffit of the sewers would be unacceptably expensive and disruptive. Intercepting these CSOs would be a more economic method of stopping accumulated fats and grease from reaching the river and all are included in the 36 to be dealt with.

Overall, fat and grease discharging from the CSOs is a minor, though objectionable and visible component of pollution that poses one of the worst forms of microbiological contamination. Lack of control over domestic sources makes this unrealistic even as a partial solution but, like the interim measures, it may have some merit as a demonstration of a more responsible attitude by the EA and Thames Water to waste disposal and pollution in the Tideway pending implementation of a complete solution.

DOMESTIC OPTIONS

The project team has considered a number of actions that could be taken by individual householders. These generally cover actions which individual property owners could take to separate storm water or even reduce the amount of foul waste drainage including:

- Removal at source
- Water storage tanks (water butts)
- Grass roofs and alternative waste disposal by compost toilets, reed beds or septic tanks etc
- Removing misconnected surface water drainage - where possible.

1.3.8. Removal of sewage litter at source (Bag-it and Bin-it)

Encouraging the public to dispose of soiled items currently flushed through the WC (sanitary towels, cotton waste, and general small sized domestic rubbish), by refuse collection is a sensitive issue. Limited reduction of aesthetically objectionable matter may be possible by this approach but the level of pollution in the river associated with the organic load and public health risk due to the presence of pathogenic organisms would be unchanged. Several "Bag-it and Bin-it" campaigns in the past ten years have been promoted by Water UK and Thames Water. The most recent, part-funded by Global Action Plan, is reported in Ref. 11. The process included analysing questionnaires, sewer surveys and assessing operational improvements. In this study success was measured by the reduction of blockages in the sewer system. Surprisingly analysis showed that blockages fell in areas both where the bag it and bin it campaign was promoted and where it was not. The results of the study were inconclusive and there was no obvious benefit.

The success of such an initiative depends on constant reinforcement of the message but without hectoring and thus losing public interest and support. Other ideas to control sewage litter at source include new household products such as toilet-cleaning wipes not intended to be disposed via the WC to the sewer. This is a sensitive issue that impacts on individual personal hygiene and general experience suggests that a London-wide "Bag-it and Bin-it" campaign would realise a barely perceptible reduction in sewage litter and may not be sustainable. It may have some merit as a small-scale interim measure pending implementation of a complete solution.

Given that a foul sewerage system will continue to exist in any case, "Bag-it and Bin-it", even if totally successful can, like screening, only ever partially improve the aesthetic litter issue and can have no impact on the issues of DO and Public Health.

1.3.9 Water Butts

From the similar arguments concerning dispersed storage above, water butts would have to be provided to match the run-off from local intense rainfall. A much larger volume than the tunnel would be required otherwise the water butts would soon fill, overflow and continue to contribute to CSO discharges.
Butts can normally impact only on run-off from roofs, which is a small proportion (approx 10%) of the overall contributing area. Considering a typical house roof area of $50m^2$ for a small semi-detached house it would only take approximately 4mm of rainfall to fill a 200-litre water butt.

Taking 3rd August 2004 as an example, the 60mm of rain that fell then would require at least 15 water butts to store storm water for a small or moderate dwelling. Larger properties would require many more. Considering also that many of the butts will not be fully empty at the start, as many as 20 per property might be required. Large buildings such as offices, warehouses etc would require purpose built storage units for rainwater run-off from roofs. If sufficient water butts were provided to all domestic dwellings and their operation and effectiveness could be guaranteed then peak flows and run-off volumes may be reduced by up to 10%. This does not necessarily mean however that the pollution load of river discharges would be reduced by this factor.

Measurements from trials have shown that one of the most noted effects of such domestic storage is reduced flow and greater levels of sedimentation in the sewerage system. Provided peak velocities remain sufficient to re-suspend sediment the vast majority of detritus accumulated in the sewerage system would still be discharged to the river in the first flush. The actual polluting load discharged and the impact on the river, would be only slightly reduced and less than 10%.

Using water butts to achieve suitable storage is also technically problematic. The tank would need normally to be empty at the start of an event and to ensure this, the tank must drain after the previous event. This is easier said than done. Butts would need a bleed type valve fitted to allow slow discharge at the appropriate time. This might entail a powered control unit, which would increase the cost of installation.

Current water company policy is to encourage the use of butts to ***retain*** rainwater for later use to ease demand on potable supplies. Used in this manner they would probably be full when the rain comes and thus of little value. The current policy direction is thus not based on using domestic rainwater storage for storm water attenuation. To try to change this policy could cause confusion with the general public and would probably compromise the promotion of the issue.

1.3.10 Other Domestic Ideas

These include grass roofs, composting toilets, reed-beds with domestic small-scale sewage treatment and reuse of grey water. Once regarded as eccentric, these “low-tech” domestic solutions are gaining credibility in a world facing water shortages and general problems with large-scale waste disposal systems. However in any large urban environment these schemes are defeated by the large numbers of multi-occupied premises, which would require extensive land space to succeed and entail communal maintenance arrangements that often lead to disputes over liability such as those already evident in the case of many SuDS installations.

Methods of domestic sewage disposal like reed beds or composting toilets could lead to reduced solids load at the STW. Even large-scale implementation is unlikely to achieve more than a 10% reduction in total load and this would not significantly affect the accumulation of detritus in the system, which is then flushed out during storm events. Such methods are also potentially counter-productive since STW operation becomes compromised as sewage strength weakens.

In a number of local catchments there is a history of surface water – particularly roof drainage - being wrongly connected to foul sewers when either soakaways or surface water sewers are available. Some effort could help to eliminate, or at least reduce, this nuisance although there would be very little impact in the inner London catchments of Beckton and Crossness, which are already combined.

1.4 Integration and Phasing of Options

1.4.1 Integration of Smaller Scale Measures

Since the partial options individually have less significant impact than the preferred option A(ref), a number of combinations have been considered, such as H+ and H++, so as to raise the projected improvements to a higher level of achieved benefits. It has been suggested that tackling some of the smaller scale options in localities where they are easier to achieve or make a particular impact may produce an "integrated" solution, spreading the range of measures employed to take advantage of a broader front which could involve a larger number of potential suppliers and contractors and increase the chances of success.

For example a solution, which involved some Source Control and SUDs, localised screening or treatment and even a domestic type answer, might be provided. However, the research done to date has produced a number of powerful arguments against this approach.

The experience of screening has confirmed that, except in conjunction with permanently manned continuous treatment plant, screening CSOs locally is likely to be impractical and ineffective. All the substantial benefits identified so far are associated with storage options. Two key factors have dominated the analysis of this measure: location of the storage and the return of flows to treatment.

The first attempts to identify the value of dispersed and localised solutions quickly revealed that centralised storage serves all events anywhere in the catchment. If the storage is dispersed, much larger volumes would have to be provided to achieve the same effect. In addition it is evident that providing 1.5 million m^3 of storage in a hundred or so separate schemes across London will be far more expensive than in one large tank. Although there is potential value in a number of smaller tanks coming into service sooner and delivering some early benefits, this is more than cancelled out by much greater overall cost and timescale for complete delivery. In fact the volume required in this way designed to provide the correct storage commensurate with local forecast rainfall would be upwards of 8 million m^3 and during most local events much of this storage would be empty.

Local tanks to supplement a central tunnel also do not emerge well from the modelling analysis. This has revealed that attenuation in the whole network acts to restrict the flows passing to the CSOs. If every part of the catchment was provided with local storage to reduce run-off from a rainfall event of 30mm by 10% the reduction of discharge from the CSOs is less than 3%. Local tanks in the upper catchments will fill but will not pass on the same amount of deferred storage to the tunnel. Cost savings achieved by making the tunnel slightly smaller are also likely to be quite small (see 2.6.1).

Returning stored flows to treatment isn't as easy as it appears to be at first sight. Flow measurement and analysis of the wider inner London sewer networks has revealed how little surplus capacity is available anywhere in the system. All storage facilities provided which return flows for treatment other than near the east London STWs present network capacity problems and the risk of aggravated overflows.

These factors strongly support the logistical competence of a central storage facility with an outfall near the east London STW facilities.

1.4.2. Combined Benefits

The other aspect of integration is to consider the potential improvements, which the solution offers to other network deficiencies than storm sewage discharge. Evaluating these potential benefits has been generally excluded from the body of the study and no extensive modelling has targeted this issue. However, the data has variously shown that the main storage option(s) are likely to have a significant impact on reducing the risk of sewage flooding to property.

1.4.3. Phasing

PHASED IMPLEMENTATION OF THE MAIN STORAGE TUNNEL - A(REF)

The most effective approach at reasonable cost to achieve all the required objectives is considered to be to implement the storage tunnel A(ref), ultimately to provide a complete and continuous storage tunnel between Hammersmith and Crossness, including the Abbey Mills link.

In the context of the water quality around the Olympic site described above the H++ option could form the first two phases of the preferred option A(ref). Building the tunnel in phases would entail dividing the construction into three sections as follows:

- *Upstream (western) section:* 7.2m diameter tunnel approximately 10.6km in length, from Hammersmith to Heathwall, intercepting 19 CSOs. Includes treatment plant, pumping station and controls to drain tunnel to main trunk sewers or via treatment to river when there is no spare capacity. This represents the partial storage tunnel as described in 1.3.2(a) above.
- *Downstream (eastern) section:* 5m diameter tunnel approximately 4.5km in length from Abbey Mills to Greenwich and 7.2m diameter tunnel approximately 9.4km in length from Greenwich to Crossness. Including link tunnel to Beckton, pumping station and treatment plant at Crossness
- *Middle section:* 7.2m diameter tunnel approximately 14km in total length linking Heathwall and Greenwich via St Georges Wharf, intercepting the remaining unsatisfactory CSOs.
- This order of implementation starting at the western end has been selected so that implementation would provide some protection to the most sensitive part of the river first. The influence of the Olympics would however dictate that the eastern section should come first.

The three phases would be implemented sequentially. The main programme implication is that major construction activities, such as the main tunnel drives, would not be carried out in parallel. Therefore the overall time for construction will be at least twice that for the storage tunnel option built in one go. Currently the construction programme allows approximately 7.5 years for construction of the storage tunnel. Assuming a start in 2006 the phased outline programme of delivery could be:

Activity	Start	Finish	Period
Outline design, Planning, EIA	2006	2011	5 yrs
Phase 1	2011	2018	7 yrs
Interval	2018	2019	1 yr
Phase 2	2019	2026	7 yrs
Interval	2026	2027	1 yr
Phase 3	2027	2034	7 yrs

Table 1.4.3.a

Construction phases could be separated by an interval period of say one year.

Even if the interval between the phases were to be completely eliminated, the projected delivery of the complete solution would still be beyond 2030. It is also important to note that to achieve a start in 2006, approval to proceed and an allocation of funding would be required now.

Implementing the storage tunnel in three phases would also add to the overall cost of delivery. Additional main shafts will be required and significant works will eventually become redundant. This is especially true at the Heathwall PS site where planning approval for the treatment plant could impact on below ground works and increase complexity. The impact of the process plant on the local area would be much more serious and a new outfall to the river may be required. The following additional cost items are approximations based on existing estimates (at 2002 levels) for the complete storage tunnel. They are intended as an indication of potential additional cost and should be subject to more rigorous assessment should it be required to progress this phased approach:

Item	Description	Approx. Cost (£M)
1	Additional shafts at Heathwall and Greenwich to facilitate construction of the tunnel for phase 3, recovery of the TBMs and construction of connections to previous phases. Provision of these shafts will enable the previous two sections to remain in operation while the last section is under construction	30
2	Allowance for costs of actual construction of connections to previous phases	10
3	Standby screening plant and peroxide dosing plant at Heathwall to permit alternative means of discharge during periods of extended wet weather	5
4	Pumping and power generation plant at Heathwall	6
5	Pressure pipelines installed in existing storm relief sewers to distribute pump-out flow to trunks sewers, including controls and connections	6
6	Extended duration of site establishment, main management and site management.	80
7	Additional contingency based on 30% of items 1 to 6	41
8	Additional resources based on 12% of items 1 to 6	16
9	Additional land at Heathwall to accommodate extra main shaft, screening plant and power generation plant. Additional land at Greenwich to accommodate extra main shaft	60
10	**Total estimated additional cost**	**254**

Table 1.4.3.b

1.4.4. Parallel Implementation of Phases

Implementing the three phases described above in parallel would allow delivery of the full scheme in a shorter timescale. This would help to address the concerns over the currently estimated long delivery period.

The current programme is based on the main construction activities being carried out in two parallel work streams. If the works were split into three sections and carried out in parallel it should be possible to reduce the programme to just under 5 years. Including a similar contingency allowance construction in just over 6 years is not unrealistic. This represents a potential saving of three years.

Additional resources would be required to achieve this accelerated programme, which may partly be offset by reduced time based costs. The following items are an indication of potential additional cost and should be subject to more rigorous assessment if this accelerated approach is adopted:

Item	Description	Approx. Cost (£M)
1	Additional TBM so that main tunnelling work can proceed in three work streams	18
2	Additional power generation plant	5
3	Additional site establishment for third work stream	16
4	Additional management and operative resources. Cost increase partly offset against shorter timescale	10
5	Additional contingency based on 30% of items 1 to 6	15
6	Additional resources based on 12% of items 1 to 6	6
7	**Total estimated additional cost**	**70**

Table 1.4.4

Compared with the sequential phased implementation as described above, it should be noted that there are no additional main shafts or redundant plant with this approach.

The two parts of Option H++ could also be done in parallel, which might bring the benefits for the whole tideway as early as 2012, which would have a wider overall public appeal in the light of the Olympics. There is no doubt that any Option driven by the Olympics would be focussed on delivering the river Lee improvements as a priority

1.5 Investigations Update

1.5.1 STW Upgrades

A number of issues have arisen regarding the upgrade works currently in hand at Beckton and Crossness STWs. These relate to the reliability of the upgraded works being able to receive the pumped flows from the tunnel and handle the extra sludge, which the stored flows will generate.

Although the upgrades should increase the combined flow to treatment at Beckton and Crossness from the current 28 m^3/s to some 38 m^3/s in storm conditions, the two works will be loaded more heavily by the existing interceptor sewers, which will be able to deliver more flow than currently. If these increased flows do not subside fairly quickly the works operators will have to decide on the balance of stored tunnel flow they pump either to full treatment or to the storm filter plant.

Alternatively the tunnel A(ref) may remain full for longer to be pumped out when capacity becomes available. This option may be attractive to the process controllers but presents two risks: an increased risk of septicity and no available storage if another storm should quickly follow. Experimentation with stored sewage suggests that septicity will not become a serious matter probably for at least 4 to 5 days. However, back-to-back storms are not unusual and this is the greater risk. It is true that the system is likely to be flushed by the first event so that a subsequent storm would carry a smaller biological load but with this scenario the system would spill to the river more often than currently proposed.

It is difficult to be certain if the upgraded works will be able to handle the extra sludge arising from the stored intercepted flows as this largely depends on the formulation of the future sludge strategy and optimisation of the existing Sludge Powered Generators (SPG). If the sewage is heavily loaded this could exceed the future capacity of the sludge power generators.

To counter this possibility two measures are now allowed for in the project estimate with appropriate supplementary risk assessment. Firstly a sludge transfer main between Beckton and Crossness will allow sludge flows to be balanced between the two works. The second measure would provide for the appropriate increase of incineration capacity at the works either by optimisation of the existing SPG or by providing additional incineration plant.

1.5.2 Impact on Non-Connected CSOs

Recently the issue of whether to connect all the CSOs was considered by an assessment of the environmental impact of the Tideway CSOs by the EA. Two matters of concern have been expressed which need to be addressed. Firstly, the proposal that 21 of the operating CSOs are not intercepted by the proposed tunnel A(ref). It has been suggested that these would continue to discharge at current frequencies and produce pollution which, if not currently problematic, might be considered unacceptable in the light of the improved state of the river following implementation of the tunnel. It should be understood that these outfalls are currently the least polluting and least frequent to discharge and it is not the case that similar numbers of spills will continue after the tunnel is built. Modelling indicates that once the tunnel is available, most of these outlets will discharge less at high tide because the surplus flow currently emanating from them will be drawn to the more freely discharging intercepted CSOs.

Furthermore once the tunnel is full and rainfall continues at a rate greater than the pump-out rate the system will overflow and the CSOs will still discharge unscreened. Experience from modelling and the screening installation at Abbey Mills have convinced the project team that attempting to screen any of the main London CSOs, even for such residual spills would be operationally unacceptable and uneconomic.

Therefore it is considered that as they are expected not to operate frequently nor cause an adverse environmental impact there is no need to protect the Tideway from their limited discharges.

1.5.3 Volumes Discharged Annually

Earlier, in the Steering Group report, the total volume of CSO discharges in any one-year was stated to be typically 20 million m^3 and concern has been expressed because some much higher estimates have been recently published. This earlier estimate was an approximate assessment intended only to give an indication of the likely volumes of storm sewage discharging to the Tideway.

During the study the storage volumes used as design criteria to develop the solutions came from modelled rainfall data from a number of different storms using the largest real rainfall events from the last 14 years (see Appx I). These calculations were not based on or related to the total annual discharge, which was assessed using average modelled discharge rates for the CSOs and the estimated periods of discharge. Using the latest time series generated rainfall together with pumping information for Abbey Mills, it is now reckoned that rather than 20 million m^3, a more realistic average annual figure is 32 million m^3 for all the CSOs and PSs and this figure has been used throughout this report.

The recently stated higher figures are based on feedback from operational groups who compile pumping station records. These figures are known to overestimate discharges due to reduced pumping efficiency, tidal state, and certain inherent inaccuracies of the recording methods. They also include storm discharges from the STWs, not included in the earlier figure.

These STW storm tank discharges are also about 20 million m^3 per year and adding this gives a total of 52 million m^3 of storm sewage discharged to the Tideway each year which is more in line with the more recent estimates.

Work is in hand at Beckton, Crossness and Mogden STWs to reduce this amount significantly through capacity increases but the annual discharge figure is not material to the calculations used in arriving at the size and effectiveness of the tunnel option.

1.5.4 Similar Projects Elsewhere

Table 1.5.4 shows an analysis of some similar projects carried out to assist with the management of CSOs in other places. It is notable that many other cities, e.g. Paris, have carried out or propose similar storage schemes and that several of these, especially the one at Brighton are performing better than anticipated.

Thames Tideway Steering Group – Supplementary Report
Table 1.5.4 - Comparison With Other Sewerage Projects

Project Country Location	3.14159					Unit Costs					Delivery Date	Construction Period Months	Comments
	Dia'	Length	Storage Volume 000m3		Operating Cost £M/yr	Tunnel Only			Whole Scheme				
	m	Km	Tunnel Only	Total		Total Capital Costs £M	£/m3 Storage	£k/m Construction	Total Capital Costs £m	£/m3 Storage			
Tideway Option A(ref) London, England	7.2	34.5	1405	1500		1,217	866	35.3	1,699	1133	2020	120	
Don Valley Trunk Sewer Yorkshire, England				0					723				
Ayr Sewerage Scheme Scotland	2.75	5.5		0				1.5	8		2000	18	
Cardiff Trunk Sewer Wales		9.9		0				3.6	36				
Perryhall to Gravelly Sewer Wolverhampto,n England	3.05	2.5		0				3.5	9		2000	21	
Paris				1600					1,621	1013			
Milwaukee									1,260				
Rochester (New York)	3 - 5	21.4							315			70s-80s	CSO excellence award. Flushing from river, odour control, de-aeration chambers at drop shafts, transient pressures overcome.
Nashville (Tennessee)	2.7	5							415			Early 90s	

2. Current Tunnel Proposal Aspects

2.1. Sustainability and Environmental Issues

2.1.1. Sustainability

The newly proposed pumping station at Crossness and the extra sludge drying plants would consume approximately 11GWhrs of energy per year. To offset this energy requirement the project will have to include a level of renewable energy provision with a target of 10% of the overall energy use for the site. Three potential options for the utilisation of renewable energy have been identified. Considering potential renewable energy applications with the National Energy Foundation, the most favourable options are wind generators, bio fuels and sludge incineration. The recovery of hydro-energy from intercepted flows is unlikely to be cost effective. The plant would be expensive and difficult to maintain and flows are too intermittent and short in duration to be reliably exploited.

Other possibilities such as photo-voltaic cells would be expensive and recovering energy from the intercepted flows by heat pump are of little value as the STWs no longer require large quantities of heat for the treatment process.

The main issues with the favourable options are:

1. **Wind Generators**: A large generator at Beckton or Crossness would generate about 3 to 4 GWhrs pa, which exceeds 10% of the typical estimated annual energy consumption of 11 GWhrs required by the project. Previous investigations show that the proximity of the nature reserve adjacent to Crossness may make the installation of a wind generator unacceptable at this site.
2. **Bio fuel Usage:** Bio fuels are those sources of energy generally obtained from the refinement of certain seed crops, such as oilseed rape, instead of mineral fossil fuels. To generate the required power for the pumping plant on site, there are several options for running this generation plant either on bio fuels alone or in admixture with diesel. Thus virtually all the energy required could be obtained from renewable sources.
3. **Sludge Incineration:** The intercepted flow may produce approximately 10,000 tonnes of dry solids per year. Incineration at the existing Sludge Power Generators (SPG) would provide an effective means of sludge disposal releasing calorific energy. The additional power generated could be between 10% and 20% of the annual energy required for pumping. This would require a sludge transfer main between the works and additional sludge treatment plant to facilitate effective optimisation of the SPG plants. It is possible that optimised capacity may still prove insufficient and additional incineration capacity may ultimately be required.

Thus the total renewable energy needs required of the project could be met by this method.

2.1.2. Environmental Impact of Construction

There are several issues regarding the potential environmental impact (Refs. 3 and 9). Key items are spoil disposal and impact on the aquifer. Traffic congestion is discussed in 2.8.

The majority of excavated material from the tunnels and shafts will be transported by barge and reused to improve development sites and as fill for landscaping, embankments, flood protection, etc. The clay component could be used as a capping material for brown field sites.

The proposed tunnel option A(ref) will pass through the chalk aquifer for a significant distance. There are two risks of contamination of the aquifer: during construction and from leakage of intercepted storm water. Construction risk can be mitigated by careful control of the TBM and appropriate selection of lubricants and soil conditioning agents.

There is a risk of contamination arising from leakage of stored storm sewage so the tunnel will have a complete secondary lining through the water bearing strata of the Upnor, Thanet Sands and Chalk formations. The joints in modern primary segmental linings are normally very successful and watertight. Also groundwater pressure in the chalk strata will be higher normally than in the stored storm water so infiltration, not exfiltration, is more likely. Should this ground pressure prove to be sufficiently high it would be possible to omit the secondary lining, which would present a considerable saving to the project cost.

2.2 Interception Shafts

2.2.1 Location Issues

Interception sites for all 36 unsatisfactory CSOs have been identified and assessed in outline. Many are dictated by the arrangement and location of the existing sewers and outfalls. Where practical existing Thames Water sites were selected, however this was only possible at five locations. Generally locating interception works in the highway was preferred to public parks and open spaces to minimize temporary loss of amenity, the least preferable sites being on private land. The river foreshore has only been selected where none of the other options are possible.

Detailed analysis of all the potential interception shafts is comprehensively described in the study report by Faber Maunsell and AMEC – see Ref 12.

Although disruptive during construction, the CSO interception works would be finished entirely below ground and accessed only by manhole covers. A small surface mounted control cubicle for power packs and instrumentation may be required and located nearby.
The possible sites for the interception works are located as follows:

<u>On Thames Water owned land at pumping stations</u>:

- Hammersmith Pumping Station (on outlet).
- Western Pumping Station (on inlet).
- Heathwall Pumping Station (on inlet).
- South Western Storm Relief (at Heathwall PS).
- Greenwich Pumping Station (on discharge).
- Abbey Mills Pumping Station (on inlet).

Of the above, only Greenwich pumping station was taken to a concept level of design.

<u>In Roads or Road Verges</u>:

- Acton Storm Relief.
- Putney Bridge.
- Church Street.
- Clapham Storm Relief.
- Brixton Storm Relief.
- Grosvenor Ditch.
- Regent Street.
- Northumberland Street.
- Savoy Street.
- Norfolk Street.
- Essex Street.
- Shad Thames Pumping Station (on discharge).
- Holloway Storm Relief.
- Earl Pumping Station (on discharge).

Wherever possible interception points have been located in roads, as Thames Water will be able to use their statutory powers under the New Roads and Street Works Act to facilitate the works.

Concept level designs have been produced for Clapham and Brixton, Regent and Northumberland Streets and Norfolk and Essex Streets. As the interception works and drop shafts are located in busy and sensitive central London highways, traffic management schemes have been developed.

<u>In public parks and open spaces:</u>

- Stamford Brook.
- North Western Storm Relief.
- West Putney.
- Queen Street.
- North East Storm Relief.

Where location in the highway is impractical public parks and other open spaces have been considered. The works will be finished flush with the ground so the only disruption will occur during construction. However, it is recognised that some of these sites are environmentally sensitive and public objection may occur.

<u>On private land:</u>

- Frogmore.
- Lots Road Pumping Station (on discharge).
- Falconbrook Pumping Station (on discharge).
- Smith Street
- Ranelagh.
- Kings Scholar Pond.
- Deptford Storm.
- Charlton Storm.
- Wick Lane

The works to intercept Smith Street and Ranelagh are proposed to be located within the Royal Military Hospital Grounds. As this is Crown land, the statutory powers under the Water Industry Act are not valid. Permission for access and construction of the works would need to be sought from the Crown. Similar permissions have been granted in the past provided there was no obstruction to public events such as the Chelsea Flower Show.

It is known that the sites identified for Lots Road and the Wick Lane diversion shaft are likely to be subject to planning application for redevelopment. Consequently significant compensation costs could be incurred if planning permission has already been granted for redevelopment.

It is proposed to relocate the Greenwich main construction shaft to an industrial site adjacent to the Charlton outfall. Acquisition of this site would be required to accommodate the remaining superstructure and also to act as a principle marshalling yard for the construction works. Should approval to proceed with the project be delayed there is a risk that this site may be lost to redevelopment proposals.

<u>In the river foreshore:</u>

- Jews Row (plus addition of Falcon Brook).
- Fleet Main Line.

CSO interception structures have only been located in the river foreshore when other more suitable sites are not available. The Port of London Authority has granted approval in principle for the river works to intercept Jews Row outlet.

The proposal for interception of the Fleet outfall includes construction of a culvert located within the foreshore immediately adjacent to the river wall and the abutments for Blackfriars Bridge. Approval in principle has been granted for these works subject to appraisal of potential scour around the abutments.

2.2.2 Construction Issues

A summary of the details and assumptions for each CSO connection is included in Appendix 2 of this report and described in detail in Ref 12. The drawings are included in Volume 2.
The main issues are summarised below:

- Caisson shaft sinking is now preferred to underpinning as this method decreases the risk of hand injury to operatives.
- Shafts constructed as caissons would be provided with an under-ream to provide resistance to uplift.
- Several construction issues associated with deep excavation and construction influence the required shaft diameter. It is proposed that a minimum shaft diameter of 7.5m be adopted to maintain safe working spaces during construction for shafts greater than 60m in depth. Gantries or winches are proposed for shafts over 50m in depth, as cranes would not be able to manage the increased cable weights.
- Previous reports recommended that the connections would be tunnelled from the main storage tunnel to the interception shaft due to restrictions of available space. It is recognised that this method could adversely impact on main tunnel drive productivity. However, as nearly all CSO interception shafts will now have a larger diameter due to depth considerations, they can be utilised as drive shafts. It is now recommended that all CSO interception tunnels be driven from the interception shaft to the main tunnel.
- For the smaller CSOs the minimum diameter of the interconnecting tunnel has been taken as 1.5m due to length of drives and to provide adequate emergency man-access during operation. It is further proposed that these minimum sized tunnels would be constructed as pipe jacks to avoid manual segment handling problems typically associated with small diameter tunnels. For similar safety reasons the minimum shaft diameter will be 6.0m, unless the shaft is deeper as discussed above.

2.2.3 Overall Conclusions

Feasible layouts with least practicable impact have been identified for all the CSO shafts, together with all the main construction challenges. The cost estimates and construction programme have been modified to take account of these proposals.

The construction of the CSO interception structures has been studied in greater detail and additional time and cost has been allowed in the estimate. The scope incorporates mitigation measures identified in the risk assessment process, in particular allowing for specialised geotechnical works at many of the shaft sites. This aspect has increased the estimate and is reflected by a reduction in the contingency sum. These works include:

- Nitrogen ground freezing for the CSO shafts whose bases are located in the Lambeth and Thanet beds.
- Interception tunnel drives requiring additional resources due to driving from the shafts to the main tunnel – this is offset by more effective use of the main tunnel resources.
- Driving the interception tunnels from the shafts to the main tunnel generates additional excavated material to be transported by road - this additional cost has been limited by using three of the sites as marshalling yards to receive this material prior to loading onto river barges.

- CSO shafts sunk by caisson rather than under-pinning as previously allowed. More expensive but lower risk with such a method of construction in water bearing ground.

Once the tunnel is underway, effective site investigation and the sophistication and capability of modern TBMs mean the risk of cost escalation on the drive itself is fairly low.
With the shafts, however, the potential for unforeseen costs is much greater due to their number and difficult locations, especially for the interception structures. This is the area subject to the greatest construction risk. However, a recent review has produced some confidence that the level of this risk previously perceived was greater than should apply in practice.

There will be seven construction shafts for the main tunnel. The main risks associated with these are the size and depth and the latter point can be minimised with good ground investigation. Four of these shafts will be on Company owned land and only three are in the highway. Even so, the three shafts to go on new land are reasonably flexible as to their location. The main risk here is related to land availability rather than construction.

Although the estimated cost for these structures has increased, the contingency has been reduced as many previous items of risk are now better understood and are included in the base cost as a known item.

2.3 Construction Overrun

The main impact of late delivery is the additional cost of maintaining the site establishment and extending management and project resource cost. From the current estimate the time related cost for these items is approximately £1M per month. Obviously there may be other additional costs related to resolution of any encountered problems. At this stage it can be assumed that the costs of resolving such problems are covered by the contingency sum.

It is useful to reflect on the performance of recently completed tunnelling projects to place such risk in context.

1. **Channel Tunnel Rail Link (CTRL) tunnelling contracts:** All main tunnelling contracts for CTRL were completed within programme and to budget. Two minor problems were encountered which had an insignificant impact on overall performance.
2. **Jubilee Line Extension (JLE):** All main running tunnel works progressed well. The main problems, which caused the considerable programme and cost over-runs were due to late design changes and the cessation of works due to the Heathrow Tunnel collapse using NATM (the New Austrian Tunnelling Method). It is not proposed to utilise this method of construction.
3. **Channel Tunnel:** The main tunnelling works were completed generally to time and budget. The main cost over-runs were due to delays of other works such as track installation and late changes in the design of the rolling stock to cope with fire risk.

2.4 Risk Assessment

2.4.1 Construction Risks

INTRODUCTION

The risk assessment processes employed throughout this study are described in detail in paragraph 7.3 of Ref. 3. Initially these were used to assist selection of the most appropriate solution and then to assist refinement of the proposed storage tunnel option A(ref). Potential risks, their context and proposed measures of mitigation are discussed in Ref 9.

The proposed storage tunnel option A(ref) has been subjected to a rigorous quantitative risk review, which has been carried out leading to a Latin Hypercube statistical analysis to assess a reasonable level of contingency.

Several of the initially identified risk items have now been removed from the risk register as they have been addressed and mitigated in the scope for the base estimate.

Risk allowance, has been excluded for the following items:

a) Additional land costs arising from loss of optimal sites to redevelopment due to delayed authority to proceed

b) Additional costs associated with accelerating the works to construct the eastern section of the proposed storage tunnel works to accommodate the 2012 Olympics. Additional land costs due to any unexpected rise in land costs generally.

All these risk items are outside the control or influence of the project promoters, in particular the responsibility for items 1 and 2 reside with government decision-makers.

The overall contingency value is now assessed as £264M, which is 24.4% over the main work elements.

FIRST STAGE RISK RANKING

All main identified risks were ranked by likelihood, impact on cost and impact on time on a scale of 1 to 5 as follows:

Scale	Likelihood (%)	Cost Impact (£M)	Time Impact (months)
1	1-10	0-1	0-1
2	11-30	1-10	1-3
3	31-50	10-50	3-12
4	51-70	50-100	12-24
5	71-99	100+	24+

Table 2.4.1

The product of the score for likelihood and cost gives a measure of risk impact on cost. Similarly the product of likelihood and time gives a measure of risk impact on time. The sum of these two products gives an overall risk ranking score, which is used to prioritise the risk items in terms of potential impact on the project as a whole.

SECOND STAGE RISK RANKING

The proposed mitigation measures should reduce the potential risk impact. A process of three point estimating is used to assess the most likely, minimum and maximum values of impact on cost for each item together with a revised estimate of the likelihood. These post mitigation values were subjected to the Latin Hypercube analysis resulting in a contingency figure of £264M at 75% certainty. This means there is a 75% probability that this figure will be sufficient to cover the risk items and therefore out-turn cost will be less than the estimated cost. Thus there is a 25% probability that this figure may not be sufficient and consequently the out-turn cost would exceed the estimated cost.

CONCLUSIONS

Following the recent risk review the revised risk register is attached as Appendix G. It is interesting to note that this has elevated the importance and potential impact of items associated with treatment. Previously insuring the project had been assumed to be one of the more serious issues but the proposed mitigation measure of self-insurance lowers its impact.

Potentially the greatest impact on the project may arise from the need to introduce more contracts for implementation. This is due to the value of construction work, which may be too high a financial burden for a single large joint venture. It may be necessary to share implementation of the project between two or possibly three joint ventures. This approach would introduce additional management and site establishment, which would increase costs.

2.4.2 Operational Risks (including STWs)

The review also assessed the potential risks in long-term operation of the Tunnel solution. A number of key operational risks were identified which need to be mitigated or if possible eliminated during the design phase. This information will form part of the brief given to the design team to be signed off by the constructors and the operators.

2.5. Budget Cost Update to 2004

2.5.1. Summary

Estimates to date have been assessed to the second quarter of 2002, as this was the date required for the AMP 4 submission. EC Harris reviewed the Civil Engineering Construction cost indices to update these to the third quarter of 2004 indicating an increase of 11.6% to allow for inflation. It is reasonable to apply this increase to Tunnels & Structures, Screens, Treatment and Pumping and Power elements of the estimate as these are based on a significant proportion of civil engineering content. Contingency, Risk and Resource Costs are percentages and therefore increase automatically by the same proportion.

The estimates have been further refined in the light of the detailed appraisal of the CSO interceptions structures, a revised construction programme, review of the scope for treatment plant and the quantitative risk assessment. The overall cost estimate is detailed below. In line with previous estimates the costs are assessed at 2002 levels and updated to 2004:

Cost Base	Option A (ref) - Estimated Cost (£M)								Comments
	Tunnels & Struct's	Screens	Treatm't	Pump & Power	Contin-gency & Risk	Res-ources 12%	Land	Total Costs	
2nd Q 2002	*936*	*32*	*22*	*50*	*312**	*125*	*50*	*1,527*	*Sols Report Volume 2*
"	**949**	**32**	**52**	**50**	**264****	**130**	**55**	**1,528**	**Now**
3rd Q 2004	*1,044*	*36*	*25*	*56*	*348**	*139*	*50*	*1,698*	*Sols Report Volume 2*
"	**1,059**	**36**	**58**	**56**	**295****	**140**	**55**	**1,699**	**Now**

Table 2.5.1 Updating of Cost Estimate

*Note: Contingency * = 30%; ** = 24.4%*

2.5.2. Tunnels and Structures

Overall the estimated cost for this item has increased by approximately £13M due to various design and methodology refinements. A construction management fee of 8% for head office overheads and profit is included. The insurance premium is currently estimated at 7% of the overall contract value and, as indicated above, is likely to be used as a form of contingency since obtaining project insurance at a reasonable rate may be impossible.

The locations of the main shafts have been modified resulting in more balanced lengths and drive times, which has lead to an overall reduction in duration and costs for the main works.

2.5.3. Treatment

The scope of the upgrade works at Beckton and Crossness STWs under AMP4/5 is now confirmed and the extra capacity to treat intercepted flows determined. The works have also been subjected to a risk assessment, which highlighted a number of issues. The main areas of concern are the ability of the works to treat the intercepted flows and to dispose of the additional sludge that will be generated.

Pumping out the intercepted CSO flows to full treatment at Beckton and Crossness will extend the periods of high flow, which normally follow wet-weather events. The proposed improvements will ensure that the treatment plant will be sufficiently robust to operate at full capacity satisfactorily for extended periods.

Thames Water is currently reviewing the future sludge treatment and disposal strategy at Beckton and Crossness. The production of sludge will increase as a result of the enhanced treatment capacity and this would rise further with treatment of the intercepted CSO flows.

Currently sludge is incinerated in the Sludge Power Generators (SPG) at Beckton and Crossness. Significant quantities of energy are generated from the incineration process and this is used to run the treatment works. The ideal solution to dispose of the additional sludge would be by increasing incineration at these plants resulting in additional power generation.

Preliminary calculations show that that the additional sludge produced from the stored flow would be about 10,000t dry solids per year, generating 2 - 3GWhr, which is approximately 20% of the estimated 11GWhr annual energy consumption of the new pumping station.

The SPG plant at Crossness STW is already operating at close to maximum capacity and the potential to improve is limited. However, optimisation of the SPG plant at Beckton may be possible where there is potentially more headroom between average and peak disposal capacity. Trials are in hand to determine the level of improvement that may be available at Beckton within the next few years. Should the potential for increased incineration at Beckton prove to be limited then additional incineration capacity will be required for the stored flow.

Until the strategy for sludge treatment and disposal is resolved the size of the additional plant required cannot be precisely determined. At this stage, therefore, allowance has been included in the project estimate to cover any additional sludge treatment plant at both Beckton and Crossness together with the provision of twin sludge transfer mains between the works. An additional contingency is included in the risk register; items 47 and 49 (see Appendix G).

2.5.4. Pumping and Power

The estimated cost is based on generating all additional required power on site with the facility to use bio-fuels to enhance sustainability of both works. As mentioned, some mitigation measures are now included in the scope thus increasing the base estimates and reducing the overall risk and contingency requirement.

2.5.5. Land

The estimate for land costs is unchanged as it is still proposed to target low value or commercial land rather than high value residential or retail developable land. If authority to proceed is significantly delayed optimal sites may be lost to redevelopment. This has already occurred for the proposed sites at St Georges Wharf and Pear Tree Way both in Greenwich. Both sites, targeted some 12 months ago, are now part of high value development proposals.

To continue to pursue and acquire these sites could cost these developments around £100M each. Obviously compensation costs at this level are plainly uneconomic. Alternative sites have already tentatively been identified.

If authority to proceed to the next stage is delayed the risk of losing optimal sites to redevelopment increases resulting in a significant rise in the estimated cost, which the project promoters could not control. The currently targeted sites should be reserved or acquired for the project as soon as possible to avoid the risk of serious cost escalation.

2.6. Reliability of Cost Estimate

2.6.1. Relationship Between Cost and Storage Capacity

During the study there have been suggestions of potential improvements to the sewerage catchment to reduce peak flows and volumes of CSO discharge, in order to reduce the storage capacity of the proposed tunnel option A(ref).

The previous estimates for the 6m and 9m diameter tunnels have been revisited to incorporate the refinements of A(ref) to the proposed 7.2m diameter storage tunnel and the detailed assessment of CSO interception works. In summary:

Tunnel diameter (m)	6.0	7.2	9.0
Approximate Storage (m^3)	960,000	1,500,000	2,240,000
Cost (£M)	1,565	1,699	1,823

Table 2.6.1

Interpolating these figures indicates that if the required storage volume is reduced by 10%, the tunnel diameter would become 6.8m but cost approximately £37M, or only 2%, less. Alternatively, by increasing the tunnel diameter to 7.6m to achieve a greater factor of safety and improved flood relief the storage would increase by 10% but cost only an additional £25M, or 1.5%. Such variations in cost are small compared with providing similar storage in separate discrete elements elsewhere in the network. This demonstrates the inherent economy of a centralised tunnel solution and that quite substantial changes to the tunnel volume have a low impact on the cost of construction.

This is shown graphically in fig 2.6.1, which emphasises the economy of scale for such a tunnel and the significant reduction in cost, per m^3 of storage, provided as the diameter increases.

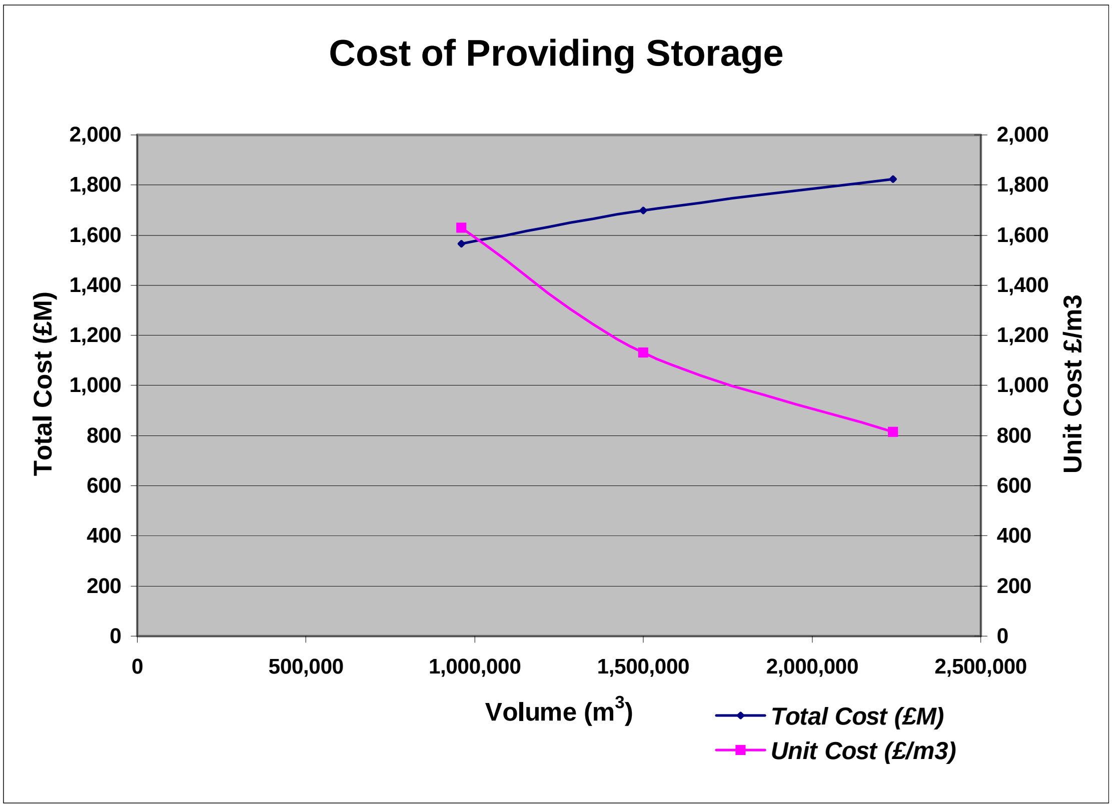


Fig 2.6.1

2.6.2. Contingency

During the cost review the contingency was re-evaluated. The contingency at just over 24% is large for a project of this scale and is mostly allowed for planning and environmental factors, the construction of the intercepting structures and the mechanical elements (treatment plant and pumping stations). There is little risk attached to the tunnel itself.

Analysis of the CTRL project, recently published in New Civil Engineer magazine showed, that the tunnel was driven on time with little disruption and within a few percent of the estimated cost. The project team declared that constructing such tunnels could be considered fairly low risk.

2.6.3. Comparison with Other Tunnelling Projects

Table 2.6.3 below shows comparison with five other recently completed or current tunnel contracts. They are of similar diameter and generally constructed in variable ground types. The overall rates for tunnel construction were calculated, adjusted for the diameter of the proposed storage tunnel option A(ref) and corrected to 2002 price levels.

The nominal rate is the overall cost per kilometre and the adjusted rate is the cost per kilometre adjusted to remove non-tunnel related costs and to take account of the different diameters of the proposed tunnels and to reduce all the costs to the 2002 cost base.

The estimated costs for the proposed tunnel works has already been compared with the out-turn costs for the CTRL tunnelling contracts as detailed in the Solutions Group Report Vol 2. This showed a notably close comparison justifying a high level of confidence in the estimate.

The rate for the proposed storage tunnel, excluding CSO interception works, is approximately £22M/km. Once again this confirms that a high level of confidence in the estimate for the tunnel works is justified.

Country	Location	Project	Tunnel Diameter	Tunnel Length	Nominal Rate £M/km	Adjusted Rate £M/km
UK	**London**	**Tideway Tunnel A(ref)**	**7.2m**	**34.5km**	**46**	**22**
Ireland	Dublin	Port Road Tunnel	11.00m	11.20	33	22
Netherlands	Westerschelde	Marine Highway	10.10m	13.20	29	22
Netherlands	Rotterdam	Tramway	6.50m	5.80	15	15
United Kingdom	Hastings	Storm water Relief	6.50m	1.60	19	23
United States	Rhode Island	CSO Tunnel	7.92m	4.90	23	19

Table 2.6.3

2.7. Land Acquisition and Planning Issues

Land acquisition and planning issues have been investigated and developed, by a specialist consultant, throughout this study. Several studies on land availability, appropriate planning process and preliminary environmental impacts have been undertaken. The main planning risks including an outline programme are included in Appendix D and summarised below.

The main implication of the planning risks is time delay, as the planning process is controlled by the Planning Inspectorate or the Secretary of State. Even if a public inquiry were required the overall planning process could still be completed with a successful outcome by 2010 allowing implementation at the start of AMP5.

Early acquisition of the main shaft sites is critical to fixing the route and the design of the proposed tunnel and to enable the planning process to be linear. If the shaft sites are not available at the end of the planning stage alternative locations would then have to be found and this could possibly result in delays of several years. Early acquisition of sites by private treaty rather than compulsory purchase may help to minimise the risk of invoking a public inquiry.

Of the various options for pursuing the planning process the most favourable appears to be by the lead authority route. Expert consideration by QC experienced in planning law is being sought to improve confidence.

2.8. Traffic Congestion Issues

River barges will service construction of the main storage tunnel to minimise traffic congestion. However this will not apply to the CSO interception structures and drop shafts so many of these sites will impact on traffic. Initially only a high level review was undertaken but this was extended to a rigorous investigation of eight sites detailed in Ref. 10 to clarify the risks associated with construction of the CSO interception structures.

The costs arising from the issue of Traffic Congestion have been assessed in two ways. Firstly, the normal estimating process does not include a specific separated item for the cost to the project caused by traffic congestion. Some elements of the contingency are associated with the possible additional costs of occupying and servicing the shafts and interception sites. This would be because of elaborate traffic management requirements and potential compensation claims for nuisance caused by large numbers of truck movements. The value of this element is estimated to be about £20m.

Secondly, there is an assessment of the likely environmental impact on the community expressed in financial terms. Methods by Peter Brett Associates for assessing traffic disruption in Metropolitan London were used. Roads were categorised and congestion estimated from the duration of site works as tabulated below.

Congestion costs associated with 14 of the sites where significant impact is expected:

	Average duration per shaft site	**Average cost per shaft site**	**Total cost**
All sites	30 weeks	£1.7m	£18m

Table 2.8a

Congestion costs associated with spoil disposal:

	Number of HGV movements	Total distance km (return)	Congestion Cost
Using 11 tonne HGVs	69,873	869,665	£0.44m
Using 16 tonne HGVs	48,038	597,895	£0.3m

Table 2.8b

It should be stressed that these costs are produced only for the purpose of Cost Benefit analysis and do not represent an anticipated cost to the project. The above sums are not included in the estimate in 2.4. A list of the 14 sites is included as Appendix H.

2.9. The SMART Tunnel (Storm Management and Road Tunnel)

This scheme recently built in Malaysia combines a surface water storage tunnel with a road tunnel to ease traffic congestion and offering a significant cost saving over building separate projects.

The desire for innovation has led to the suggestion that it might be possible to combine the Tideway storage tunnel with the new Crossrail tunnel, which is slightly ahead in design terms. There would be a number of problems with this suggestion, which are outlined below.

The SMART scheme in Kuala Lumpur was planned for storm relief and presented an option for providing a road short cut over a short length of the tunnel without affecting its route. In a monsoon climate the period of use for storm drainage is fairly predictable and the roadway is closed during this time.

The tideway tunnel will fill at random times dictated by rainfall and with no warning which would not be acceptable to a mass transit railway function.

Crossrail has a route determined by fixed stations, which is completely at odds with the Tideway tunnel whose ideal route is located along the river and at a depth that would be problematic for the railway.

Crossrail is to be electrified which would present major insulation difficulties when the tunnel became flooded.

3. Legal Aspects

The Steering Group were requested to study the following:

1. Review of smaller scale and long-term options in accordance with the decision-making requirements under the Guidance to the implementing Regulations of the UWWTD

2. During review, account to be taken of possible requirements under the water framework directive and any other relevant legislation

Outputs:

3. The assessment of the smaller scale options and/or the interim measures in terms of the UWWTD has not been carried out, as this is beyond the scope of the steering group and is a decision that resides solely with Defra;

4. No further detail as regards the implications of the Water Framework Directive has become available during the review period. The agreed position regarding the reviewed Bathing Waters Directive appears to have no immediate relevance for the Tideway.

4. Project Plans

Project plans have been compiled and are summarised below. Estimated costs and programme are included in spreadsheet Continued Works Strategic Programme H.

4.1. Smaller Scale Measures

This Project Plan includes for the smaller scale interim measures that could be implemented during AMP4 to ameliorate the worst effects of pollution once discharged to the river. The sum of 655k allowed during AMP4 for such works is unclear although it is assumed to be sufficient to meet the obligations imposed.

4.2. Progress Storage Tunnel Proposal

This Project Plan includes all the necessary work items to progress the proposed storage tunnel scheme through outline design, planning application, EIA and land acquisition over a five-year programme so that the scheme could commence construction in 2011

The principle items include:

1. Outline design to confirm scope and detail
2. Planning application and EIA, including potential public inquiry
3. Detailed design
4. Risk assessment
5. Site Investigation
6. Land Acquisition
7. Flow and quality monitoring and modelling to assist optimisation
8. Fishery study
9. TBM development
10. Review of similar projects worldwide
11. Stated preference survey
12. Stakeholder involvement and communication

The estimated cost for AMP4 is as follows:

£, 000 at 2004 prices					
Total	**2005/06**	**2006/07**	**2007/08**	**2008/09**	**2009/10**
62,730	260	13,710	14,360	13,520	20,880

Table 4.2

Appendix A

Terms of Reference

This report has been produced in response to the reply to the Report to Government of last summer received from Defra in September 2004, and further considerations by the Steering Group e.g. in relation to the Olympics in 2012. Its purpose is to identify the potential of smaller scale measures to deal with the harmful effects of the CSO discharges to the Thames and for clarification of certain aspects of the current storage tunnel proposal based on the request for further work as follows:

1. **Smaller scale measures**
   - a detailed look at what could be achieved by smaller scale measures to improve the condition of the Thames Tideway and their cumulative impact

2. **Proposed tunnel solution**
   - a detailed investigation of a number of aspects which could potentially affect the case for this scheme

3. **Legal Aspects**
   - review of both smaller scale and long-term options in accordance with the Guidance to the implementing Regulations for the urban waste water treatment directive (UWWTD)

An expansion of these considerations is set out below and will we hope serve as the basis for the next stage of the Steering Group's work. The immediate need is to identify as precisely as is currently possible the extent of the investigative work required to address the issues, to enable an estimate to be made of the costs and likely timescale involved, so that a decision can be reached about whether further specific funding will be needed.

The Terms of Reference may be summarised thus:

OBJECTIVES

- To reach a clear view on what further measures need to be taken to ensure that London's collecting system is adequate in terms of limiting pollution from storm water overflows
- To identify appropriate measures to protect the environment of the Thames Tideway
- To produce reports on further work within the agreed timescale

OUTCOME

To provide an informed view about the risks and uncertainties around the cost and delivery of the proposed tunnel scheme as compared with the costs and benefits of phased or interim smaller scale measures.

DELIVERY – TIMESCALE, COSTS, RESPONSIBILITIES

Areas of work

- Detailed consideration of proposals for smaller scale measures and their cumulative impact
- Proposed tunnel solution: a detailed consideration of a number of aspects which could potentially affect the case for this scheme
- Legal Aspects
- Project plans for delivery of proposed options (smaller scale and long-term).

1. Smaller Scale Measures

- Identification of smaller scale combinations of measures that could be taken in the near future to improve/control/prevent some of the identified pollution problems.
- Evaluation of these smaller scale options to establish their effect over relevant time periods, their costs and benefits, their cumulative contribution and overall effect, and hence implications for a longer term solution.
- Consideration of incremental phasing of the options to deliver increasing and appropriate environmental improvements over time, having regard to relevant legal requirements.
- Consideration of measures that may need to be taken at Abbey Mills and Lower Lee Valley in light of 2012 Olympic bid, their impact, and costs and environmental benefits with regard to the overall strategy

2. Detailed consideration of certain aspects of the current tunnel proposal as a long-term solution

Evaluation of proposal to identify areas needing further investigation or additional consideration, including:

- Environmental and sustainability issues e.g. renewable energy possibilities, assessment of pollution risks and impact during construction
- Risk assessment, development of risk register and contingency measures
- Review of risk of construction overruns and impact on delivery costs
- Revision of costs using up-to-date baselines
- Assessment of land acquisition and planning issues egg establishing whether a public inquiry is likely for any planning application(s)
- Review of possible traffic and congestion issues
- Further Stated Preference Survey on customers' "willingness to pay" and subsequent cost/benefit analysis
- Greater quantification of health risks based on existing epidemiological information, Health Protection Agency study, bacteriological monitoring, recreational usage, and cost/benefits of proposal

3. Legal Aspects

- Review of smaller scale and long-term options in accordance with the decision-making requirements under the Guidance to the implementing Regulations of the UWWTD
- During review, account to be taken of possible requirements under the water framework directive and any other relevant legislation

4. Project plans for delivery of proposed options (smaller scale and long-term)

The group will provide project plans for delivery of proposed options. The plans should cover both smaller scale and long-term proposals and take account of:

(i) cumulative impact, and

(ii) phasing possibilities to deliver increased benefits over time.

Appendix B

Constraints

A number of specific features of London's sewerage system constrain the options available to achieve the objectives.

THE SIZE OF THE CATCHMENT

The area served is about 557km^2. Rainfall intensity and duration over such a large area, is rarely consistent and generates different flow patterns in the sewers even for events of the same overall magnitude. A complete solution must therefore be capable of dealing with excess flows that are generated in any part of the system.

The area is about 45% impermeable so the contributing area of just over 250km^2 would generate a run-off flow of 250,650m^3 from every 1mm of precipitation if uniformly applied. A blanket rainfall of 6mm on this basis would fill the preferred tunnel option. The pump out rate of 10 m^3/s would allow rain to fall continuously over the area at a rate of 0.15mm/hr. None of these values is exceptional although as stated it would be rare for the entire catchment to be affected simultaneously. These factors mean that the tunnel cannot be allowed to simply "fill" but that some degree of management must be employed to optimise catching the first-flush and retaining some storage for predicted flows even when some of the CSOs are overflowing to the river. In dry weather, Beckton and Crossness treat a total flow of about 22 m^3/s combined. As rain falls the maximum combined flow to treatment rises to about 29m^3/s but total flow from the two catchments can rise to well over 200 m^3/s and the excess discharges to the Thames. 300 m^3/s would be generated by a rainfall intensity of 4mm/hr uniformly over the whole catchment. Similarly shorter high intensity storms will generate high volumes of rainfall runoff that cannot be conveyed to the works. Rainfall of this type will occur at least 50 times a year in London. Flows through the east London Treatment works are being increased to 38m^3/s approximately. Although this increased capacity will reduce the volume and impact of CSO spills by treating a greater total flow, it will not be able to prevent discharge from initial high flows from a storm and the frequency of discharge is likely to remain the same.

COMPLEXITY OF THE SYSTEM

The system has evolved over more than 200 years and has been extended, enlarged and refined into a complex system comprising 12,000 kms of sewer with over 600 cross-connections and overflow weirs. Sewage can take different routes and even flow in different directions depending on the loading on the system. Potential solutions need to incorporate sufficient flexibility to deal with this.

TIDAL EFFECTS

London is unusual within Europe in standing on a tidal river estuary. A key potential impact of the tide is to distribute storm discharges up and down the river for up to 15km on average. In general terms any potential impacts are dependant on the significance of the discharges, where they occur in the Tideway and the river flow conditions. For example, a significant overflow in east London, including those from the STWs themselves, will, due to this tidal excursion, quickly be transferred to more sensitive areas upstream like Putney, Barnes and Chiswick on a flood tide during summer low flow conditions. The relatively low freshwater flow in the river means that discharges can take many days after the event to clear.

At high tide many of the gravity CSOs cannot discharge freely and discharges from the pumping station outfalls increase to compensate. This is an automatic system response, which has evolved to prevent sewage flooding, which would otherwise affect large parts of London adjacent to the river. The flood relief sewers target particular parts of the network and drain direct to the river, some collecting flow from up to 20 overflow weirs en-route. Different discharge patterns may therefore occur according to the state of tide as well as the rainfall characteristics.

LACK OF CAPACITY IN THE SYSTEM

The intercepting sewers, in general, flow at about two thirds capacity even in dry weather, which means that there is normally little excess capacity and minimal scope for the speedy return of any substantial quantity of stored flows to the system after the cessation of rainfall. The system has little capacity to deal with wet weather flows and is quickly overloaded throughout even in moderate rainfall. This means that there are not just a few specific "pinch points" in the system that could be dealt with as one-off issues and resolve the overall system deficiency. This leads to one of the key elements of any successful storage solution being its ability to discharge on the east side of London near to the main STWs. Lack of system capacity throughout London means that any flows returned to the system in the west or central catchment areas can overload the interceptors and cause the very discharge to the river, which the storage is designed to prevent.

HIGHLY DEVELOPED AND URBAN NATURE OF THE CATCHMENT

The inner London area has very little available land that could be utilised as part of a solution and any operational sewage-related activity would be highly unpopular with any local residential and commercial properties in close proximity. Inevitably any surface storage would be forced into existing open spaces such as parks and gardens. Although at first sight this might seem a possibility for detention ponds, which might form attractive lakes or water features, it should be realised that this would not quite work as one might think. London's drainage system already exists in combined form so that storage ponds would inevitably impound storm sewage which, however dilute, is not clean rainwater but contains an element of foul sewage. The few extant surface storage tanks that Thames does operate, such as in Acton and Walthamstow, are already subject to odour complaints.

The availability of underground space, except beneath the river itself, is also restricted by the many service and transport facilities throughout the area. Construction work, either above or below ground, would cause extensive disruption to transport systems or could incur large costs in compensation payments resulting from the temporary closure of parts of the Underground railway. The CSOs that stand to be intercepted are, almost without exception, in locations that will potentially cause nuisance, disruption and complaints from the public when construction is attempted.

LACK OF AVAILABLE ALTERNATIVE DRAINAGE OPTIONS

Most of London's original rivers and watercourses have already been incorporated into the sewerage system. There are no other existing potential surface water drainage channels that could be utilised as disposal routes for rainfall run-off. The clay subsoil geology of London is not suitable for rapid infiltration or soak away to take place and there are already existing problems with rising groundwater levels, which would be exacerbated by any attempts to dispose of large quantities of run off into the ground.

LOCATION OF THE UNSATISFACTORY CSOS

The CSOs that require action are spread along the river over a distance of about 30 kms and a solution needs ideally to be applied to all of these. The Abbey Mills CSO is situated on the river Lee, about 5 kms away from the Tideway. This geographical spread restricts some of the options available for applying a compact solution, but it is unlikely that it would prove to be efficient for each CSO to have its own local solution. In fact one can see how, if each CSO were to have an individual storage tank near the river and the discharge had to be taken to east London a tunnel the length of the Tideway inevitably emerges as the way for this to be achieved.

AVAILABILITY OF SUITABLE TREATMENT SITES

Crossness and possibly Long Reach, are the only existing STWs that have available land to accommodate any additional treatment plant that would be required. There would be extreme difficulty in establishing a new treatment facility in central London due to land availability and planning constraints. Additionally, a treatment plant that was only dealing with intermittent storm discharges would not be able to support secondary treatment.

Appendix C

Smaller Scale and Interim Solutions – Modelling Results

INTRODUCTION

The aim of the modelling assessment was to produce some quantification and test the compliance of the likely improvements made by the smaller solutions to Tideway DO levels.

SMALLER SCALE OPTIONS & INTERIM MEASURES

It was agreed that the modelling exercise should focus on the smaller scale options, which are considered to be part of more long-term solutions, and not the interim measures as these were specified as being only temporary.

The modelling group therefore selected the following smaller scale options to model for compliance against the DO standards:

- As the previous Option H but including primary treatment of the tunnel discharge at Heathwall using a new dedicated treatment facility.
- Providing a new primary treatment plant at Abbey Mills, firstly on its own with no other improvements to the Tideway and secondly In conjunction with the enhancement of option H as 1 above.
- Phased implementation for the full complete solution A(ref): Phase 1 - Tunnel linking Abbey Mills to Greenwich and to Crossness (The river Lee Option 2): Phase 2– phase 1 with upper Tideway tunnel (primary treatment at Heathwall) and Phase 3 – Phase 1 & 2 with link between Hammersmith and Greenwich constituting solution A(ref) as already modelled in main study.

THE COMPLIANCE TESTING RESULTS

Table C.1 Options selected for compliance testing:

Option	Description	Run Name
1	Upper Tideway Tunnel (primary treatment at Heathwall)	Q_1
2a	Primary treatment at Abbey Mills only	Q_2a
2b	Primary treatment at Abbey Mills and Upper Tideway Tunnel (primary treatment at Heathwall)	Q_2b
3a – phase 1	A(ref): Phase 1 - Abbey Mills, Greenwich, Crossness link tunnel	Q_3a - Phase 1
3b – phase 2	A(ref): Phase 2 – Upper Tideway Tunnel (primary treatment at Heathwall) + Phase 1.	Q_3b -Phase 2
3c – phase 3	* A(ref): Phase 3 - Completed solution	Q_3c -Phase 3 (same as completed A(ref)

** Return stored flow to Crossness and Beckton for full treatment incorporated.*

All the solutions were assessed using the same models and the same CTP (Compliance Test Procedure) as the large-scale options assessed in the main study using the revised 154 rainfall events (see Objectives Working Group Report, Vol 2: Modelling studies). See also the following graphs, which display the raw data collected from the model runs.

RESULTS

1. The upper Tideway tunnel option variant H with treatment plant at Heathwall reduces the number of events failing the standards, but is not a compliant solution for any of the DO standards assessed.

2a. The effect of treating spills only at Abbey Mills is to reduce the number of failures considerably (compared to the baseline), such that standard 3 is compliant, while standards 1 and 2 fail.

2b. Treating spills from Abbey Mills, as well as the upper Tideway tunnel with treatment at Heathwall, has an improvement in compliance for all standards, with standards 2 and 3 being compliant; however, the more stringent standard 1 fails.

3a. The impact of Phase 1 of the option A(ref) tunnel reduces the number of failures from the baseline situation resulting in compliance for standard 3, but not for standards 1 and 2.

3b. The impact of Phase 2 of the option A(ref) tunnel along with phase 1, makes standards 2 and 3 compliant but still fails for Standard 1 (the most stringent standard)

3c. The impact of Phase 3 completing option A(ref) reiterates that only the complete tunnel solution is able to produce compliance with the DO standards

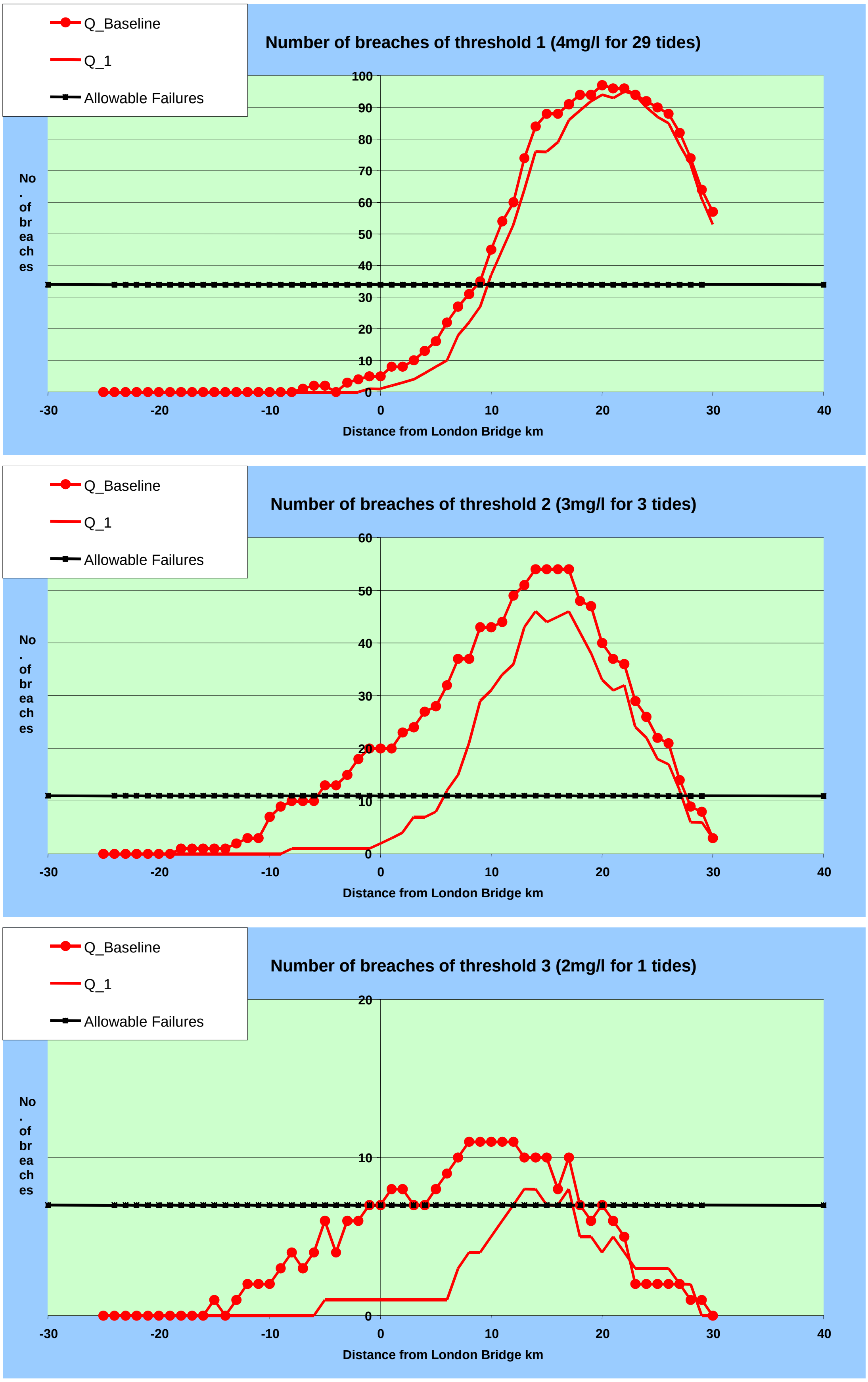
CONCLUSIONS

Although the results show a marked improvement in DO in the Tideway for some options, they do reinforce the previous study conclusions that the smaller scale solutions would not be sufficient to produce complete compliance with the DO objectives. The results show that this is the case whether the options are considered as stand-alone alternatives or in combination.

Note: *It had been hoped to model the effect of installing dispersed offline storage units throughout the catchment to understand the scope implications of such an approach. Desktop analysis showed that this would undoubtedly involve a much larger overall storage volume than the main tunnel option and would create many pump-back issues, especially on the west side of London. However to model such dispersed offline storage would entail in practice re-designing the sewerage network model and this was not considered feasible within the time available.*

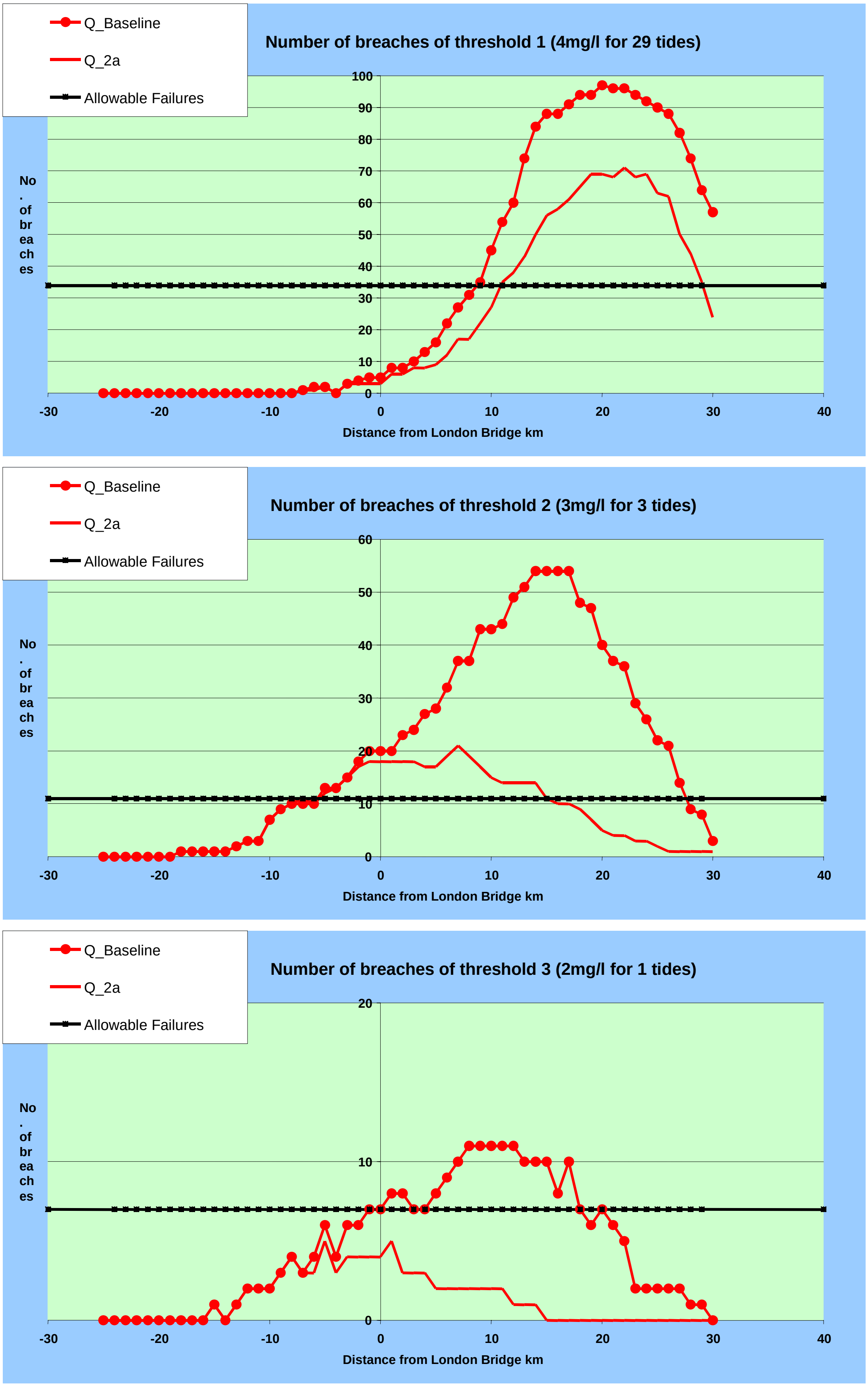
It was also found that accurately modelling the pump out of variant option H to the existing sewers would not be possible due to the limitations of the CTP. This is based on the impact of 154 individual rainfall events which are each assessed as a single occurrence and not part of the 'time-series' rainfall events which happen in reality. This means it is not possible to use the existing CTP to accurately represent the limitation on transfer of stored sewage back to the network before a further rainfall event causes the tunnel to fill again. This would make this solution artificially to appear beneficial and thus not truly comparable to the other small-scale solutions.

Figure 1 - Compliance plots: Baseline and Option H with treatment plant at Heathwall



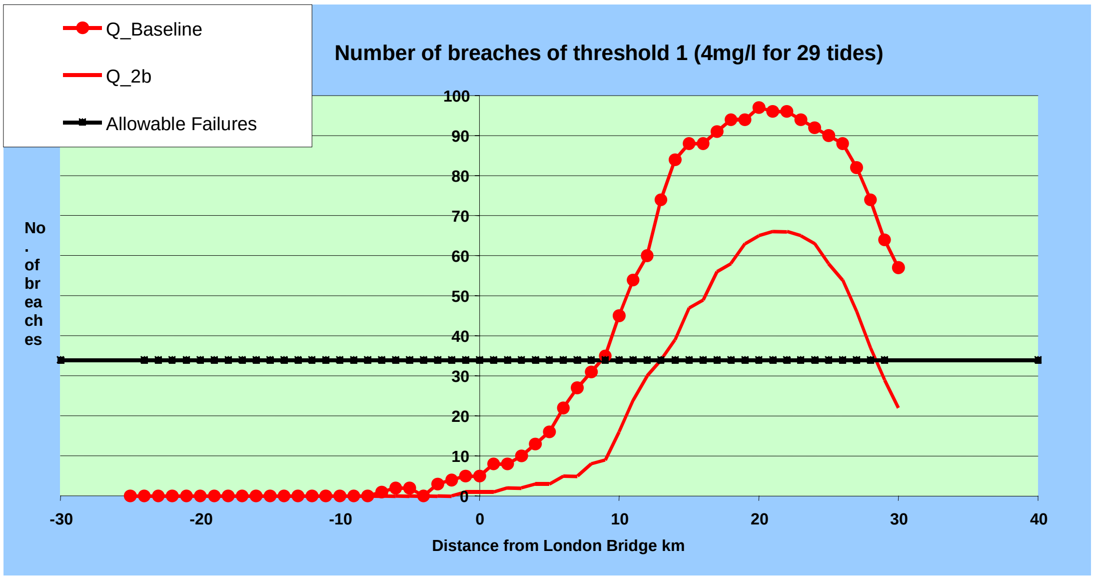
Baseline refers to runs undertaken with no solution or improvements included

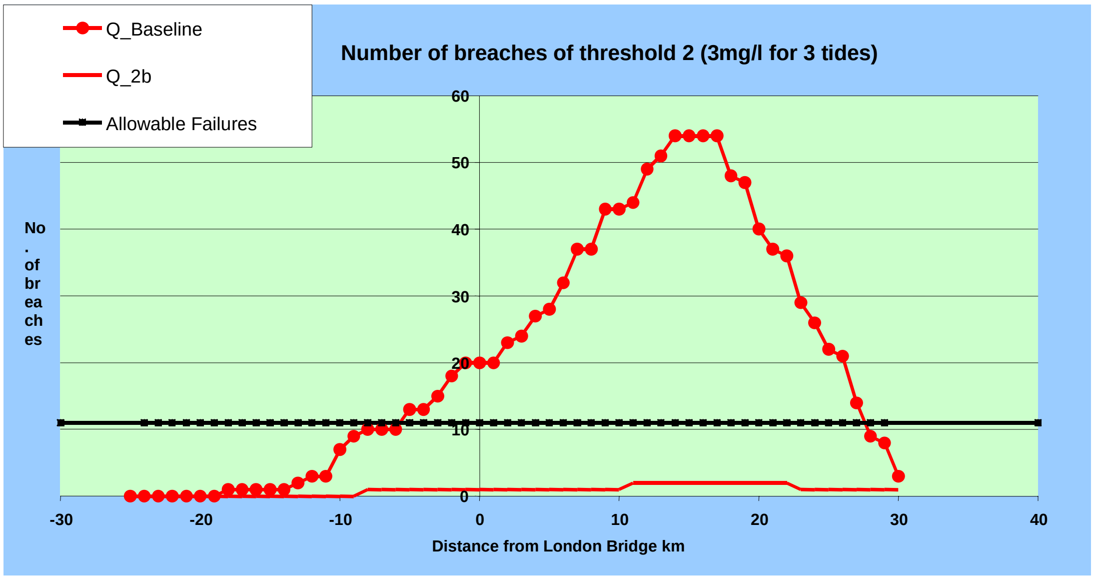
Figure 2 - Run 2a Compliance plots: Baseline and Baseline with treatment plant at Abbey Mills alone

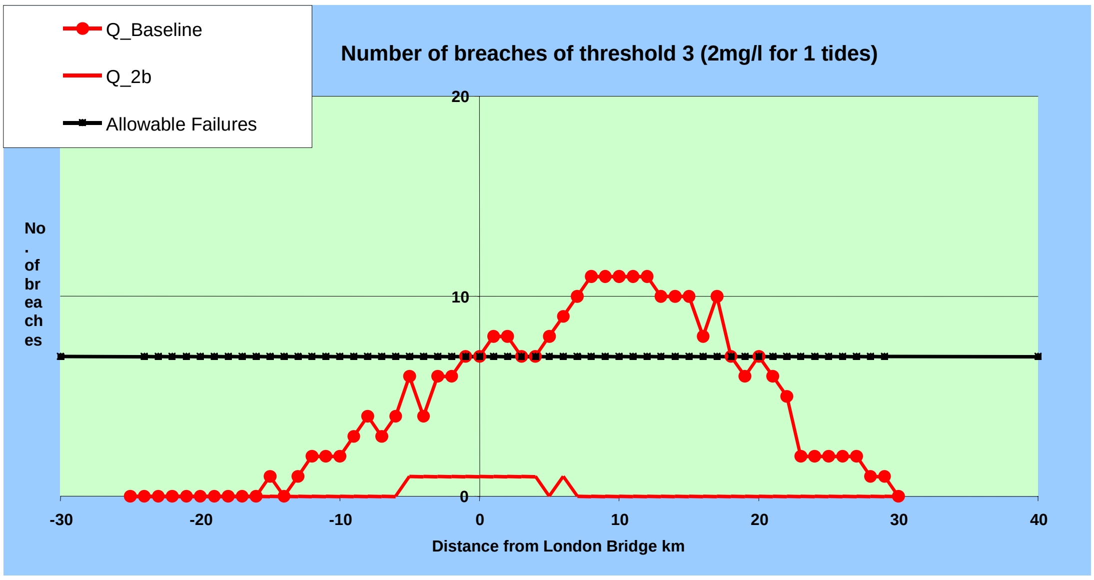


** Baseline refers to runs undertaken with no solution or improvements included*

Figure 3 Run 2b - Compliance plots: Baseline and Option H with treatment plant at Abbey Mills and at Heathwall

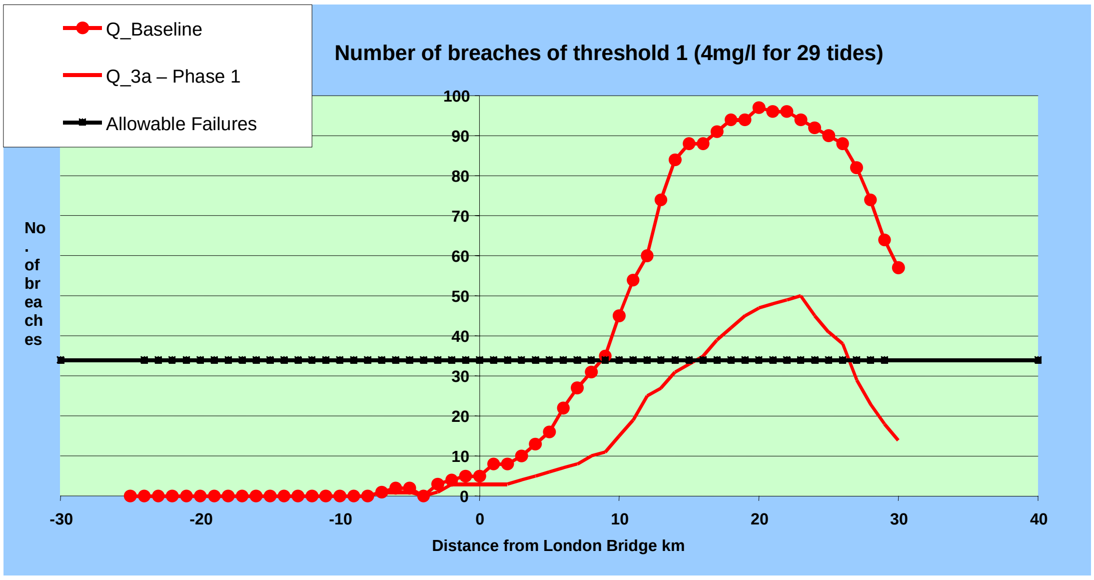


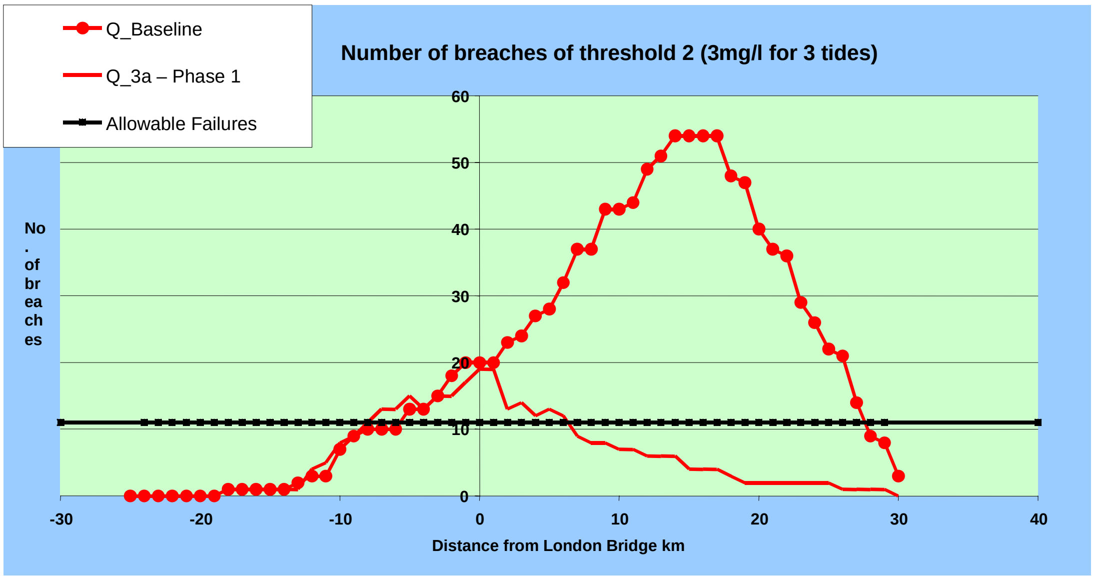


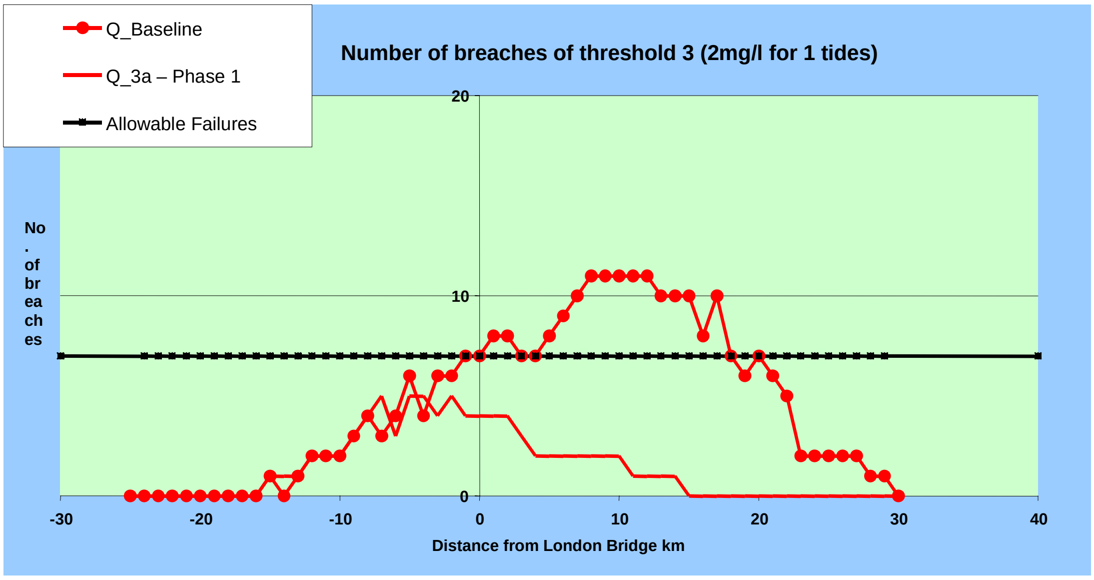


** Baseline refers to runs undertaken with no solution or improvements included*

Figure 4 Run 3a - Compliance plots: Baseline and Phase 1 of Option A tunnel

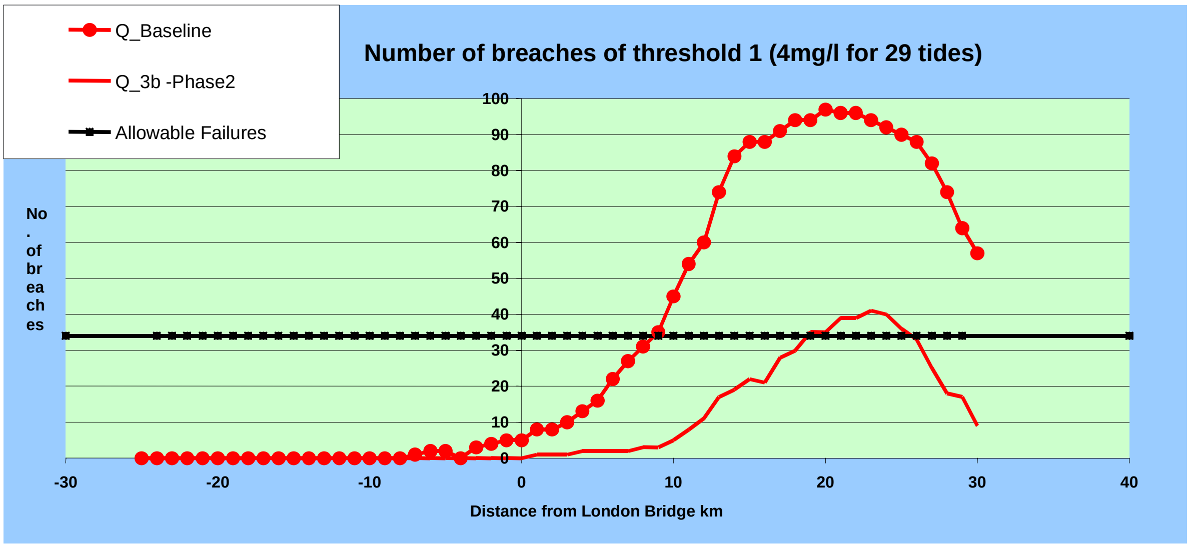


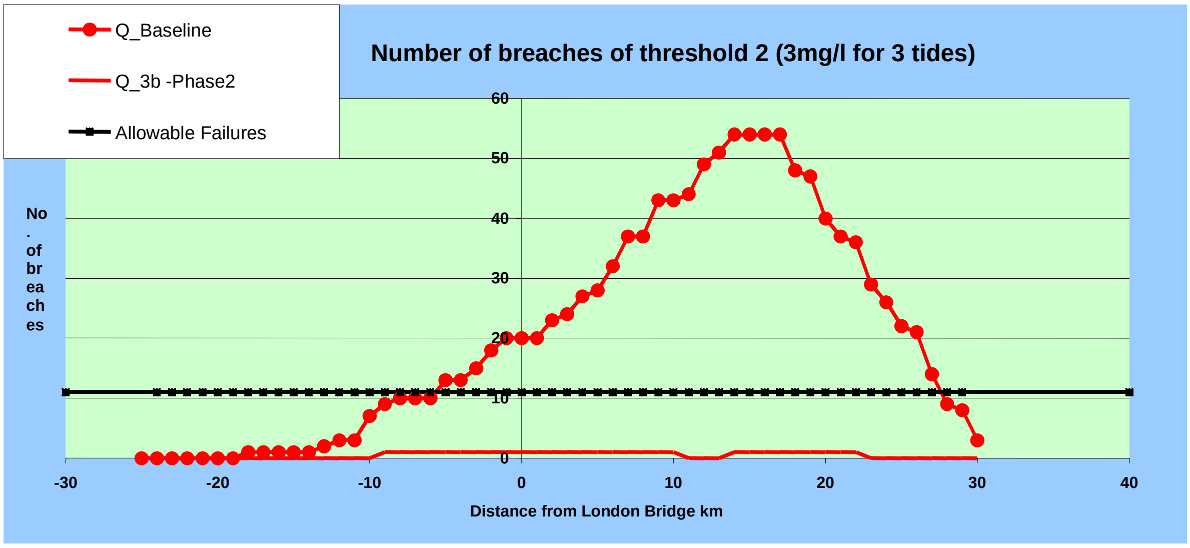


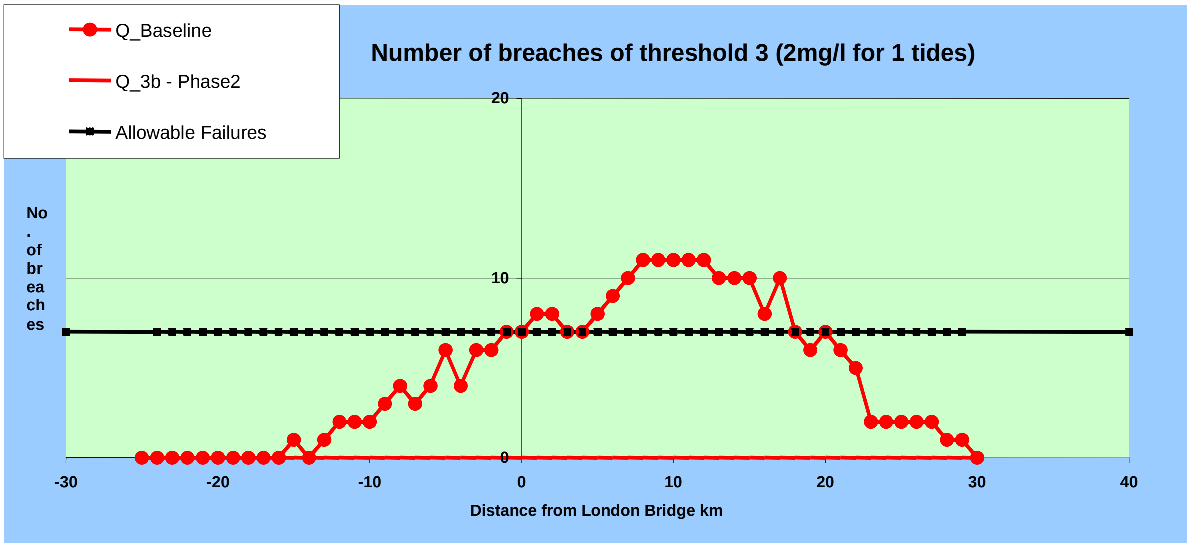


** Baseline refers to runs undertaken with no solution or improvements included*

Figure 5 Run 3b - Compliance plots: Baseline and Phase 2 + Phase 1 of Opt A tunnel

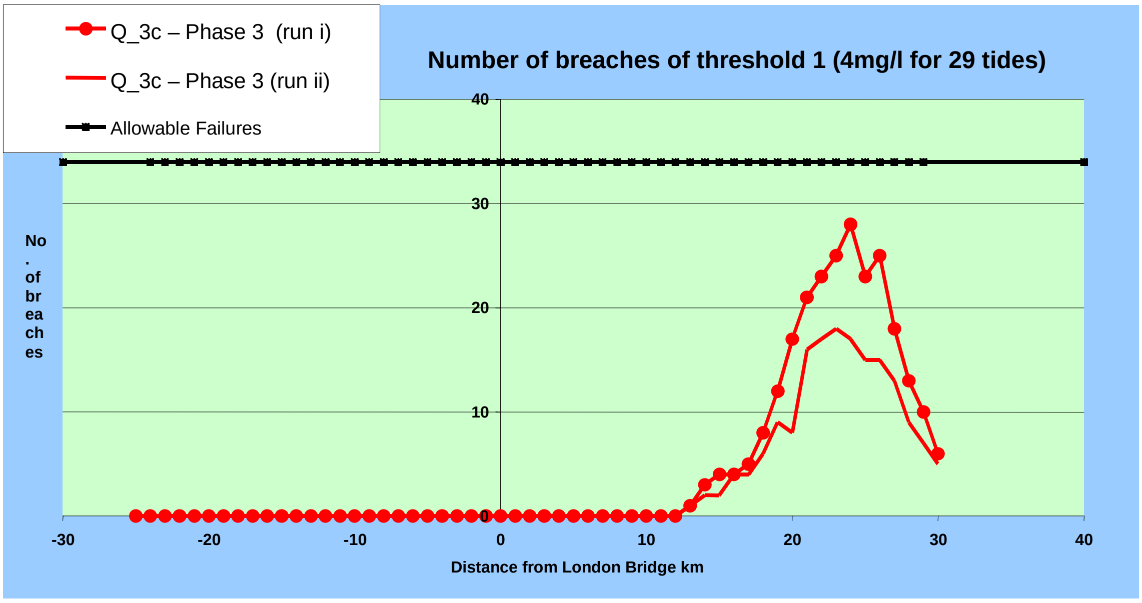






** Baseline refers to runs undertaken with no solution or improvements included*

Figure 6 – Run 3c - Compliance of option completed A(ref) Phase 3. Standard 1 [Note: no failures recorded of standards 2 (3mg/l) and 3 (1mg/l)]



Note: Two runs were undertaken for the completed solution A(ref) in the compliance testing; Runs (i) and (ii) represent slightly different treatment capacity values for Crossness STW to test the sensitivity for this treatment works – both runs were below the allowable failures line and therefore the solution is compliant.

Appendix D

River Lee Bid Phased Approach

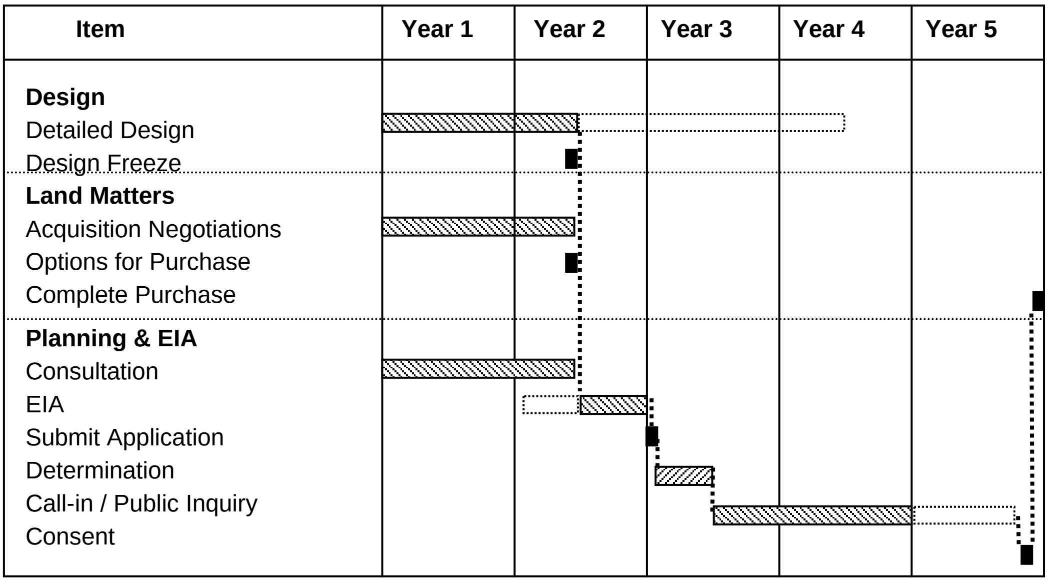
Phase	Engineering and Operation	Cost (£M)	*Benefit*	Comments
Eastern Section	1. 5.0m dia tunnel 4.5km Abbey Mills PS to Greenwich and connections to Deptford and Charlton) 2. 7.2m dia tunnel 9.4km Greenwich to Crossness STWs + PS + treatment 3. Link tunnel to Beckton STW from Main Tunnel	**554**	• Possible completion by Olympics • DO problems in middle reaches eliminated once STW improvements completed • Reduced health risk in Lee and middle reaches • Improved aesthetics in middle reaches	• Tight deadline may only be met if covered under possible Olympic Bill with Planning process accelerated • Aesthetic problems in middle reaches remains with solids from upper Tideway
	1. Outline design, planning application and EIA for Phases 2 and 3. 2. Land acquisition for main shaft sites	**Approx 60**		• Progress separately from fast track process for Phase 1
Western Section	1. 7.2m dia tunnel 10.6km Chiswick to Heathwall PS + connections to 19 CSOs 2. Pumps + screening plant + Peroxide dosing at Heathwall. Intercepted sewage pumped to Low Level sewer (48hr pump out). 3. Excess screened and peroxide dosed.	**501**	• Significant improvements to aesthetics and health risk • Improved measure of protection to sensitive section of river	• Major aesthetic pollution through central London remains. Some health risk and sub-lethal DO problems remain. • Screening plant, pumping station and peroxide dosing would become redundant after Phase 3
Central Section	1. 7.2 dia tunnel 14km Heathwall to Greenwich + connections to 14 CSOs 2. Additional main shafts	**642**	• Full Compliance with objectives • DO, health risk and aesthetics pollution eliminated	• Combination of Phases equates to proposed storage tunnel solution but at additional cost of £204M • Compliance for all objectives achieved by 2020 if phases delivered one after another

Note: Budget costs are at 2002 level
Timescales assume that approval is given in spring 2005 and that the planning process is facilitated and accelerated over normal
Split between phases is approximate and should be verified by more rigorous assessment should this approach be progressed.

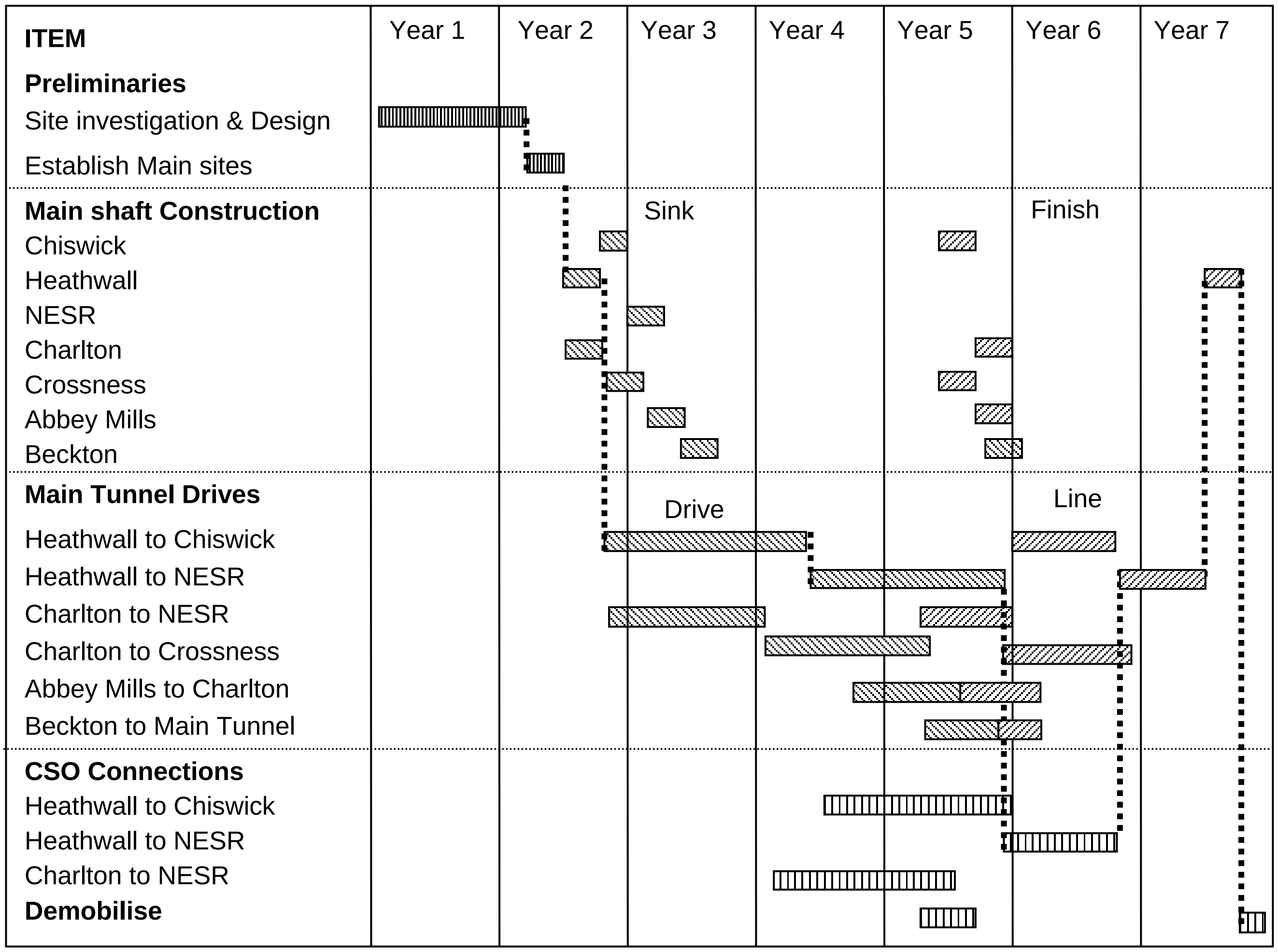
Appendix E

Implementation Programmes

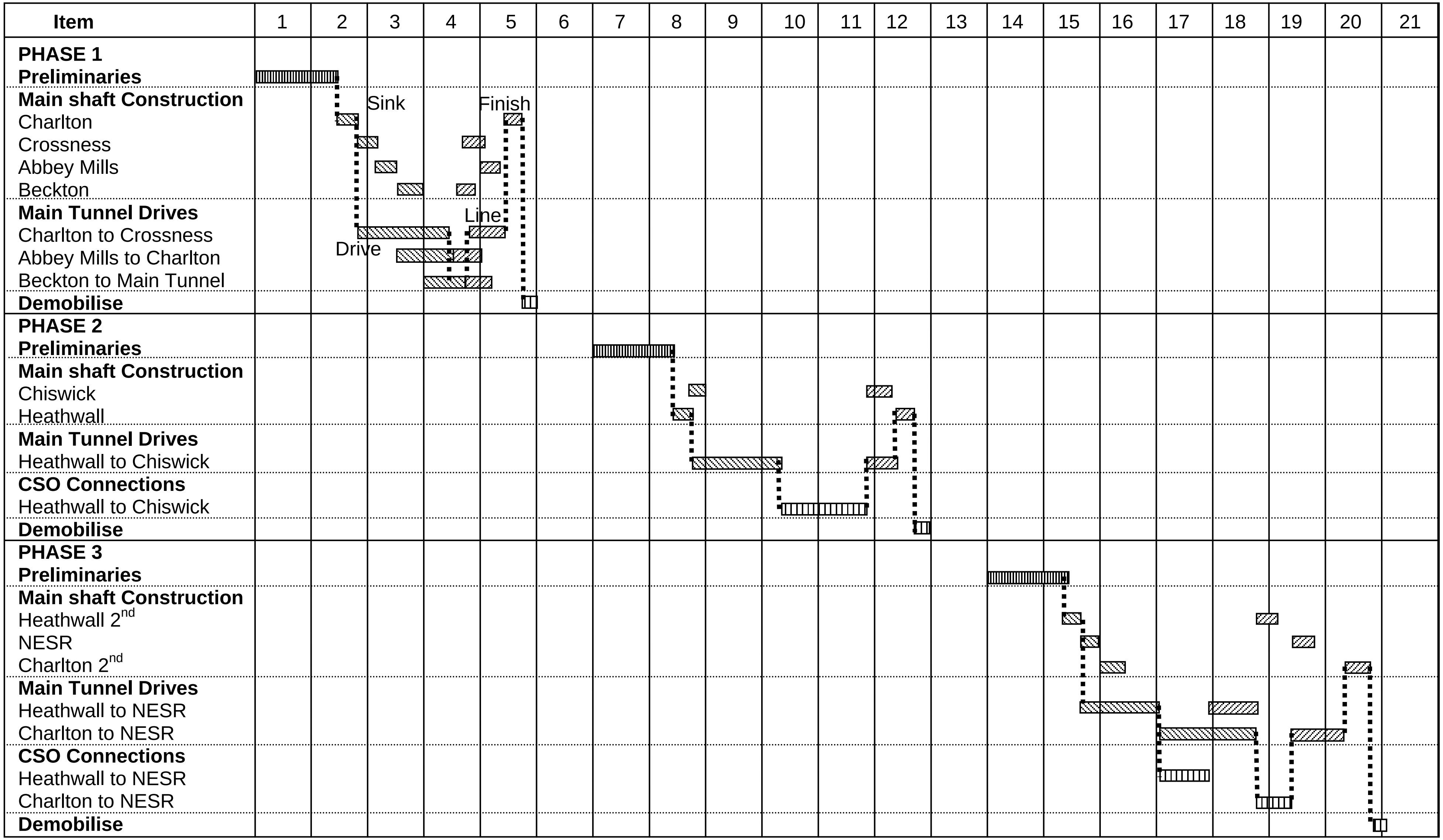
E1. Planning & Development Programme



E2. Construction Programme – Continuous



E3 Construction Programme – 3 Phases



Appendix F

Planning Risks

POTENTIAL RISKS

- Scheme requires planning permission and cannot be done under PD rights
- Scheme requires EIA
- This option has been considered under the SuDs option and has been rejected as impossible now to install on any sensible scale in central London. Even if approval of the installation were not a problem – which of course it is – the cost would be prohibitive for not much gain given that the sub-soil in London is clay and has poor permeability. Planning applications for scheme elements are submitted to relevant planning authorities individually and one or more refuses permission
- Planning application is submitted to a lead authority who coordinates responses from individual authorities and one or more refuses permission
- Mayor's office directs refusal of one or more applications to boroughs
- Thames Water appeal against refusal, Public Inquiry is held and Inspector recommends dismissing appeal
- Planning application is deemed to be a departure from local plans, or a significantly controversial scheme, and is called in by Secretary of State (ODPM/DEFRA) for Public Inquiry
- Technical or non-technical objector requests SoS to call application in for Public Inquiry and SoS does so
- Planning inspector recommends refusal and SoS refuses permission
- Planning inspector recommends approval and SoS refuses (for political reasons).

IMPLICATIONS

The main implication of the above planning risks is time delay; as soon as the planning process is in the hands of the inspectorate or the Secretary of State, Thames Water loses control of its programme.

A realistic estimate of the time from submission of an application to the end of a public inquiry is approximately 18 months. The planning and environmental programme issued in June 2003 (see Figure 1 overleaf) has been constructed fairly conservatively, allowing 6 months for a local authority determination; 18 months for a public inquiry (assuming that Thames Water would appeal a refusal) and another year for the inspector's report and final determination by the SoS. The programme thus takes the potential delays associated with planning risk into account.

The programme may nevertheless be subject to further extension due, for example, to design changes driven by internal or external factors extending and/or delaying subsequent tasks.

Appendix G

Revised Risk Register - Statistically Adjusted

Reference	Risk Description	Risk Response Plans	Minimum Impact (£m)	Most Likely Impact (£m)	Maximum Impact (£m)	Adjusted value for Statistical Analysis (£m)	Likelihood %	Risk Value (Likelihood x Most Likely) (£m)
1	Operations refuse to accept design for H&S reasons	Ensure active involvement of Operations in design process	50	500	50,000	464	80	400
2	Tunnel wrong size due to error in modelling	Continuous development and independent review of model	10,000	50,000	150,000	2,902	5	2,500
3	Tunnel wrong size due to changing objectives	Continuous review of agreed objectives	10,000	50,000	150,000	11,608	20	10,000
4	Method of operation leads to over sophisticated control system which is undeliverable	Keep it simple get Ops sign off and involve system suppliers early	2,000	10,000	30,000	3,483	30	3,000
5	Inadequate design resources to meet program	Keep market under review	5,000	10,000	15,000	3,483	30	3,000
6	failure to select appropriate pump supplier	Bring KSB to project team test pumps with sewage	100,000	1,000	25,000	116	10	100
7	AMP4 treatment capacity not available for project as anticipated	Continuously review model	10,000	50,000	100,000	17,413	30	15,000
8	Not taking account of flooding	Consider flooding as a secondary objective and remodel JTDI	10,000	50,000	150,000	17,413	30	15,000
9	Poor ventilation and odour control	Good ventilation design	200	1,000	5,000	464	40	400
10	Design assumptions for sewage strength and flow are incorrect	Instigate adequate sampling program to determine likely loadings	10,000	20,000	100,000	11,608	50	10,000
11	Tightening of discharge consents	Establish consents	10,000	50,000	150,000	5,804	10	5,000
12	Lack of liaison between process and network design teams for Crossness, etc.	Establish liaison route between teams	10	100	6,000	12	10	10
13	Scope/capacity of additional sludge treatment plant inadequate for tunnel flows	Instigate adequate sampling program to determine likely sludge loadings	2,000	4,000	54,000	464	10	400
14	Climate change scenarios are incorrect	Plan to best available knowledge	1,000	8,000	150,000	2,786	30	2,400
15	No design and planning team in place	Develop a plan	9,000	18,000	36,000	12,537	60	10,800
16	Lack of operational strategy	Work with Ops to develop operational strategy	0	0	0	0	0	0
17	Delay to Ministerial approval beyond Spring '06 makes construction sites unavailable	Early acquisition of sites and identify alternatives	1,000	31,000	150,000	0	0	0
18	Increasing land values lead to insufficient funding in project for site acquisition	Develop a land acquisition strategy	1,000	31,000	150,000	0	0	0
19	SPZ constraints more severe then assumed	Clarify position with EA and TW	1,000	5,000	10,000	1,451	25	1,250
20	Additional contracts required to deliver the project then assumed for base cost	Develop an appropriate contract strategy	20,000	50,000	100,000	46,434	80	40,000
21	Limited number of insurers	Self insurance	100	13,000	30,000	10,564	70	9,100
22	Rejection of planning by GLA on sustainability	Early consultation with GLA and provision of 10% renewable energy	100	5,000	10,000	174	3	150
23	Forced down to choose the unconventional planning route	Develop planning strategy and early consultation	100	250	5,000	29	10	25
24	Objections to embankment work	Alternative interception of embankment CSOs and early consultation	100	2,000	5,000	464	20	400
25	Difficult ground conditions at CSO tunnel connections	Adequate SI and temporary works design	1	2,500	10,000	290	10	250
26	Failure of tunnel integrity	Adequate SI and temporary works design	20,000	20,000	40,000	232	1	200

Reference	Risk Description	Risk Response Plans	Minimum Impact (£m)	Most Likely Impact (£m)	Maximum Impact (£m)	Adjusted value for Statistical Analysis (£m)	Likelihood %	Risk Value (Likelihood x Most Likely) (£m)
27	Tunnel machine breakdown	Segmental bearings design	100	5,000	20,000	580	10	500
28	Developing tunnelling technologies fail to meet scheme expectations at depth	Develop technology with manufacturers	1,000	10,000	200,000	1,161	10	1,000
29	Failure to control verticality of shaft lining over the depth	Contingency measures available on site	2,000	8,000	24,000	3,715	40	3,200
30	Lack of resource availability due to competing projects	Source labour/resources from international market	10,000	30,000	50,000	20,895	60	18,000
31	HSE stop job due to failure to meet NO legislation	Plan and agree with HSE	1,000	2,000	3,450	1,161	50	1,000
32	Failure to meet new H&S legislation outside current working practice	Respond when known	100	200	400	23	10	20
33	Unsustainable soil disposal	Identification of sustainable soil disposal strategy -including possible re-use in flood risk strategy	5,000	54,000	108,000	12,537	20	10,800
34	More contaminated soil for disposal than anticipated	Adequate site investigation	640	1,280	2,560	149	10	128
35	Riverside disposal site unavailable	Develop soil disposal strategy and acquire land if necessary	1,000	20,000	50,000	4,643	20	4,000
36	Encountering unforeseen ground obstructions in shafts and CSOs	UXB survey and archaeological survey	2,250	3,250	5,250	1,886	50	1,625
37	need to meet Olympic bid demands or requested to deliver accelerated programme to meet EC directives	Identify long lead items and early planning approvals	20,000	50,000	100,000	0	0	0
38	Unexpected complexity of utility diversions in CSO connections	Early liaison with Utility Companies and associated surveys	3,000	30,000	60,000	10,448	30	9,000
39	Unexpected complexity of utility diversions in main shafts	Early liaison with Utility Companies and associated surveys	350	700	1,400	81	10	70
40	Obligations imposed by owners existing structures due nearby to construction work	Early liaison with owners and associated surveys	300	1,000	3,000	348	30	300
41	Inaccurate modelling of pollution plume in river outfalls	Independent review of modelling additional treatment required	50	5,000	50,000	580	10	500
42	Increase number of CSO requiring connection	Develop contingencies for each non connected overflow	100	12,000	90,000	697	5	600
43	Design development (scope creep)	Value Engineering Workshops	1,000	5,000	15,000	1,161	20	1,000
44	Exchange rate fluctuations	Investigate potential for commercial protection	1	1	20,000	0	5	0
45	Budgeting omissions	Continual scope check	100	17,900	35,800	6,234	30	5,370
46	Preliminary treatment plant at Beckton has insufficient capacity for additional tunnel flows	Investigate condition/capacity of proposed refurbishment	5,000	10,000	30,000	5,804	50	5,000
47	Treatability of sludge arising from tunnel flows. Could have low calorific value and adverse impact on incineration	Monitor sample from CSO and sewerage system	10,000	20,000	30,000	6,965	30	6,000
48	Proposed storm treatment plant at Crossness may not perform. Solids loading possibly too high	Pilot plant trials. Possible synergy with tertiary treatment	11,000	60,000	150,000	34,825	50	30,000
49	Scope/cost estimates for sludge transfer main inadequate	Investigate and develop scope during detailed design	1,000	2,000	4,000	232	10	200
		Items 17,18, 37 allocated 0% as uncontrollable items.				264.2		227.7
		Actual Risk value calculated (£m)						**264.3**
		Adjustment factor						1.16084

Appendix H

The 14 CSO Sites Having the Greatest Local Impact

Road Classification Types and Accompanying Congestion Costs

CSO Name	Modified DMRB UAP Road Type [1]	Traffic management type [2]	Duration (weeks)	Cost £k
Acton	4b	Road closure	25	£58
Putney Bridge	2	Road closure	25	£1,600
Church Street	4a	Shuttle working	26	£230
Clapham	1	Shuttle working	31	£5,950
Brixton	1	Shuttle working	31	£5,950
Grosvenor Ditch	2	Shuttle working	28	£480
Regent St	3	Shuttle working	29	£620
Northumberland St	3	Shuttle working	29	£620
Savoy Street	1	Shuttle working	30	£5,760
Norfolk St	2	Shuttle working	30	£510
Essex St	2	Shuttle working	30	£510
Shad Thames	4a	Road closure	31	£430
Holloway SR	4b	Road closure	34	£78
Greenwich PS	3	Shuttle working	33	£700
Total				**£23,500**

Appendix I

Comparison of CSO Discharges for Sizing Storage Options

Following the first phase of the Tideway Investigations described in the Solutions Working Group Report Volume 1, it was decided at the end of 2003, to include in the main solution discharges from the river Lee CSOs. The main impact was to take account of the flows from Abbey Mills pumping station, which had been specifically excluded from the original brief. This was quickly assessed to see the impact on the solutions which had been formulated at that time and it was quickly seen that the addition of the major discharges to the Lee would not be likely to change the order of benefit of these options and thus change the storage Option A from being as the preferred type of solution. For this reason the reassessment of the compliance with the objectives was applied to Option A only.

At that time the 1200 storm events, which had been used to test the impact of the solutions, had been generated using standard computer modelling methods. By early 2004, because of the study it was now possible to use rainfall data from real storms falling in the London area over a number of years, especially from 1989 onwards. Some 154 significant storm events occurred when river sensitivity was highest (i.e. in the warmer months from May to October) and these were fed into the hydraulic models which were upgraded to include Abbey Mills flows and in addition the effect of the AMP 4/5 upgrade works at Beckton and Crossness and the discharge volumes from each CSO were thus recalculated. This process revealed there was originally an error in the apportionment of flow between Abbey Mills and Beckton via the NOS that underestimated the flow discharged to the river by the pumping station. This was corrected for all subsequent modelling work and flow calculations. The change in the proportion of the total discharge from each of the larger CSOs compared with the earlier assessment is shown in the chart below (Fig I.1).

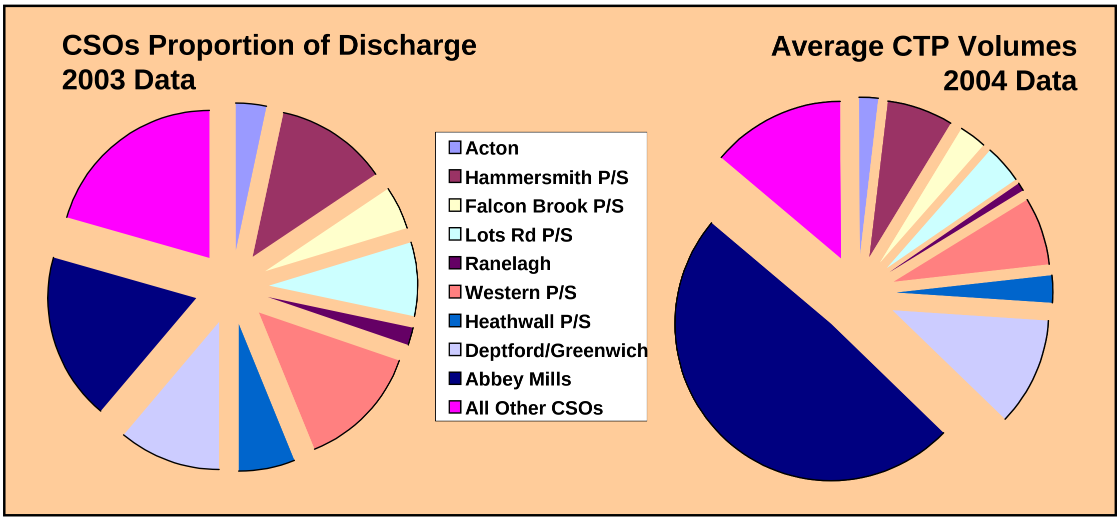


Fig I.1

Using the improved rainfall data and recognising the detailed objectives now in place, the models were re-run to see which variation of tunnel size in option A would just meet all the objectives most economically. This was the "Compliance Test Procedure" (CTP) and led directly to the preferred option, A(ref) (see 1.1.2).

In this report the following method was used to assess the volumes of discharge that would be captured by the various partial options including H, H+ and H++. The annual intercepted volumes were calculated mainly using the data stored in the spreadsheet "Vol 154 events for partial solutions.xls – J. Greenwood". The individual discharges from each CSO for each of the 154 CTP events for each option were summed to give the total spill volume for each CTP event. These spill volumes were then arranged in descending order.

The spill volume values of all 154 events are shown graphically in fig I.2 below.

As the CTP events are generated from many years of rainfall data the resulting spill volumes were statistically assessed to give the expected frequency of occurrence for a given volume of discharge. The storage volumes for the range of options were selected on the basis of the volume of discharge they would intercept and therefore the number of times per year that a bypass may occur. The larger the volume the fewer the bypasses.

The storage for each variation of the options was then compared with the total spill volume of each CTP event to assess volume stored and volume bypassed.

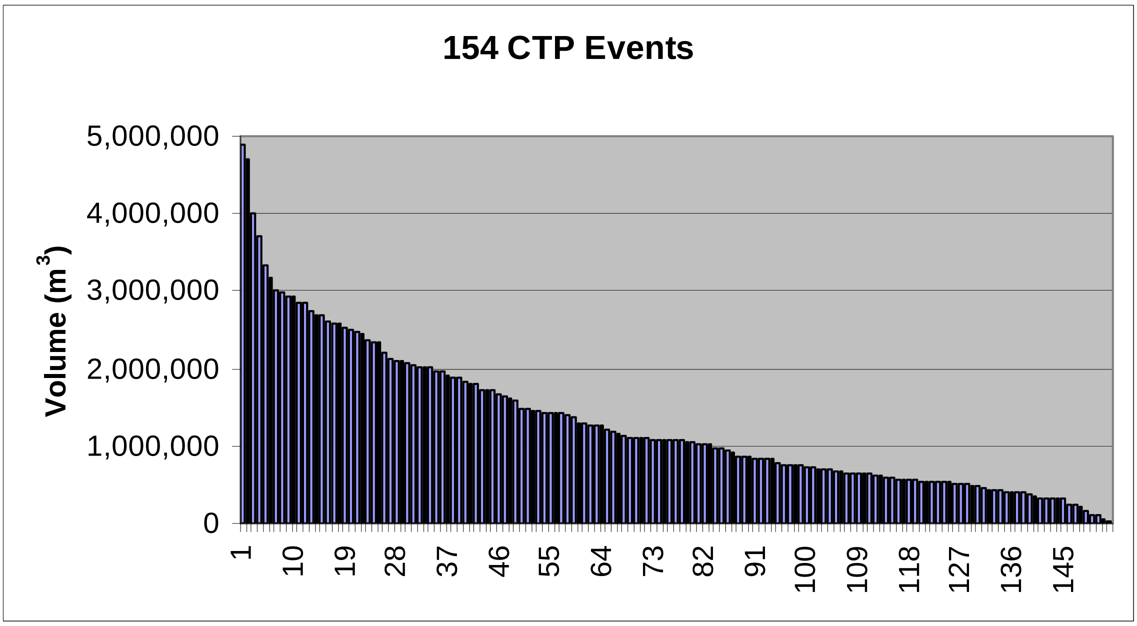


Fig I.2

The CTP events represent the most significant rainfall in the period and thus the capture of discharges from smaller events is not included in the above step. To allow for this the flows captured from the remaining smaller events were therefore estimated in the following way.

From the 154 CTP events the typical percentage of discharge captured by each option as a proportion of the whole Tideway was calculated. This factor was applied to the difference between the estimated total actual annual volume predicted by the models (see 1.5.3) and the total annual discharge volume for the CTP events for the whole tideway to estimate the volume of the remaining smaller events. It is assumed that all these smaller events would be completely captured by each variation of the relevant option. Thus the overall percentage captured is this sum divided by total estimated discharge for the whole tideway.

The data is shown in table 0.4 and described in detail in the various options in section 1.3.1

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