Bloomberg NEW ENERGY FINANCE

Contents

Tunnel vision: Thames Water and the London Tideway Tunnel

For over a decade Thames Water has been planning a GBP 4.1bn tunnel to capture raw wastewater which overflows from its sewer system into the Thames River during heavy rains. The project is currently seeking final development consent and has the support of key stakeholders including the Government, the Department for Environment, Food and Rural Affairs, the Environment Agency and the Greater London Authority. However, it remains controversial, principally because no in-depth study has ever been carried out on alternative green infrastructure or blended approaches, and also because Thames Water's dividend policy and increasing leverage has left it unable to finance the investment without significantly raising water bills. In this note Bloomberg New Energy Finance analyses the largest wastewater project planned for in the UK since the Victorian era and explains why more work should be done to study the alternatives.

- London is served by a 19th century combined sewer system which collects sewage and rainwater using the same pipes and tunnels. Combined Sewer Overflows (CSOs) are positioned along the Thames to prevent flooding of streets and homes with storm sewage when the system is overloaded following rainfall. On average each CSO discharges about once a week.
- In October 2012, the Court of Justice of the European Union ended a 12-year case by ruling that the UK had breached the Urban Waste Water Treatment Directive (91/271/EEC), partly as a result of London's frequent raw sewage discharges into the Thames. The European Commission is set to levy a fine on the UK Government unless a plan is under way to resolve the situation.
- Thames Water has for over a decade been developing plans to build a 25km long Thames Tideway Tunnel (TTT) running under the river to capture sewage overflows at the most hazardous CSOs in order to comply with EU law. This tunnel is currently expected to cost GBP 4.1bn and increase households' wastewater bills by a maximum of GBP 70 to GBP 80 in the early 2020s.
- Due to its policy of increasing its leverage and distributing generous dividends, Thames Water's gearing increased from 44.4% in 2006 to 77.4% this year, a level which will prevent it from financing the TTT from its own balance sheet. Instead, it is proposing that a special purpose vehicle be created which will raise debt and equity on public markets, with the government underwriting the biggest risks during the construction phase of the project.
- Modelling the economics of the project under different scenarios suggests that the maximum increase in water charges of GBP 70 to GBP 80 per year proposed by Thames Water would result in a post-tax return to equity investors in the TTT of between 14.7% and 24.1%, considerably higher than the estimated 7.1% cost of equity for existing water utilities. This corresponds to returns of between 16.4% and 25.5% in pre-tax terms.

- Our model also suggests that a post-tax IRR of 7.1% would require an increase in bills of GBP 30.8 to GBP 35.3 per annum, depending on debt rates achieved by the project. In addition, a post-tax IRR of 12% could be achieved with bill increases in the range of GBP 44.7 to GBP 57.8.
- International case studies have shown that Integrated Water Management (IWM) approaches based on a range of measures to capture, slow down, absorb or divert stormwater can have better economics and performance than tunnel-only solutions. IWM solutions also bring a range of co-benefits, including improvements in air quality, leisure amenities and urban realm improvements.
- No comprehensive study assessing different IWM options for the London catchment has ever been carried out. The partial studies which have been carried out are regarded as flawed and out-of-date. One of the key experts who led the early studies pointing to the TTT solution has now changed his position to support an IWM solution.
- A number of MPs, members of the House of Lords, non-governmental organisations and boroughs adjacent to the Thames are opposing the planning consent on the basis that technological alternatives have not been properly considered. While it looks most likely that planning consent will nevertheless be granted due to the project's strong institutional support, there are a number of potential legal challenges which opponents could deploy to derail it.
- European regulation appears to be evolving quickly towards the promotion of IWM solutions, as exemplified by the publication of an EU-wide Green Infrastructure strategy in May this year. We believe there is a strong case that an independent and comprehensive study of potential IWM approaches should be conducted before adopting a tunnel-only solution that will likely not reflect best-practices by the time it is constructed in the mid-2020s, while adding considerably to Londoners' water bills.

1. LONDON SEWER OVERFLOWS

Much of London is served by a combined sewerage system which collects both sewage and rainwater within the same pipes. Combined Sewer Overflows (CSOs) are positioned along the Thames to prevent flooding of streets and homes with storm sewage when the system is inundated following rainfall. There are 57 sewage overflow points in London (Figure 1).

A total of 39m m^3 of raw wastewater is discharged into the Thames every year because of sewer overflows. CSO discharges have become more frequent and greater in volume over the past few decades as a result of three trends:

- Building activity and urban growth has increased London's impermeable surface area and therefore augmented the volume of rainwater that flows into sewers during rainy events.
- Population growth has increased the volume of raw sewage discharged into the sewer system daily.
- The number of extreme rainfall events has increased over the past few decades[1].

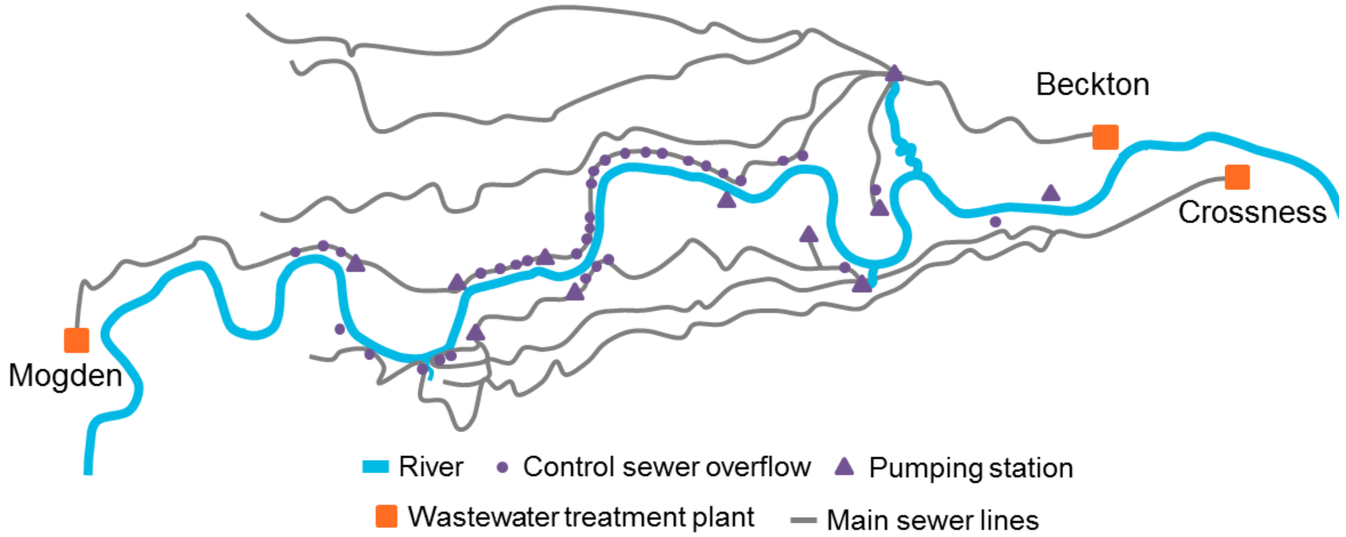
Today, some CSOs overspill on average once a week, even after very light rain (2mm), according to the UK Environment Agency. These discharges have three adverse environmental impacts:

- Reduction of dissolved oxygen (DO) levels in the receiving body of water. This damages the local aquatic ecosystem and raises fish mortality rates.

[1] The increase in extreme rainfall events was demonstrated for East London in *Lloyds*, 2010, 'East London Extreme Rainfall Report'. Currently, there is a lack of data to extend this finding to the whole of London with full certainty. However, this preliminary finding is a strong hint that extreme weather events have increased London-wide over the past decades.

- Increased risk to human health, as those using the river for recreational purposes are exposed to higher concentrations of pathogenic organisms.
- Degradation of river aesthetics and detrimental impact on people's enjoyment of their aquatic environment.

Figure 1: Simplified map of London's sewer system, 2013.



Source: Bloomberg New Energy Finance, Thames Water. Note: Only the 36 Control Sewer Overflows with an unsatisfactory level of discharge according to the Environment Agency are represented. There are another 21 Control Sewer Overflows in London but they have not been classified as having an adverse environmental impact.

The UK has a duty in law to limit pollution from stormwater overflows, including CSOs. In England and Wales, the Environment Agency is in charge of supervising CSOs under the terms of the European Urban Wastewater Treatment Directive, the principal legislative instrument regulating wastewater discharges in freshwater bodies in Europe. In 2004, the Environment Agency classified 36 of London's 57 CSOs as having an unsatisfactory environmental impact. 34 of these 36 CSOs discharge into the tidal Thames and the remaining 2 into the River Lee.

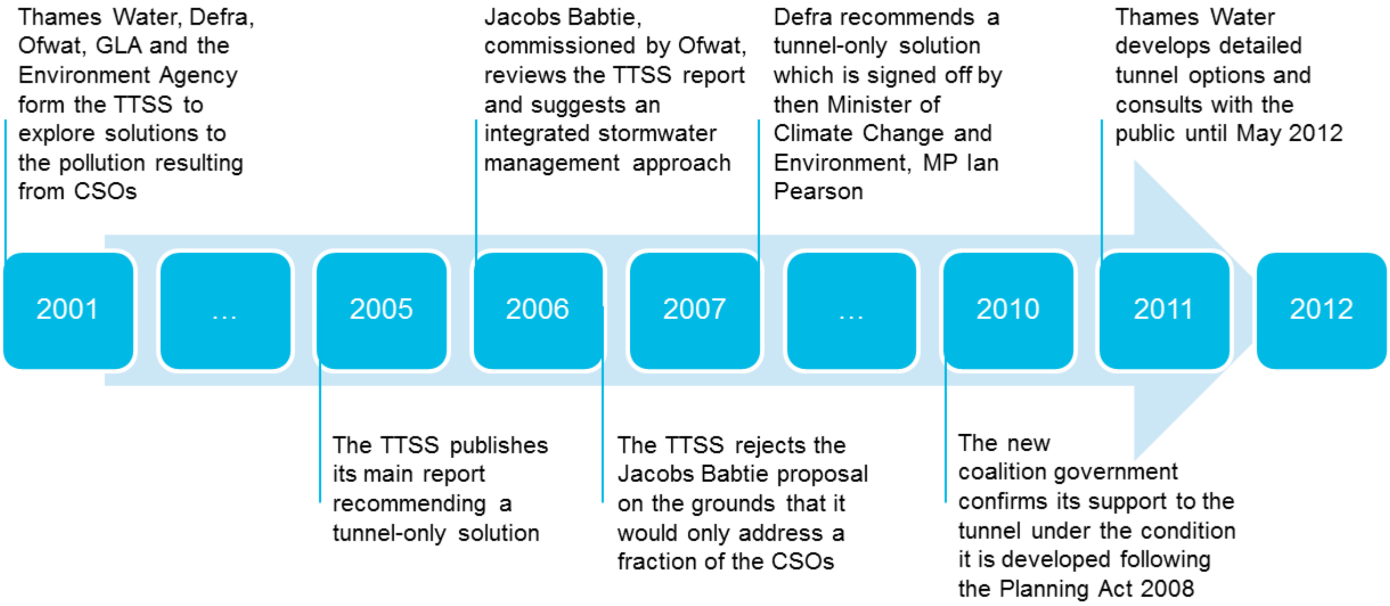
2. PROJECT BACKGROUND

In 2001, Thames Water together with the Department for Environment, Food and Rural Affairs (Defra), the Environment Agency and the Greater London Authority (GLA) began the Thames Tideway Strategic Study (TTSS) in order to assess the environmental impact of CSOs, define objectives for improvement and propose solutions. The Water Services Regulation Authority (Ofwat) took part to this effort as an observer. The TTSS published its main report in February 2005 (Figure 2).

The main objective guiding the work of the TTSS group was to reduce the frequency of overspills to comply with the Urban Wastewater Treatment Directive. According to this law, sewer overflows are only legal if they happen in "unusual" circumstances. However, this instrument does not give a numerical or other definition of the word "unusual" in terms of CSO discharges. The TTSS interpretation was that to comply with the law CSOs in London could "occur several times per year, but not several times per month". We infer from this statement that the informal quantitative objective of the group was for the frequency of overspills not to exceed 12 per year and achieve less than a handful of CSOs in a typical design year.

In addition, pollution objectives were also set. These included the reduction of aesthetic pollution due to sewage-derived litter, the protection of the Thames Tideway ecology and the protection of the health of recreational water users. The TTSS worked on turning these objectives into well-defined standards that would meet the group's interpretation of the regulation and against which different technological solutions could be benchmarked.

Figure 2: Main milestones in the development of the Thames Tideway Tunnel, 2001-12



Source: Bloomberg New Energy Finance. Notes: Defra (Department for Envrionment, Food and Rural Affairs), Ofwat (The Water Services Regulation Authority), GLA (Greater London Authority), TTSS (Thames Tideway Strategic Study), CSO (Combined Sewer Overflows).

Three main set of standards were laid out:

1. To reduce the frequency of discharges at CSOs which cause significant aesthetic pollution, "to the point where they cease to have a significant impact".
2. To limit ecological damage by complying with dissolved oxygen standards (Table 1).
3. To protect river users by substantially reducing the number of "elevated health risk"[2] days following CSO discharges.

Table 1: Dissolved Oxygen floors for the Thames Tideway as proposed by the Thames Tideway Strategic Study, 2005

Dissolved Oxygen floors (mg/litre)	Return period (years)	Duration (tides)
4	1	29
3	3	3
2	5	1
1.5	10	1

Source: Thames Tideway Strategic Study. Notes: Dissolved Oxygen should not fall lower than the stated mg/litre value more than once per stated return period. When Dissolved Oxygen falls lower than the stated mg/litre value this should not last for longer than the duration specified in number of tides. A tide is a single ebb and flow. The objectives apply to a continuous length of river of more than 3km.

The TTSS considered four possible strategies to deal with the overflow. Each strategy aimed to intervene at a different stage of the problem. The points of intervention were:

1. …before the rainwater runoff enters the sewerage system e.g. source control, sustainable drainage system (SuDS).

[2] "Elevated health risk days" is a concept created by the TTSS based on microbiological standards outlined in the World Health Organisation "Guidelines for the Safe Recreational Water Environment (2003)". In its assessment the TTSS established a base case of 60 "elevated health risk days" per year when spills occur at London's 57 CSOs.

2. …within the sewerage system e.g. separation, in-line storage (attenuation), new on or off-line storage tanks.
3. …at the interface between the river and the sewerage system e.g. screening to remove litter, new storage, return flows to treatment.
4. …after wastewater has spilled into the river e.g. more injected oxygen from river craft, riverside dosing of discharges.

As reported by the TTSS, "it was recognised at an early stage in the study that" strategy 3 "represented the only solution that could be considered potentially viable and worthy of further investigation". Strategy 1 was considered to only be applicable in certain outskirts of London and not in central London where it was thought that suitable sites were lacking. Strategy 2 which would have involved significant upgrades and separations in the existing sewer was also regarded as generally too expensive and disruptive. Strategy 4 was considered ineffective by the Environment Agency. Strategies 1, 2 and 4 were therefore not explored in anything like the same detail as strategy 3. Eight options within strategy 3 were studied further.

The preferred option within strategy 3, according to the TTSS, was a 7.2m diameter storage and transfer tunnel with a capacity of 1.5m m^3. The tunnel would run under the river from Hammersmith in the west to the Crossness wastewater treatment plant, and thence to the Beckton wastewater treatment plant through a link tunnel. It was reported that such a tunnel would require a 5 years engineering design and planning period and an 8-10 years construction period.

In 2007 the government decided to support a tunnel project to collect the overflows

Given the scale of the tunnel project, Ofwat commissioned the consultancy Jacobs Babtie to review the TTSS work independently. The main critique formulated in the review was that each strategy had been considered as a standalone solution. No integrated stormwater management plan, mixing the different strategies was explored. To the best of our knowledge, TTSS has still not carried out in-depth analysis on an Integrated Stormwater Management solution to deal with London's sewer overflows.

Following this review, Defra asked Thames Water, as reported in a July 2006 press release, to assess two tunnel options and report back about them by 31 December 2006. Following the development of options by Thames Water, Defra developed a Regulatory Impact Assessment (RIA) to define the objectives of the Thames Tideway Tunnel scheme. The RIA recommended that "a phased single tunnel approach" be adopted. The RIA was signed off in March 2007 by Ian Pearson MP, then Minister of Climate Change and the Environment at Defra, which confirmed the government's support for a tunnel option in dealing with the sewer overflows.

In May 2010, the UK Labour government was replaced by a coalition between the Conservative and Liberal Democrat parties, led by Prime Minister David Cameron. On 6 September 2010, the Secretary of State for Environment, Food and Rural Affairs confirmed the government's commitment to a tunnel option, but announced that the development consent for the project should be dealt with under the Planning Act 2008, the regime for nationally significant infrastructure projects in the UK.

The current tunnel option would be 25km long and east to west more than 30m deep under the Thames

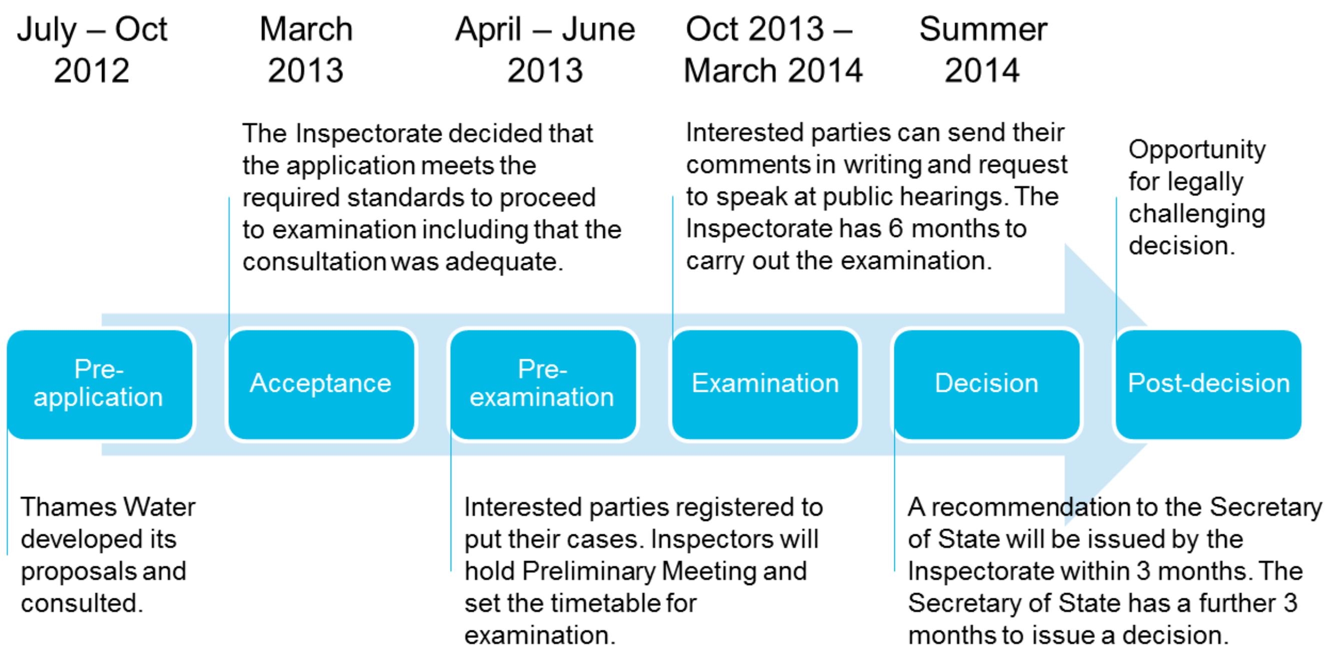
Thames Water started developing more detailed options after the government's go-ahead. A project overview was then submitted for a two-phase consultation[3] with the public that ended in March 2012. Thames Water consulted with relevant stakeholders on different tunnel routes and potential location of construction sites. Following the consultation the Abbey Mills route and the preferred construction sites were identified. They are described in detail in the following section.

Under the Planning Act 2008, nationally significant infrastructure projects go through a streamlined decision making process described in Figure 3. As of today, the project has passed

[3] Phase 1 report: here. Phase 2 report: here.

the acceptance process and is in the examination phase. If the project is granted development consent, construction is expected to start in 2015 and finish in 2023.

Figure 3: Decision making process under the Planning Act 2008 for the Thames Tideway Tunnel



Source: Bloomberg New Energy Finance, Planning Inspectorate

3. CURRENT PREFERRED OPTION

The tunnel is projected to cost GBP 4.1bn and to be built between 2015 and 2023

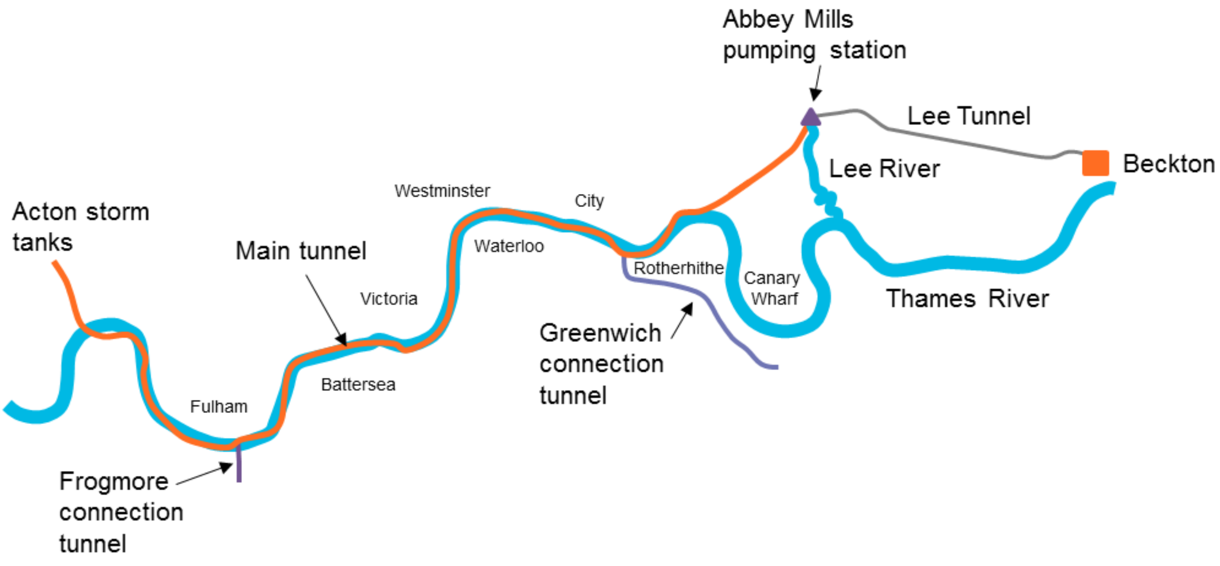
The current project comprises a storage and transfer tunnel running under the Thames between Acton Storm Tanks and Abbey Mills Pumping Station. The tunnel would capture sewage overflows at 34 of the CSOs identified as unsatisfactory by the Environment Agency. This main tunnel would be approximately 25km long with an internal diameter of 6.5m in the west increasing to 7.2m through central and east London. Its approximate depth would be between 30m in the west and 65m in the east.

The main tunnel would start in the west at Acton and run south east to the River. It would then run underneath the Thames to Rotherhithe in East London. At this point it would divert from beneath the Thames and head north east towards Abbey Mills Pumping Station where it would connect with the Lee Tunnel, which is currently being built. The combined sewage would then run to Beckton wastewater treatment plant, which would be upgraded to deal with the influx.

Two additional connection tunnels would be built to reach five[4] remote intercepted combined sewer overflows. The Frogmore connection tunnel would be located in Wandsworth and run for approximately 1.1km with an internal diameter of 2.6m. The Greenwich connection would be 4.6km long with an internal diameter of 5m, passing through Southwark, Lewisham and Greenwich. A number of shorter tunnels would also be required to connect CSOs to the main tunnel.

[4] These five CSOs are included in the 34 referred to earlier. The Lee tunnel is intercepting an additional CSO bringing the total to 35.

Figure 4: Current preferred option for the Thames Tideway Tunnel, 2013



Source: Bloomberg New Energy Finance

4. PROJECT FINANCE

The latest cost estimate for the Thames Tideway Tunnel stands at GBP 4.1bn (2011 prices) which includes a GBP 0.9bn contingency element to account for risks. This is much more than typical UK water infrastructure projects and is more comparable with the Channel Tunnel[5] linking France and the UK, which cost GBP 4.6bn in 1985 (equivalent to GBP 11bn today). The Thames Tideway Tunnel will entail annual investment of about GBP 600m per year during construction between 2015 and 2023. After 2023, the operation of the tunnel should cost around GBP 11m for direct staff and energy costs related to pumping in a typical year, according to Thames Water[6]. Finally, every 10 years a major inspection would be required for the tunnel, estimated to cost about GBP 20m.

Thames Water's gearing is too high for it to finance the tunnel on its balance sheet without jeopardising its credit rating

Thames Water's gearing[7] has significantly increased over the past eight years which means it would find it almost impossible to finance the tunnel on the strength of its balance sheet alone (Figure 5). In 2006 its net debt (class A) to regulatory capital value ratio was 44.4%. Following Thames Water's acquisition by Kemble Water in December 2006, the company's gearing steadily increased to reach 71.9% on 31st of March 2010, close to the 75% cap defined by Ofwat for class A debt. On the 1st of April of the same year, Ofwat allowed Thames Water to issue subordinated debt (class B) and at the same time allowed the senior debt (class A + class B) cap to increase to 85% of the company's regulatory capital value[8]. As of 31st of March 2013, Thames Water's gearing stood at 77.4%.

[5] The Channel Tunnel project has two track tunnels and one service tunnel. The track tunnels are 50km long and 7.6m in diameter.

[6] These are figures quoted in December 2012 during Parliamentary questions by Lord De Mauley, Parliamentary Under Secretary of State for Resource Management, the Local Environment and Environmental Science. Available: here.

[7] We define gearing following Ofwat's guidelines as the ratio of net debt to regulatory capital value.

[8] Regulatory Capital Value (RCV) is the capital base used in setting price limits by Ofwat. For the companies that were privatised in 1989 (including Thames Water), the formula is the initial market value including debt, plus subsequent net new capital expenditure (net of depreciation and infrastructure renewal changes)

This trend is not unique to Thames Water. As noted by Jonson Cox, Chairman of Ofwat, in a March 2013 report: "Over the past six years, a sector that was largely listed has become substantially owned by institutional investors. The overall proportion of equity has diminished from 42.5% in 2006 to 30% of regulatory capital value today with several companies at 80% gearing, thus obtaining only one fifth of their financing from equity. This reduction is a serious concern to many parties […] including some companies, investors and owners." Figure 5 shows that in 2006 Thames Water's gearing was significantly below industry average while today its leverage is a few percentage points higher than the mean of its peers. This illustrates that the company has been among the most proactive in taking on debt over the past few years.

Figure 5: Evolution of Thames Water's gearing (%), 2006-13

Source: Bloomberg New Energy Finance, Thames Water. Notes: Gearing is defined as the ratio between net debt and RCV (regulatory capital value). For each year the gearing is given on the 31st of March. The cap for Thames Water's Net debt changed on the 1st of April 2010. 2013 industry gearing has not been published by Ofwat to the best of our knowledge.

Table 2: Moody's credit rating for Thames Water, 2013

Category	Rating
Outlook	Stable
Long term rating	Baa1
Long term corp. family rating	Baa1

Source: Bloomberg, Moody's

An independent Infrastructure Provider will likely be created to finance and own the tunnel

Although Thames Water could in theory finance the project alone this would jeopardise its credit rating (Table 2) as explained by Moody's in an April 2012 Bond report: "If TWUL [Thames Water Utilities Limited] was required to assume responsibility for the entire project this would likely place significant strain on the company's credit standing. More limited involvement could also weigh upon the company's creditworthiness given the liabilities typically associated with projects of this type and TWUL's limited financial flexibility given its high level of gearing."

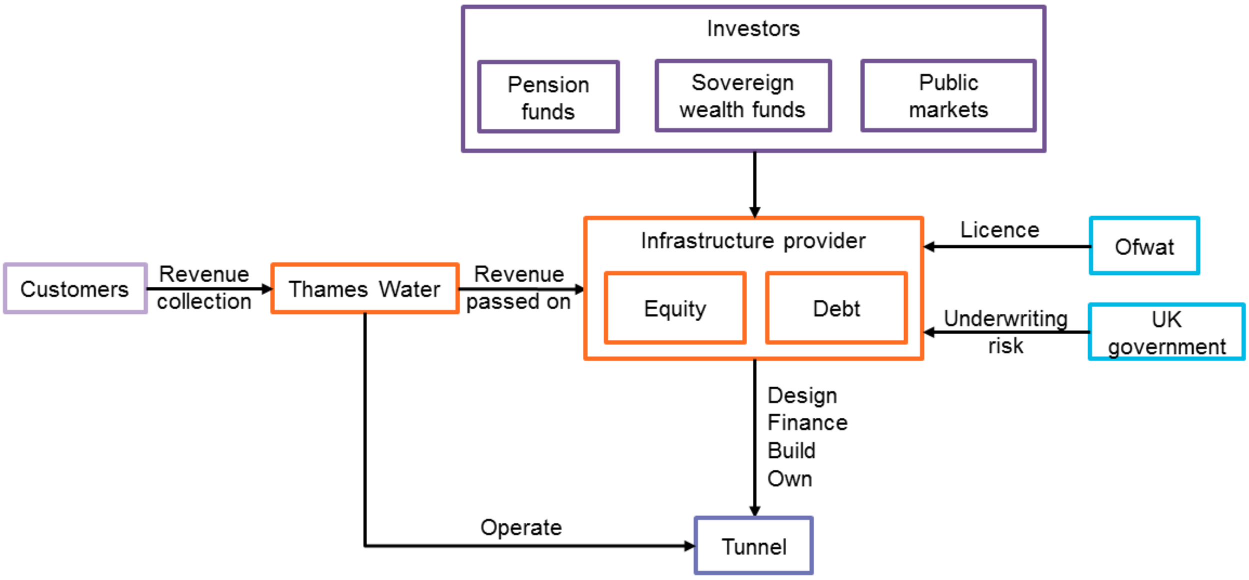
As a consequence, Thames Water has been in discussion with Ofwat and Defra to determine alternative financing models for the tunnel. Thames Water detailed its preferred funding structure in a Funding Statement in its Application for Development Consent published in January 2013. As of today, "the preferred structure for the project is that it will be delivered by an independent and separately licensed Infrastructure Provider that is privately financed and funded by customers, procured by Thames Water Utilities Limited".

The proposed financing structure has three distinguishing characteristics:

1. All the risk of the project would be ring-fenced into a financial vehicle, the Infrastructure Provider, independent from Thames Water. This vehicle would be owned by infrastructure private investors and would design, finance, build, own and maintain the tunnel. The operation of the tunnel would however most likely be undertaken under contract by Thames Water. Thames Water would also collect the revenue from customers and pass it on to the Infrastructure Provider. This type of independent vehicle has been used for other large infrastructure projects such as the Eurotunnel.

2. In order to attract investment, the Infrastructure Provider would need special regulatory treatment. It would require certainty that the basis for investment would not change over the first decades of the project. It would also likely require provisions for returns during the construction period and the first decades of operation. Ofwat would provide these different guarantees through a special licence to the Infrastructure Provider, which would therefore have a status close to an independent utility.
3. The UK government would also have to be involved in order to mitigate risks, to a level with which investors are comfortable. This would require the government to provide contingency support to the project in case certain risks materialised at different stages of the project.

Figure 6: Preferred option project structure - Illustrative, 2013



Source: Bloomberg New Energy Finance, Thames Water

Table 3: IRR calculation assumptions

Title	Values
Construction dates	2015-23
Useful life	60 years
Depreciation	0%
Inflation rate	2%
# customers	5.4m rising at 0.5% p.a.
Gearing	60%, 70%
Debt rates (real)	Flat 5% and 6% refinanced to 3.6%

Source: Bloomberg New Energy Finance

As of today, many aspects of the project financing are still being worked on by Thames Water, Ofwat and the Government. One of the main uncertainties is the extent of the Government's financial support. So far the Government has announced that it "is willing in principle to provide contingent financial support for exceptional project risks where this offers best value for money for customers and taxpayers and the private sector is unlikely to bear the risks at an acceptable cost." However, the details of this support are still being finalised and will influence the cost at which debt can be raised.

We have modelled the economics of the project to estimate the likely returns available to equity investors in the tunnel based on the following assumptions (Table 3 and Appendix A:):

- *Revenues.* Thames Water estimates that the tunnel could add a maximum of GBP 70-80 to households' bills (2011 prices), a 60% hike over the current wastewater charge of about GBP 123 per year. Thames Water has not given a specific schedule for the increase in customers' bills. It only commented that "the project will not have an impact on bills before 2013 at the earliest" and that its full impact on bills "will come into effect in the early 2020s". In our model we have assumed bills will increase incrementally from the start of construction (2015) to when the project is delivered (2023). We assume they increase with inflation thereafter to spread the cost of the tunnel fairly between the different generations of Londoners that will contribute to finance it.

  In August this year, Thames Water has asked Ofwat for a one-off GBP 29 increase in bills in 2014 to cover for land acquisition costs for the tunnel and other unrelated expenses. In

September, Ofwat challenged Thames Water's application and rejected it in October. We therefore do not take this revenue into account in our model.

- *Use of revenue collected during construction.* The fact that revenue for the project is collected before it becomes operational could enable Thames Water to lower the capital and debt that needs to be raised on markets by directly investing the funds coming from customers' bills into the construction works. We model two different scenarios here. In the "*Investing revenue*" scenario, revenues collected during the construction phase (2015-23) are directly invested into the construction works which effectively lowers the amount of capital needed to be raised from debt and equity investors. In the "*Retaining revenue*" scenario, GBP 4.1bn is directly raised from debt and equity investors and the revenues collected during the construction of the tunnel are directly added on to the projects balance sheet (equity cashflows).
- *Number of customers.* Thames Water currently has 5.4m sewerage customers. This figure has been growing at 0.5% per year over the past decade. In our model we assume this growth rate stays the same in the future.
- *Capital cost.* Today, the project is estimated to cost GBP 4.1bn, including a GBP 900m contingency. We have assumed in our modelling a unique scenario at GBP 4.1bn (2011 prices). To the best of our knowledge, the capital expenditure schedule for the tunnel has not been made public by Thames Water. We therefore assume the construction costs are split evenly from the start of construction (2015) to the delivery of the project (2023).
- *Running cost*. The operational and maintenance expenditures in the following years will be comparatively marginal. After 2023, the operation of the tunnel should cost around GBP 11m for direct staff and energy costs related to pumping in a typical year, according to Thames Water[9]. Finally, every 10 years a major inspection would be required for the tunnel and is estimated to cost about GBP 20m.
- *Gearing*. The gearing of water projects in the UK has historically been 60% debt, 40% equity. Although the project developers may aim for a similar split for the initial financing, a refinancing to increase leverage looks likely once the tunnel is in operation. We have modelled two scenarios: one at 60% leverage and one at 70% leverage.
- *Cost of debt*. Ofwat estimated the cost of debt for the water industry at 3.6% during its latest price review. For such projects as the Thames Tideway Tunnel, most of the risk is concentrated during the construction of the asset, during which time debt rates might be expected to be higher, depending on what sort of Government guarantee is in place. Once construction is finished, debt will likely be refinanced to bring down its cost. We looked at two scenarios: debt costs of 5% over the lifetime of the project, and 6% during construction, dropping to 3.6% thereafter. We have assumed loan repayments will stretch over the first three decades following the project completion.
- *Depreciation*. We assume that water underground assets are not depreciated under the current regulatory tax regime in the UK. However, this is an additional lever the Government could use to make the project more attractive to investors. If it were to allow the underground asset to be depreciated over a number of years this would essentially be equivalent to giving a tax cut to the project owners.

To illustrate our model we plot the project's cash flows (Figure 7) with the following assumptions: Debt cost at 5% p.a., 60% gearing, bills' increase at GBP 80 in 2023. In addition, we assume that revenues collected during construction are directly invested into construction works ("Investing revenue" scenario). Under these conditions we expect the project to yield a post-tax return of 16.9% (18.3% pre-tax) and to break even in 2026.

[9] These are figures quoted in December 2012 during Parliamentary questions by Lord De Mauley, Parliamentary Under Secretary of State for Resource Management, the Local Environment and Environmental Science. Available: here.

In Figure 8, we make the same set of assumptions as in Figure 7 except we assume that GBP 4.1bn are directly raised from equity and debt investors and the revenue collected during the construction of the tunnel is added to the projects' balance sheet ("Retaining revenue" scenario). Under these conditions we expect the project to yield a post-tax return of 20.0% (21.4% pre-tax) and to break even in 2022.

Figure 7: Thames Tideway Tunnel project cash flows for the "Investing revenue" scenario, 2015-84 (GBP m)

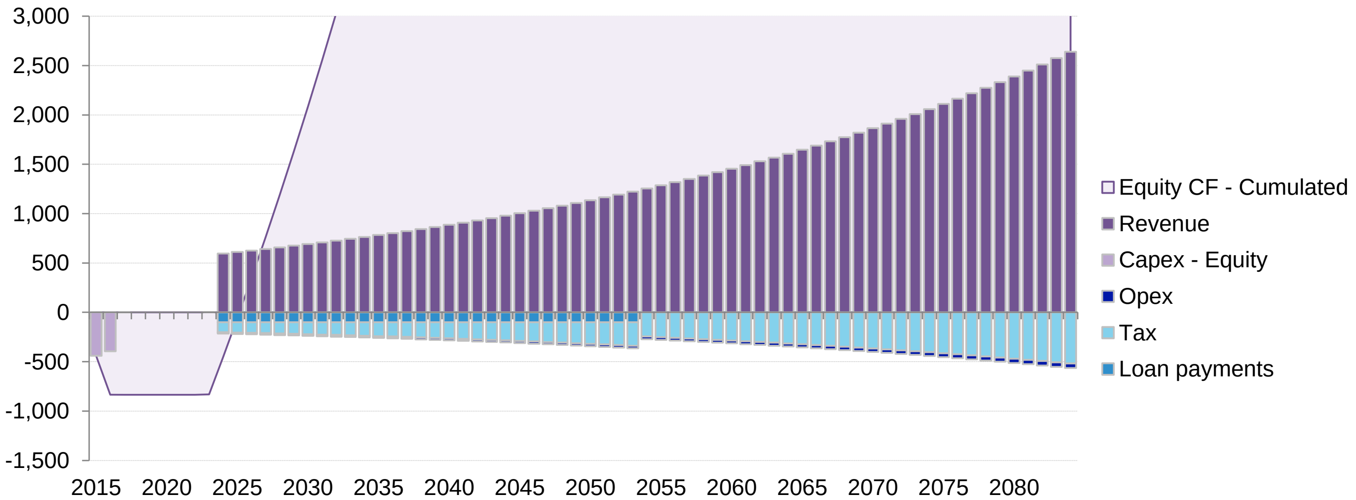
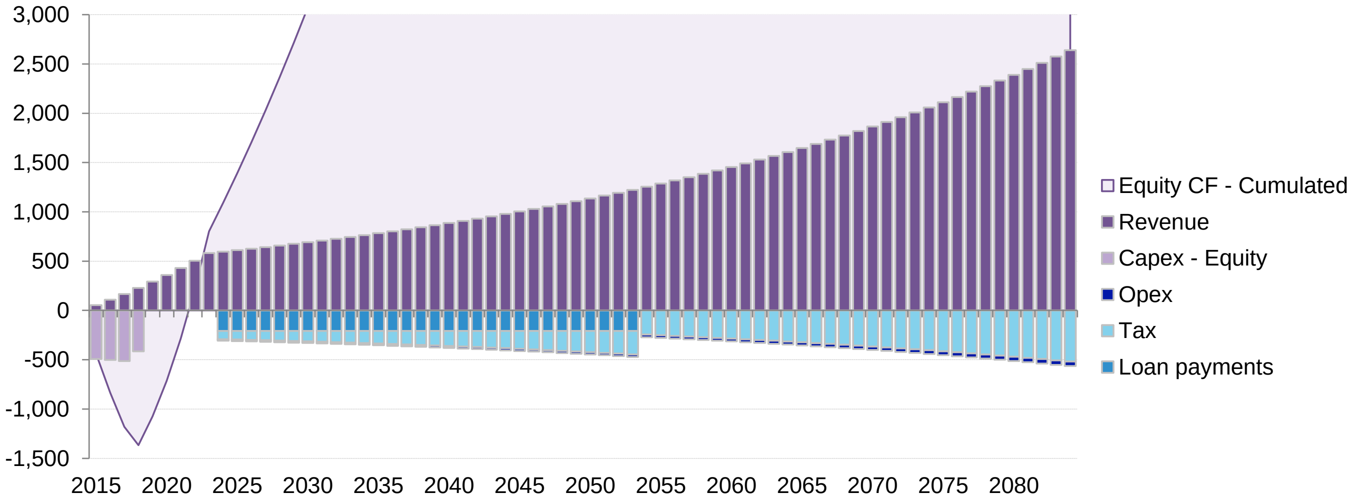


Figure 8: Thames Tideway Tunnel project cash flows for the "Retaining revenue" scenario, 2015-84 (GBP m)



Source: Bloomberg New Energy Finance. Notes: We assume a debt cost of 5% p.a., 60% gearing and a GBP 80 bill increase per household in 2023. We assume that the bills' increase starts in 2015 and rises steadily until 2023 when the tunnel is delivered. After 2023, bills only increase with inflation. In Figure 7, the revenue collected during construction is directly invested in works and therefore reduces the capital expenditure needs. After 2023, bills only increase with inflation. In Figure 8, GBP 4.1bn are directly raised from equity and debt investors and the revenues collected during the construction of the tunnel are added on to the projects balance sheet (equity cashflows).

Ofwat estimates the cost of equity for water and wastewater utilities in England and Wales every 5 years as part of a process to determine by how much each utility will be allowed to raise its prices. The latest price review was concluded in November 2009 for the 2010-15 period, which assumed a post-tax cost of equity of 7.1%. As can be seen in Figure 9, our economic model suggests that Thames Water's proposed *maximum* GBP 70 - GBP 80 annual increase in customers' water bills will result in post-tax equity returns in the range of 14.7% to 24.1% depending on scenarios. This corresponds to returns of between 16.4% and 25.5% in pre-tax terms. While the Thames Tideway Tunnel may have to provide a somewhat higher rate of equity return as its construction will entail larger risks than the smaller assets typically built in England, the range of returns suggested by our model and based on the proposed GBP 70-GBP 80 increase in water bills looks extremely generous.

We have also used the model to calculate the required long-term increase in household water bills, based on achieving various equity rates of return. As can be seen in Figure 10, a post-tax equity IRR of 7.1% would require an increase in bills of GBP 30.8 to GBP 35.3 per annum, depending on scenarios. In addition, a post-tax IRR of 12% could be achieved with bill increases in the range of GBP 44.7 to GBP 57.8.

Figure 9: Return on equity for the Thames Tideway Tunnel for the proposed GBP 70 – GBP 80 bill increase, (%)

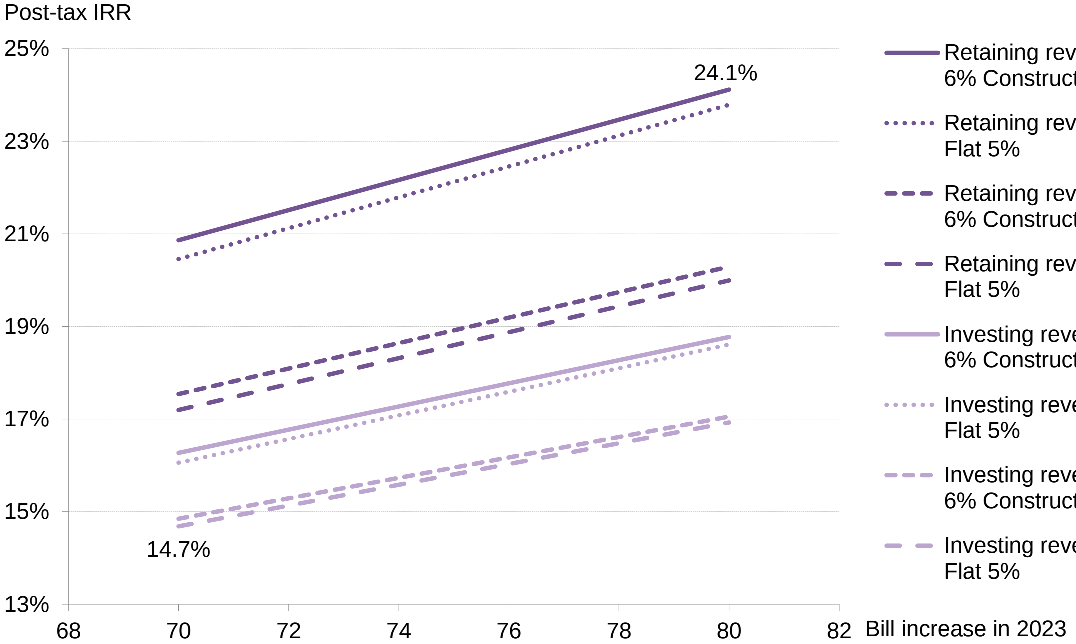
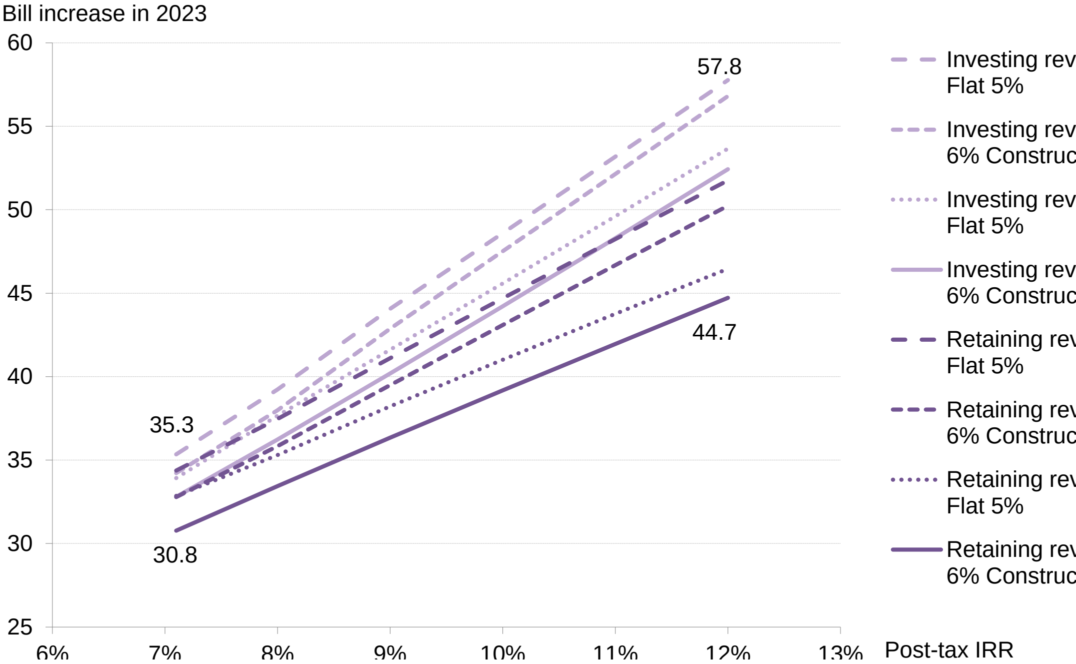


Figure 10: Bill increases to finance the Thames Tideway Tunnel for different returns on equity and debt scenarios, (GBP)



Source: Bloomberg New Energy Finance, Thames Water. Notes: The bills' increase plotted are for 2023 but given in 2011 pounds to be comparable to the GBP 70 to GBP 80 increase announced by Thames Water. In the "Investing revenue" scenario revenues collected during construction and directly invested into works which lowers the capital that needs to be raised. In the "Retaining revenue" scenario, GBP 4.1bn are directly raised from equity and debt investors and the revenues collected during the construction are added to the projects balance sheet.

We have contacted Thames Water to discuss the assumptions they used to estimate the "GBP 70 to GBP 80" bills increase they quote but the company refused to provide us with details about them on the basis that the information is "commercially sensitive".

5. CONTROVERSIES

Since its inception, the Thames Tideway Tunnel project has been controversial in many ways.

5.1. CSO reduction objectives

London's sewers currently overflow about once a week on average. Since it started to study options to deal with this situation in 2001, Thames Water has aimed to cut the number of Combined Sewer Overflows (CSOs) to virtually zero. This objective has been criticised by different stakeholders including Thamesbank and the specialist infrastructure consultancy CDM Smith. International case studies indicate that this very ambitious objective does not represent an optimal use of resources and virtually closes the door for any solution other than a tunnel approach. The US Environmental Protection Agency used to demand this level of CSO reduction in US cities in the 1990s but has since then changed its approach. It now lowered the bar of acceptable CSOs reduction, enabling cities to adopt integrated water management practices which can result in multiple environmental benefits at an overall lower cost than large storage projects.

The Thames Tideway Strategic Study (TTSS) derived its near-zero CSO objective from its interpretation of the Urban Wastewater Treatment Directive. This 1991 Directive is the principal legislative instrument controlling wastewater discharges to the Thames Tideway. It specifies that EU Member States should take measures to limit the pollution from sewer overflows. However, it also recognises that sewer overflows may occur under conditions of *unusually* heavy rainfall. The European Commission did not define this concept numerically. However, the European Court of Justice specified in an October 2012 ruling against the UK that *unusually* should be interpreted as wholly exceptional and that the current state of overflows in the Thames Tideway was not satisfactory.

It still remains unclear whether the European Commission would consider compliant an integrated water management solution that provides less CSO reduction than a tunnel but that delivers additional environment benefits. Recent developments suggest that this could be the case. Indeed, last May the European Union adopted a new strategy aimed at promoting green infrastructure, and putting natural processes at the heart of its spatial planning policy. However, to the best of our knowledge the European Commission has not clearly defined how this will influence the application of the existing Urban Wastewater Treatment Directive.

5.2. Failure to consider alternatives and to consult stakeholders

Thames Water has been criticised for not having studied alternatives to a tunnel approach in great depth. A number of stakeholders including Thamesbank and the Blue Green Independent Expert Team have pointed out that CSOs can be tackled by reducing and slowing the flow of stormwater into the sewage systems using a Sustainable Drainage System (SuDS) approach (also known as green infrastructure).

These claims have also been echoed by some of London's boroughs located along the Thames, which will be most impacted by the disruptions related to the construction of the tunnel (construction sites in parks, road and bankside closures, noise and dust, etc). These areas include Hammersmith and Fulham, Richmond Upon Thames, Tower Hamlets, Southwark and

Kensington and Chelsea among others[10]. Boroughs located further away from the Thames have been less vocal about the project.

Thames Water has been critiqued for not looking seriously at alternatives to the tunnel

In 2010, Thames Water commissioned a study by the University of Sheffield on SuDS and source control applications, focusing on the Putney area. The study concluded that a SuDS approach would "potentially be effective at reducing the CSO spills into the River Thames". However, the "spill frequencies" would be likely to remain at "above 10 events per typical year" which is more than the objectives that Thames Water set itself at the beginning of the process. This study was used by Thames Water to rule out SuDS as an option. However, as author Richard Ashley outlined in the report, the findings were only partial, considering the West Putney, Putney Bridge and Frogmore catchments only, and not the whole London catchment.

In any case, alternative strategies looked at by Thames Water to deal with the sewage overflows have so far been explored in isolation as detailed in Section 2 of this report. However, international case studies indicate that a combined strategy, also known as Integrated Water Management (IWM), can be more cost effective. For instance Philadelphia, Portland, and Cincinnati have adopted a combination of tunnels and SuDS to deal with sewer overflows. The consultancy Jacobs Babtie pointed this out as early as their 2006 review of the TTSS reports, but to our knowledge Integrated Water Management has not been studied in depth as an alternative to the TTT.

The consultation process was also criticised for being mainly focused on the tunnel option

Under the UK's Planning Act 2008, nationally significant infrastructure projects such as the TTT are processed via a streamlined decision-making process. One of the requirements of this act is to arrive at the best solution *in consultation with all relevant parties*. However, critics of the tunnel point out that at the time of the consultation on the project (summer 2010 to March 2012), the UK government had already approved a "single phased tunnel approach" to deal with the sewage overflows in 2007.

As a consequence, some interested parties such Thamesbank and Blue Green Independent Expert Team have accused Thames Water of promoting a tunnel solution over other available options such as SuDS during the consultation period while the company should have laid out all technological options available. Interested parties also claim they should have been given an early opportunity to question the evidence and assumptions behind the tunnel and other available options during the consultation.

In a representation submitted as part of the planning process, Thamesbank claims that the consultation was "wholly inadequate" both in terms of "national law under the Planning Act 2008 process and under EU law and the Aarhus Convention"[11], It also claims that "there was no assessment of and consultation on "reasonable alternatives" at an early and effective stage of the plan-making process, as required under Directive 2001/42/EC".

5.3. Cost and benefits of the tunnel

The cost and benefits of the project have also been controversial. The Urban Wastewater Treatment Directive is the principal legislative instrument controlling wastewater discharges to the Thames Tideway. It states that the UK should take measures to limit the pollution from sewer overflows and that it should apply the "best technical knowledge not entailing excessive costs" in doing so. Several stakeholders are concerned that the proposal currently considered does not comply with this principle.

[10] These boroughs have formed the "Thames Tunnel Commission" and published a report urging the Government to reconsider its support to a single tunnel solution in October 2011.

[11] The Aarhus Convention grants rights to the public in terms of access to information and participation in government decision-making concerning the environment.

The cost of the project has increased while under study from GBP 1.7bn to GBP 4.1bn

Interested parties have raised concerns regarding the uncertainty of the cost. In 2004, the project was estimated at GBP 1.7bn including the Lee Tunnel and upgrades at London's sewage treatment works. In 2007 this cost was estimated again at GBP 2.2bn. Today, the project is estimated to cost GBP 4.1bn, excluding the Lee Tunnel and the upgrades at sewage treatment works, which are now expected to cost around an additional GBP 1.0bn.

As a result, Thames Water has estimated that the wastewater element of water bills will rise by a maximum of GBP 70-80 per household from the current charge of around GBP 123 per year, a 60% hike. The Consumer Council for Water which represents water consumers' interests has expressed concerns that "there is no guarantee that the current estimate will not be subject to further escalation". In addition, our modelling of the economics of the project under different scenarios suggests that the increase in water charges of GBP 70 to GBP 80 per year indefinitely would result in a post-tax return to equity investors in the TTT of between 14.7% and 24.1%, considerably higher than the estimated 7.1% cost of equity for existing water utilities (See Section 4 of this report).

In order to assess if the cost of the tunnel is "excessive" compared to its environmental benefits Defra published a Cost and Benefits of the Thames Tunnel report in November 2011. In this analysis it assessed that the benefits of the project ranged from GBP 3.0bn to GBP 5.1bn and were therefore in the same ball park as the project cost of GBP 4.1bn. Chris Binnie, who chaired the TTSS from 2000 to 2005 reviewed Defra's report and published his own assessment of the tunnel's benefits. His conclusion is that the benefits of the tunnel would amount to GBP 275m only which is significantly lower than both the project cost and Defra's benefits estimates.

All estimates of benefits have included only factors for which a monetary value could be calculated. This includes benefits from the reduction of fish death through Dissolved Oxygen control, the improved health of river users (e.g. rowers) and the reduced inconvenience of sewage litter and odour. It excludes elements such as an increase in tourism as a result of a cleaner river, which is harder to quantify. Defra's latest benefits estimate is based on an update of the results of two 2006 reports: a "Willingness to pay survey" done by the environmental consultancy Eftec and a "Thames Tideway Cost Benefit Analysis" carried out by the economic consultancy NERA.

The estimates of the tunnel benefits are uncertain and range between GBP 275m and GBP 5.1bn

Chris Binnie has criticised Defra's methodology and many of the assumptions used to update the estimate. The government's work mainly relied on a survey which consisted of asking individuals how much they would be willing to pay for the overall benefits provided by the Thames Tideway Tunnel project. These survey results were then converted in monetary benefits by factoring in the number of households in the UK as well as the time over which they would benefit from the project. In his report, Chris Binnie takes a different approach to Defra's and estimates the health, dissolved oxygen and litter benefits in isolation.

For health benefits, Binnie quotes research showing that willingness to pay methods tend to exaggerate the "implied monetary value for life and health for relatively small risk reductions". He suggests using a different methodology called QALY (Quality Adjusted Life Year) that is based on the numbers of recreational water users, the frequency and length of illness, the value of time etc. Following this methodology he estimates the benefits at GBP 1.5m over the lifetime of the project.

In addition, Defra's benefits assessment includes a fall in fish kills resulting from improved Dissolved Oxygen levels in the Thames Tideway. Binnie argues that the upgrades that are currently being carried out by Thames Water at the Mogden wastewater treatment plant along with the construction of the Lee tunnel will go "a long way to meeting dissolved oxygen standards". He therefore estimates the additional benefit of the Thames Tideway Tunnel to be marginal or GBP 0.26m.

Finally, Binnie argues that the benefits associated to litter reduction will likely be small. Indeed, the TTSS estimated that CSOs account for about 10% of the total litter in the tideway. As a consequence eradicating them will have little aesthetic effect and therefore little impact on property prices. By carrying sensitivity analysis on real estate prices he estimates this benefit at about GBP 200m[12].

Binnie then adjusted his different estimates to make them comparable to Defra's and finds a total NPV benefit of about GBP 275m. Such a small benefit would likely make the cost of the project "excessive" under the Urban Waste Water Treatment Directive.

5.4. Financing of the tunnel

In November 2012, the newspaper The Observer revealed that Thames Water along with other water companies "paid little or no corporation tax" despite making operating profits and rewarding their "senior executives with performance related bonuses and investors with huge dividends"[13]. According to the British newspaper, "despite cutting its liability, by pilling up debts, Thames has paid out GBP 1.08bn in dividends over the past four years [2008-12]". Furthermore, "it avoids tax by offsetting the interest payments on its debts against its tax liability and delaying it by claiming allowances on capital project spending." The fact that Thames Water's gearing has increased in recent years was confirmed by our analysis in Section 4.

Thames answered The Observer's revelations with the following statement: "With nearly GBP 1bn of deferred tax liability on our balance sheet, tax is being delayed, not avoided. We are structured in an efficient way in accordance with the tax system and the benefits from this flow through to Thames Water customers – in the form of GBP 1bn a year of essential investment while keeping bills among the lowest in the sector. All of the Thames Water group's active companies are resident in the UK and pay tax to HMRC [Her Majesty's Revenue & Customs]."

Thames Water was further criticised for not setting aside funds for the Tideway Tunnel project, therefore requiring a Government guarantee before it could be undertaken. For instance, the Financial Times wrote in November 2012: "Thames Water has known for more than a decade that it would have to finance the project as part of the effort to clean up the Thames but has not set funds aside to do it. Instead it paid large dividends to its shareholders. It also let its liabilities balloon, making it impossible to raise new debt from the market without threatening its investment-grade status. Maintaining this is a requirement under the UK licensing regime"[14].

Ian Byatt, former Director-General Ofwat, and MP Simon Hughes wrote in a letter to the Financial Times in November 2012 that "If Thames is unwilling to make a rights issue, the owners, Macquarie, should be expected to return funds to the utility. If they do not, Thames should go into special administration and another company or financier be allowed to take over its activities"[15].

In June 2013 Thames Water again attracted criticism after its accounts revealed that it paid no UK corporation tax, despite making a profit of GBP 549m in the year to March 2013. The company cited the impact of tax allowances on investment for the apparent anomaly. Stuart Siddall, Thames Water's finance director claimed that the company's decision to fund its debt via a Cayman Islands vehicle was "purely to comply with UK company law requirements" and gave it "no tax advantage[16]".

Ofwat chairman Jonson Cox conceded that "the use of high-coupon shareholder loans by water companies to improve equity returns might be legal", but said "some aspects are morally questionable in a vital public service[17]." In other words, the use of debt financing at higher than

[12] Note that this sensitivity analysis is not made available in the report and we could therefore not assess it.
[13] *The Observer*, 2012, 'Water companies pay little or no tax on huge profits', 10 November
[14] *Financial Times*, 2012, 'Sewer problems', 5 November
[15] *Financial Times*, 2012, 'Thames Water is obliged to fund big projects', 11 November
[16] *Independent*, 2012, 'Sold down the river: How Thames Water diverts its tax liability via the Caribbean despite £549m profit and 6.7% price hike', 11 June
[17] *Financial Times*, 2013, 'Thames Water attacked for paying not a drop of tax', 10 June

market rates via an entity in a low-tax jurisdiction would have the impact of shifting profits away from the UK and could be considered as aggressive tax management by some.

6. INTEGRATED WATER MANAGEMENT

The water industry has historically been designed to provide water supply and sanitation services. Most water utilities today are focused on producing water of drinkable quality and distributing it to their customers. They then collect the waste produced by customers and treat it before discharging the water back to the environment.

Integrated water management (IWM)[18] goes a step further. It consists in managing all sources of water including freshwater, wastewater and stormwater as components of a basin-wide management plan and not separately, as has historically been the case. IWM is based on the premise that by managing the water cycle as a whole, a more efficient use of resources can be achieved, providing enhanced economic, environmental and social outcomes.

IWM plans can include a wide range of measures. In the context of London's sewer overflows, an IWM approach would combine a number of technologies, including green infrastructure, real-time digital control systems, in-river schemes, and storage facilities.

6.1. Sustainable drainage infrastructure

An alternative to tunnel would be to roll out sustainable drainage systems (or ‘green infrastructure’) technology across London (Table 4). Green infrastructure systems[19] mimic natural processes to facilitate the infiltration, evapotranspiration[20] and recycling of rainwater on site.

Table 4: Overview of green infrastructure techniques

Technology	Description
Green roof	
Green roof	A layer of vegetation installed on roofs to facilitate evapotranspiration and stormwater retention. Green roofs can reduce local runoff generation by 50-60%.
Rainwater harvesting	
Rainwater tank	Rain barrels and cisterns are installed below drainpipes to intercept runoff generated on urban roofs, before it can enter the sewerage network. This water is either reused or gradually released into the network during dry conditions.
Bioretention and infiltration	
Bioretention cell	A sunken area of vegetation, sand and organic residue that provides a natural filter for urban stormwater runoff. The treated runoff is retained within the basin until it is able to infiltrate below ground.
Bioswale	An alternative stormwater conveyance system, designed to transfer runoff to surrounding waterways or MS4 inlets more slowly. Vegetated bioswales act as natural filters and encourage infiltration and evapotranspiration.
Tree box filter	A subsurface stormwater bioretention facility which also acts as a biofilter. Treated runoff is either discharged into an MS4 or allowed to infiltrate below ground.
Infiltration trench	A one-to-four meter deep, stone-filled trench, lined with a filter fabric, which is used to treat urban stormwater runoff and facilitate infiltration.
Permeable pavement	Permeable pavements are constructed using modified, pervious concrete or porous asphalt. They allow rainwater to infiltrate into the underlying subsoil, therefore reducing the volume of runoff generated by 70-90%.

Source: EPA, Center for Clean Air Policy, Bloomberg New Energy Finance

[18] There are still today varying definitions and interpretations of integrated water management. We give the most widely accepted definition here.
[19] BNEF clients are also referred to the following Research Note: “US Stormwater Programme Poised for Green Growth”.
[20] Evapotranspiration is the transport of water from plant surfaces into the atmosphere.

The systems themselves are not technically complicated, but their widespread implementation has the potential to reduce rainwater runoff considerably, minimising peak flow within London's combined sewer network and thus reducing annual CSO discharge volumes. In addition, SuDS promote groundwater recharge[21] and lower the risk of flash flooding, while at the same time reducing energy demand, improving local air quality and amenity value, as well as raising property prices.

Green infrastructure and smart technologies have successfully decreased the cost of overflow projects in the US and Europe

Although green infrastructure cannot provide a standalone solution to stormwater management and CSO control, a number of cities across Europe and the US have chosen to install sustainable drainage technology alongside existing 'grey' stormwater infrastructure. Of these, Philadelphia is the first in the US to commit to SuDS on a citywide scale.

Philadelphia's $2.4bn "Green City, Clean Waters" programme will see $1.7bn invested in sustainable drainage infrastructure over the next 25 years, as up to 6,000 green acres are installed at an average cost of $250,000. Another $0.3bn will be spent on grey infrastructure upgrades – namely expansion of wet weather treatment capacity at each of the city's three wastewater treatment facilities – while the remaining $0.4bn will initially be held in reserve.

On completion, the $2.4bn programme is expected to achieve a reduction in annual pollutant discharges equivalent to that which would be attained through the capture and treatment of 85% of Philadelphia's CSO volume. It therefore offers a significant cost saving versus an entirely grey approach which, according to the Philadelphia Water Department, would cost up to $10bn and would require the construction of a vast underground storage system, as well as expansion of the combined sewer network.

The success of SuDS in Philadelphia has driven interest and investment across the rest of the country. In New York, for example, green infrastructure installations are estimated to cost $423/m^3 of CSO reduction over the next 20 years – 9% less than the $462/m^3 that would be needed to build an underground stormwater storage network. Overall, New York's $5.3bn Green Infrastructure Plan – part of which includes a $2.9bn grey infrastructure renewal package – is expected to reduce annual CSO discharge volumes in the city by 40% and will cost around 25% less than an entirely grey approach.

Moreover, each greened acre is expected to generate additional annual cost benefits, including $8,522 in reduced energy demand, $1,044 in improved air quality and $4,725 in raised property values. These ancillary benefits will accrue over time, making SuDS the most viable long-term solution for stormwater control in the city.

Table 5: Comparison of key metrics for the implementation of green infrastructure between London and Philadelphia

Cities	# overflows per year	Areas (km^2)	% impervious cover	# CSO outlets	CSO volume (m m^3)	Rain days per year	Rainfall per year (mm)
London	0-60	1710	33%	57	39 (soon 17)	110	558
Philadelphia	0-55	370	48%	166	61	91	1052

Source: Bloomberg New Energy Finance, World Meteorological Organisation, British Geological Survey, CDM Smith. Notes: London's rain data is a long term average for 1981-2010. Philadelphia's rain data is a long-term average for 1961-90. A "Rain day" is defined as a day were it rained at least 1mm.The CSO volume in London is currently 39m m3 per year on average but it will become an estimated 17m m3 at the completion of the Lee Tunnel and different wastewater treatment works currently under way.

In order to determine whether such an approach would be applicable for London, the British Geological Survey has put together a national infiltration map which provides an assessment of the suitability of the subsurface for the installation of *infiltration* drainage systems. The map categorises land subsurface by analysing four properties that play an important role in SuDS. For each area it lists infiltration constraints and the drainage properties of the subsurface in order to

[21] Groundwater recharge is the process by which groundwater aquifers are replenished through the downward movement of surface water.

assess the effectiveness SuDS would have if rolled out. Then, it analyses the ground stability and whether the surrounding groundwater would remain protected if SuDS were built. Using these four parameters, areas are then classified in terms of their suitability for infiltration SuDS.

Parts of London are fit to be greened which could decrease sewer overflows

In Greater London, the British Geological survey found that 8% of the surface area is compatible with free draining SuDS; 20% is probably compatible (although the design of SuDS may be influenced by the ground conditions); and 39% is potentially suitable (although the design of SuDS will be highly influenced by the ground conditions) – see Table 6. The remaining 33% of the capital's surface area were found to be associated with very significant constraints for the development of SuDS. In other words, infiltration SuDS could be developed, subject to some technical adjustments, across 67% of London's surface area. This conclusion is in contradiction with Thames Water's argument[22] that SuDS cannot be implemented in London because it was built on clay.

Table 6: Greater London Authority compatibility with infiltration SuDS

	Compatible for infiltration SuDS	Probably compatible for infiltration SuDS	Opportunities for bespoke infiltration on SuDS	Very significant constraints have been indicated
Definition	Suitable for free draining SuDS.	The subsurface is probably suitable for infiltration SuDS, but the design of the system may be influenced by the ground conditions.	The subsurface is potentially suitable for infiltration SuDS, but the design will be highly influenced by the ground conditions.	There is a very significant potential for one or more hazards associated with infiltration.
Percentage area (%)	8%	20%	39%	33%

Source: Bloomberg New Energy Finance, British Geological Survey

In addition, other techniques can be deployed where the subsurface is not optimal for infiltration SuDS. For instance, where water cannot infiltrate the ground, it can be stored temporarily in ponds, wetlands or constructed underground chambers. If no other option is available, permission can be given for water to be discharged to the drainage network.

Existing regulation is already driving green infrastructure adoption at new estate developments in London

Relevant policy frameworks are already in place to boost the installation of SuDS throughout the United Kingdom, including Greater London. The National Planning Policy Framework and London Plan both have references to urban greening. Already today, all planning applications must adhere to progressive planning policy on water run-off stating that new building developments must be designed in such a way as not to increase natural run-off. As a result, most new estate developments in London have elements of green infrastructure. Important modifications to existing developments are also covered by these planning regulations.

However, for SuDS to have an impact on overflows in the short-term, they would need to be retrofitted at existing real-estate developments, which has many practical challenges and a city-scale initiative coordinated between London's 33 boroughs, would be required.

US case studies show that retrofitting SuDS on already developed surfaces requires a two-fold plan. First, government bodies need to set an example by installing green infrastructure on already developed public land including government-owned buildings, parks, roads, pavements etc. This would require boroughs and the Greater London Authority to agree on retrofit standards and guidelines and to implement them through a 10 to 20 years plan. Other large land owners such as Transport for London and the Crown Estate would also need to contribute.

Then, once an example has been set, incentives are put in place to involve private real estate owners, encouraging them to modify aspects of their properties. For instance, in Portland, individual home owners were incentivised to disconnect their roof downspouts from the sewer and let rainwater flow into green surfaces in their gardens. 25,000 homes were awarded $50 for each

[22] Thames Water, 11 December 2012, "Are Sustainable Drainage Systems (SuDS) enough for London's river?"

of the 54,000 downspouts they disconnected, decreasing CSOs in the city by an estimated 20% at a cost of $2.7m. Similar incentives could be developed and tailored to both individual and larger real-estate owners in London.

Financing these initiatives would require levying charges on London households. In order to do so, one option would be for Ofwat to reform its price limit framework to allow Thames Water to collect and distribute the required amounts. Alternatively, a new entity with a special regulatory license allowing it to charge London's households to deal with stormwater overflows could be created.

6.2. Real-time sewer control

Smart water technologies are a collection of sensors and intelligent devices which, when combined with communication networks and software applications, help manage water distribution and wastewater collection. These technologies can provide multiple functions, including leak detection, pressure optimisation and energy management, as well as the control of sewer overflows[23].

Several cities around the world are using information and communication technologies to improve the performance of their sewer systems. Real-time control of sewers can provide several benefits including: the maximisation of sewage storage space; the control of floods, overflows and sewage surcharges; the minimisation of required wastewater treatment plant capacity; operational and maintenance optimisation; and the protection of receiving waters.

Real time control of sewers could maximise the storage space of the existing sewer system

In the case of sewer overflows, utilities can use control systems to store and move wastewater in real-time during heavy rain events and to adapt to the unique features of each event, thereby decreasing the number of overflows. To that effect, dynamic mathematical models and simulators are used to develop a program for a specific sewer system to guide automatic control systems when a wet-weather event is approaching. The most advanced systems today use radar-based rainfall measurement and forecasting tools to anticipate where exactly in the city the sewer system is expected to be under pressure and adjust accordingly.

In a number of projects utilities have managed to lower their sewer infrastructure investment needs by using these technologies. For instance, Paris eliminated the need for $800m in sewer infrastructure investment by adopting smart monitoring and control devices at the beginning of the 2000s (Table 7). Other cities having achieved savings using these technologies include Louisville, Quebec, Copenhagen, Montreal, Barcelona, Milwaukee and South Bend.

Table 7: Comparison of the economics of CSO projects with and without real-time control

City	Country	Without real-time control	With real time control	Savings
Paris	France	$3,000	$2,200	27%
Louisville	United States (KY)	$250m	$80m	68%
Quebec	Canada	$170m	$110m	35%
South Bend	United States (IN)	$126m	$6m	95%
Wilmington	United States (DE)	$114m	$27m	76%

Source: Bloomberg New Energy Finance, BPR Times, Tetratech, IBM

The economics of such projects usually depend on three elements:

- The unused volume available in the different parts of the sewer system under normal rainfall conditions. The more spare capacity there is the bigger benefits real-time control is likely to provide.

[23] BNEF clients can read more about these technologies in their applications in the following two Research Notes: Water meets IT and gets smarter and Water networks monitoring and automation: a primer.

- The existing interconnections between the different parts of the collection system. The more interconnections, the easier it will be to move sewage around the network and adapt to wet-weather events.
- The knowledge of the topology of the sewer system and of the flows in its different branches. The more information the utility has on its system at the start of the project the less time and money has to be spent mapping the sewer and flows.

To the best of our knowledge, the savings that could be achieved by using real-time control technologies have not been studied for London as of today.

6.3. In-river alternatives

A range of in-river techniques can be used to mitigate the impact of raw sewage on river water. Fixed and mobile bubblers could be used to reduce the impact of untreated sewage overflowing to the River Thames by injecting oxygen into the river, which would help fish survive sewage discharges. Such an approach has been implemented successfully in Cardiff's harbour to deal with sewers overflow, at an upfront cost of about GBP 3.5m in 2001.

Thames Water is currently operating two mobile bubblers on the river. In order to reach reasonable dissolved oxygen levels, fixed diffusers providing higher concentration levels would need to be installed on the Thames river bed near sewer discharge points. In his review of Defra's Cost benefit analysis of the Tunnel, Chris Binnie, former chairman of the Thames Tideway Strategic Study, calculated that 1,000 of these diffusers could be rolled out at the cost of GBP 30m, bringing Dissolved Oxygen levels back to the desirable level in the river Thames.

In addition, booms and skimmers could be used to collect and dispose of the litter contained in the raw sewage. Assuming that one skimmer would be permanently positioned at each of the nine most harmful CSOs and that three skimmers would constantly navigate the Thames River to collect litter, Chris Binnie estimates the capital cost for such a project at GBP 20m.

International examples show that the key to minimising overflow costs is to take an integrated approach and leverage different technologies

6.4. Integrated approach

While it would be challenging to solve London's sewer overflows by using any one of the presented technologies, as emphasised by the main report of Thames Tideway Strategic Study, they are used in combination they could potentially solve the problem faced at a more reasonable cost than a tunnel alone.

Additionally, an integrated water management solution can provide multiple co-benefits, as follows:

- Speed. As the deployment of Integrated Water Management schemes is incremental, they can provide positive economic outcomes faster than traditional large scale infrastructure projects with long lead times.
- Environment. Green infrastructure elements such as green roofs, street trees and open green spaces improve the amenity value of urban realms. They also make buildings more energy efficient by reducing heating and cooling demand.
- Resilience. IWM can contribute to reducing flood-related risks by increasing cities' infiltration capacity and slowing down stormwater runoff.
- Health. IWM provides potentially substantial health benefits through improved air and water quality.
- Community. Many aspects of integrated water management are developed at a very local level. IWM schemes can therefore be designed to foster community awareness and participation.

- Employment. The ratio of capital costs to maintenance is lower for IWM schemes, which therefore provide on-going local employment opportunities, including many for less skilled workers.

Appendix A: Thames Tideway Tunnel model assumptions

Item	Assumptions	Rationale	Ref
Construction start year	2015	Thames Water: "If consent is granted, preparatory construction work on the project is scheduled to start in 2015, with main tunnelling due to begin in 2016. The target completion date is 2023."	Here
Operation start year	2024		
Inflation rate	2% p.a.	Bank of England inflation rate target	Here
Capex (GBP m)	4,100	Thames Water: "We estimate the capital cost of the project to be £4.1bn, expressed in 2011 prices."	Here
Capex schedule	Capex spent evenly in 2015-23	No spending schedule is publicly available to the best of our knowledge. We are therefore assuming that the money is spent evenly throughout the construction period.	NA
Opex (GBP m)	11	Lord de Mauley: "A typical design year would mean that the operating costs for direct staff and power to operate the pump station would be £11 million pa (2011 price base)."	Here
Recurring Capex (GBP m)	GBP 20m every 10 years	Lord De Mauley: "Every 10 years there would be a major inspection period for the tunnel, and this is estimated to cost about £20 million. It is not expected to have any significant maintenance or repair capital costs during the first 10 years."	Here
Max bill increase	GBP 80 in 2023	Thames Water: ""This work could cost a maximum of £70 to £80 per year (excluding inflation) in an average annual household wastewater bill by the early 2020s""	Here
Number of sewerage customers	5.4m	Thames Water data submitted to Ofwat. Leaked comment made by Ofwat.	Here Here
Customer growth rate	0.5% p.a.	The number of properties connected to Thames' sewer system increased at 0.54% per annum between 2003 and 2010 according to the company's data. We assume this rate of increase stays the same in future years. No projection is publicly available to the best of our knowledge.	Here
Revenue schedule	Regular increase from 2015 to 2023. Increase with inflation thereafter.	Thames Water commented that "the project will not have an impact on bills before 2013 at the earliest" and that its full impact on bills "will come into effect in the early 2020s". We assume bills increase with inflation after 2023 to spread the cost of the tunnel fairly between the different generations of Londoners that will contribute to finance it. Ofwat indicated that the cost of the tunnel will likely be spread over several generations in a leaked comment.	Here
Use of revenue collected during construction	"Investing revenue" scenario "Retaining revenue" scenario	In the "*Investing revenue*" scenario, revenues collected during the construction phase (2015-23) are directly invested into the construction works which effectively lowers the amount of capital needed to be raised from debt and equity investors. In the "*Retaining revenue*" scenario, GBP 4.1bn is directly raised from debt and equity investors and the revenues collected during the construction of the tunnel are directly added on to the projects balance sheet (equity cashflows).	NA
Debt interests	Flat 5% and Construction 6% + Term 3.6%	3.6% is the latest cost of debt estimate for the water industry by Ofwat. Other assumptions have been made using our in-house judgement.	Here
Debt tenor	30 yr	In-house judgement.	NA
Project gearing	60% to 70%	The water industry gearing was at about 60% in 2006 and is now 70% according to Ofwat. Thames Water gearing is at 77.4% today.	Here
Tax rate	20%	According to HMRC: "from 1 April 2015 there will be only one Corporation Tax rate for non-ring fence profits - set at 20 per cent." Ring-fenced profits are defined as "income and gains from oil extraction activities or oil rights in the UK and UK Continental Shelf".	Here
Depreciation	0 yr	Underground assets are not depreciated in the UK. This was confirmed by a leaked Ofwat letter.	Here

Item	Assumptions	Rationale	Ref
Tunnel lifetime	60 yr	Costs and benefits of the tunnel have been calculated over a 60 year period in 2003/5 and 2006/7 but over a 100 years period in 2011. Modelling beyond 60 years is unrealistic and has little impact over the return on investment.	Here

Source: Bloomberg New Energy Finance, Thames Water, Ofwat, HMRC, Bank of England

ABOUT US

SUBSCRIPTION DETAILS

Water Insight **sales.bnef@bloomberg.net**

CONTACT DETAILS

Maxime Serrano Bardisa, Lead Analyst, Water Insight

Joseph Salvatore, CFA, Lead Analyst, Clean Energy Economics

Ulimmeh Ezekiel, Lead Modelling Analyst

Michael Liebreich, Chief Executive Officer

Michael Wilshire, Head of Analysis

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