

THAMES TUNNEL MAJOR PROJECT REPORT

10/2010

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LONDON TIDEWAY IMPROVEMENTS

THE THAMES TUNNEL IS A
NEW RELIEF TUNNEL THAT IS
PART OF THAMES WATER'S
SCHEME TO REDUCE
SEWAGE DISCHARGES



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The Tideway Tunnels will be London's biggest employer



For the last 150 years London has benefited from the fantastic work carried out by the

Victorians in the 1860s. The sewer network created by Sir Joseph Bazalgette and his team is still in excellent condition, but it badly needs greater capacity. When it was built London had 2.5 million residents. Today the population has trebled - and it is still growing.

In addition the system is facing new pressures. Areas that have been paved over are increasing the amount and speed of run-off water into the system, and climate change is altering rainfall patterns.

The environmental standards in the 1850s were quite straightforward with engineers simply asked to clean up the Thames and get rid of the smell. Any overflows went into a river which had been biologically dead for many years. These standards were nowhere near as high as those we expect today.

The time has come to decide what we are going to do for the next 150 years.

Our planned London Tideway Improvements programme is about building on the past and creating a legacy for the future. The upgrades to London's five main sewage treatment works along the River Thames, the Lee Tunnel and the proposed Thames Tunnel will

all provide additional capacity and improve water quality in the river. Clearly this is a huge investment for London and like other schemes, such as the Olympics and Crossrail, it does not just affect central London, it affects a whole range of sites across the city.

By looking at alternative options we have significantly reduced the number of construction sites. This will reduce the impact of the tunnel's construction on customers and businesses. We still have some way to go in terms of refining our proposals for the main Thames Tunnel, and that is the benefit of consulting with people across London - we want to collect their thoughts on how we can minimise the impact.

Learning points from around the world, in locations such as Sydney and Singapore where similar schemes have been constructed, is that if you want to invest in the future then you need to invest in the environment.

The challenge for us now is to ensure that we have the most effective solution, not just in terms of standards and engineering but the most cost-effective solution that delivers value for money.

Over the past 10 to 20 years the need to invest in the future has been suppressed, but this can only be done for so long. It cannot be continually put back.

London is a world-leading city, and its success leads to continued growth. We now need to invest in the future in the same way that the Victorians had the foresight to do 150 years ago.

Martin Baggs,
chief executive officer,
Thames Water



This may not be the most fragrant infrastructure project but it's extremely important - creating around 4,000 jobs and apprentices in the next few years and the long-term prospect of a cleaner Thames and better quality of life. London led the world when Marc Isambard Brunel and his son, Isambard Kingdom Brunel built the first Thames tunnel and Joseph Bazalgette conceived the sewers, so helping to crack the problems of cramped metropolitan living that threatened the prosperity of Victorian London. These engineering marvels set the standard for city living that we take for granted today. More than 150 years after the 'Great Stink' of London, the planned Thames 'super sewer' will ensure we can manage new challenges and the demands of a growing capital.

Boris Johnson, London mayor

Becoming a reality

Planning and consultation

Bernadette Redfern



Flows from combined sewer overflows such as this one at Putney Bridge would be captured by the Thames Tunnel

As the consultation phase begins for the Thames Tunnel other schemes in the London Tideway Improvements are already making good progress.

The London Tideway Improvements projects together represent the largest capital investment the UK water sector has ever seen.

When completed in 2020, the two tunnels and five extended sewage treatment works that make up the London Tideway Improvements project will ensure that the UK is compliant with the requirements of the European Urban Waste Water Treatment Directive, by substantially reducing untreated sewage discharges from 36 combined sewer overflows (CSOs). The improvements in river water quality linked to the sewage works upgrades should also provide an environmental boost to life in and on the Thames.

All elements of the programme will help reduce unsightly sewage related litter. "In a typical year 39M.m³ of sewage overflows into the river and in a wet year it can be three times that," says Phil Stride, head of London Tideway Tunnels at Thames Water. "At some CSOs it takes only 2mm of rainfall to generate a discharge and clearly this is not acceptable," he says.

The London Tideway Improvements programme has three elements, all at different stages of development. "The sewage works upgrades are already underway. This is the extension and modification of Thames Water's sewage treatment works discharging to the tidal River Thames – at Beckton,



Crossness, Mogden, Long Reach and Riverside. This work will ensure that they can deal with the increasing flows," explains Thames Water chief executive Martin Baggs.

A range of construction projects is underway to increase the cumulative capacity of these five sewage treatment works by just under 50% from 3,395M litres/day to 5,045M litres/day. At the same time, the treatment facilities will also be upgraded at Long Reach and Riverside. These improvements will be completed between 2012 and 2014.

The second element of the programme is the Lee Tunnel which is about reducing flows discharging into the River Thames as soon as possible. The project involves the construction of a storage tunnel to intercept the largest single CSO accounting for an average of 16M.m³ in discharges every year. This CSO is located at Abbey Mills pumping station in Stratford and will be mitigated by the 6.9km, 7.2m internal diameter Lee Tunnel, which

will transfer overflows to Beckton Sewage Treatment Works.

Construction consortium MVB, which consists of Morgan Sindall, Vinci Construction Grand Projets and Bachy Soletanche began shaft construction on 30 September. "It is a great scheme with a cost of £635M. It is a great scheme but it is small compared to the even more complex Thames Tunnel, required to ensure compliance with the EU directives," says Baggs.

The start of construction for the proposed Thames Tunnel is still some way off. Two years in fact. It depends on the scheme obtaining planning permission. The first round of public consultation began in September and will end after a 14 week period. After considering the feedback, the project team will then review the design and present a final proposal for a second consultation round commencing in spring/summer 2011. A planning submission is scheduled to be made in 2012.

Plans for the Thames Tunnel itself

150

People in the project team

9%

Design complete



Putney Bridge foreshore: New areas of hard standing would be created following construction work on the foreshore

have been significantly revised since the scheme was originally presented to Defra in December 2006. Following two and a half years of design and development the preferred route is 9km shorter than the original tunnel, which was up to 32km long.

Furthermore the team has managed to reduce the number of main work shafts from 11 to 5, and reduce the number of CSO diversion shafts from 34 to 17. "It is not just about minimising the number of construction sites but also the impact of activity," says Baggs.

These efficiencies will reduce the amount of disruption that the scheme has on inhabitants and business in London, but at the same time means more complex engineering design and construction in the foreshore of the River Thames. It is this type of work, along with a more advanced understanding of the construction requirements, which has enabled a better understanding of the overall project cost up from £2bn to £3.6bn.

"When we did the original pricing, the project was only at the initial concept stage. We only had a handful of people working on a desktop study that took four months," says Stride.

"Over the last 2.5 years we have had over 150 people working on the project and design is about 9% complete. We have a much clearer idea about what we face in terms of existing utilities and land availability."

Despite the higher cost estimate, Baggs and the project team are confident that the current proposals represent an efficient cost effective scheme. Helping Thames Water develop the plans is pre-construction programme manager CH2M HILL in

"Over the last 2.5 years we have had over 150 people working on the project"

Phil Stride, head of London Tideway Tunnels

association with Halcrow and supported by consultants from a range of framework partners.

"Teams of engineers have been looking at options and proposals over a long period of time and it has been subject to a number of independent reviews. It is a complex major project and it is right that it is subject to scrutiny and review. We are really pleased to say that CH2M HILL is working very closely with us and they have experience of these types of schemes all over the world," says Baggs.

The water regulator is also closely involved in the scheme as the price rises in customers' bills that will pay for the project must first be approved by Ofwat. It is also possible that the project will be delivered via the infrastructure service provider route identified in the Flood & Water Management Act 2010.

"The Act gives the regulator the option to ask us to pursue an alternative called the ISP route. Details

and regulations are still being mapped out but we are running it as a twin track approach. We need to explore the options with regulators, stakeholders and investors," says Baggs.

Section 36 of the Act outlines powers for ministers and the regulator to designate a separate infrastructure provider to build major infrastructure projects.

"Thames Water is working with Defra and Ofwat on development of the regulation and this will be complete at the end of April 2011," says Stride.

Regardless of the final delivery mechanism, the tunnel must first go through the planning process. The system for major projects is going through a period of change with the Infrastructure Planning Commission moving into the Planning Inspectorate.

Rather than making final decisions the IPC, which is to become the Major Infrastructure Planning Unit, will make recommendations that will be used by the Secretary of State to make a final decision. However, head of the Infrastructure Planning Commission, Sir Michael Pitt tells NCE that projects going through his unit will not be delayed by the move and says that all applications, once accepted, will have a final recommendation report made within 12 months.

In early September Environment Secretary Caroline Spelman gave renewed government support to the scheme: "A tunnel continues to offer (by far) the lowest cost solution to the problem and I believe Thames Water should continue to press forward with this project working with Ofwat, the Environment Agency and Defra on the regulatory, commercial and planning processes."

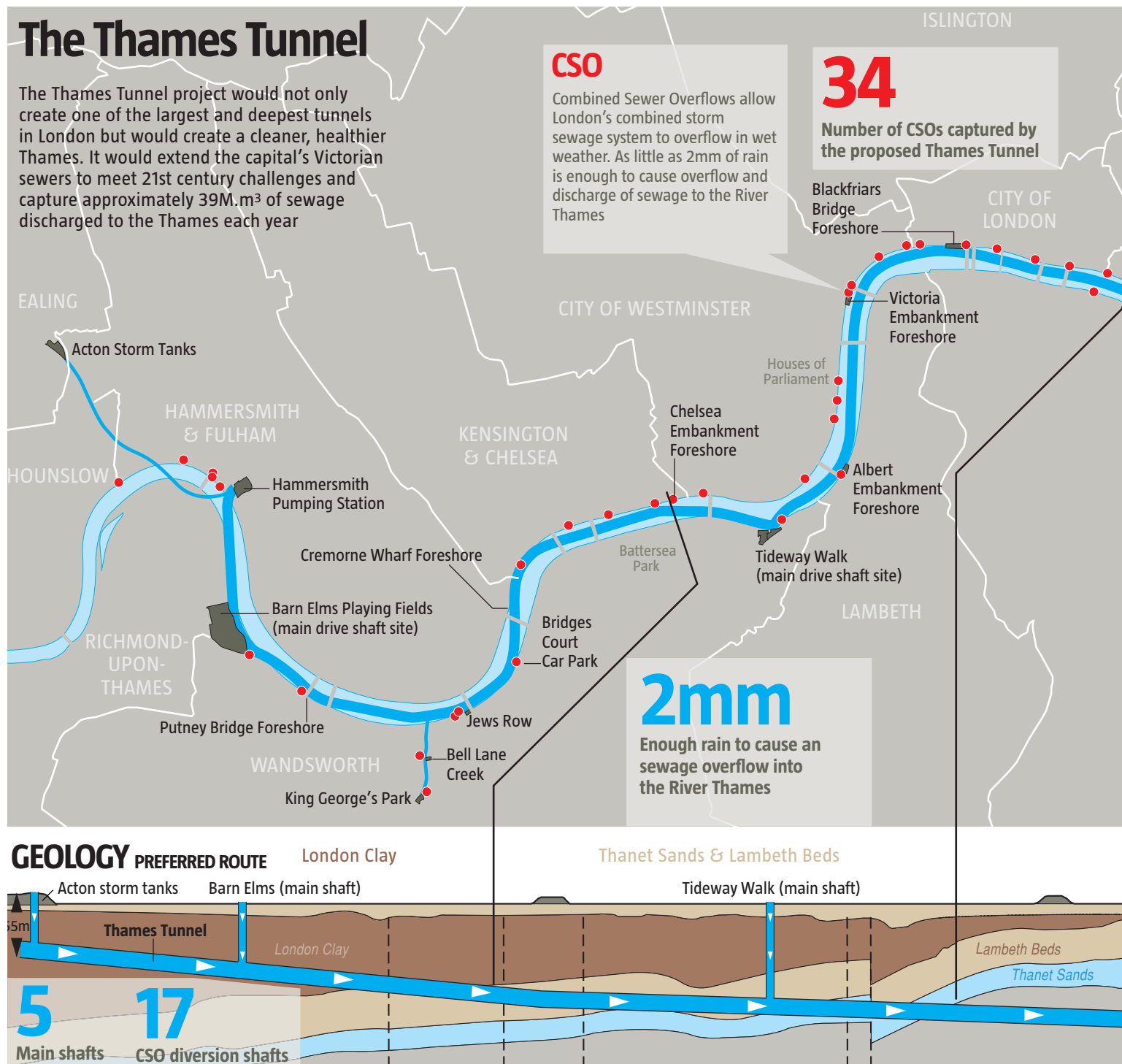
But obtaining planning permission rests on whether Thames Water has robustly assessed and mitigated the local impacts of the project. A planning application will be made in 2012 and for now the team is focused on building the schemes underway and exploring all design options for the Thames Tunnel in consultation with the public. "It is a really exciting time. Thames Water is the largest water company serving not only the capital of the UK but one of the world's most important economic hubs. We have benefited from the engineering of the past but now we have to invest in the future," says Baggs.

Taking wastewater under central London

Thames Tunnel
Bernadette Redfern

The construction impact of the UK's deepest tunnel has potentially reduced, with over 50% fewer proposed worksites.

After two and a half years of detailed design work involving over 150 professionals, the Thames Tunnel team has reached a critical milestone. The team which is made up of civil



engineers, project managers, planners, hydraulic specialists and environmentalists has developed what it believes is the most technically appropriate and cost efficient alignment for the new sewer tunnel that is set to reduce the volume of sewage overflowing into the River Thames by 96%.

Although three potential routes have been identified, the Thames Tunnel team has now developed a preferred option which is significantly

shorter than the original project presented to the Department for the Environment Food and Rural Affairs (Defra) in December 2006.

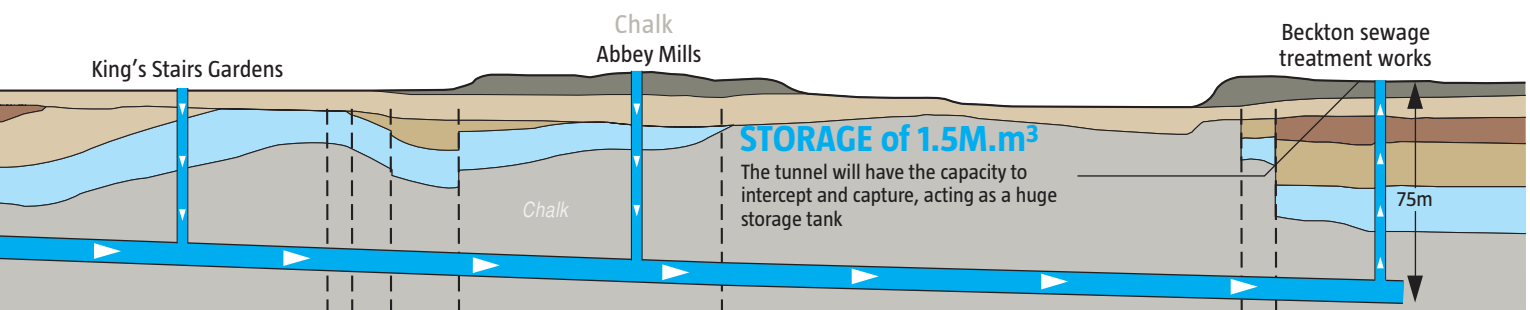
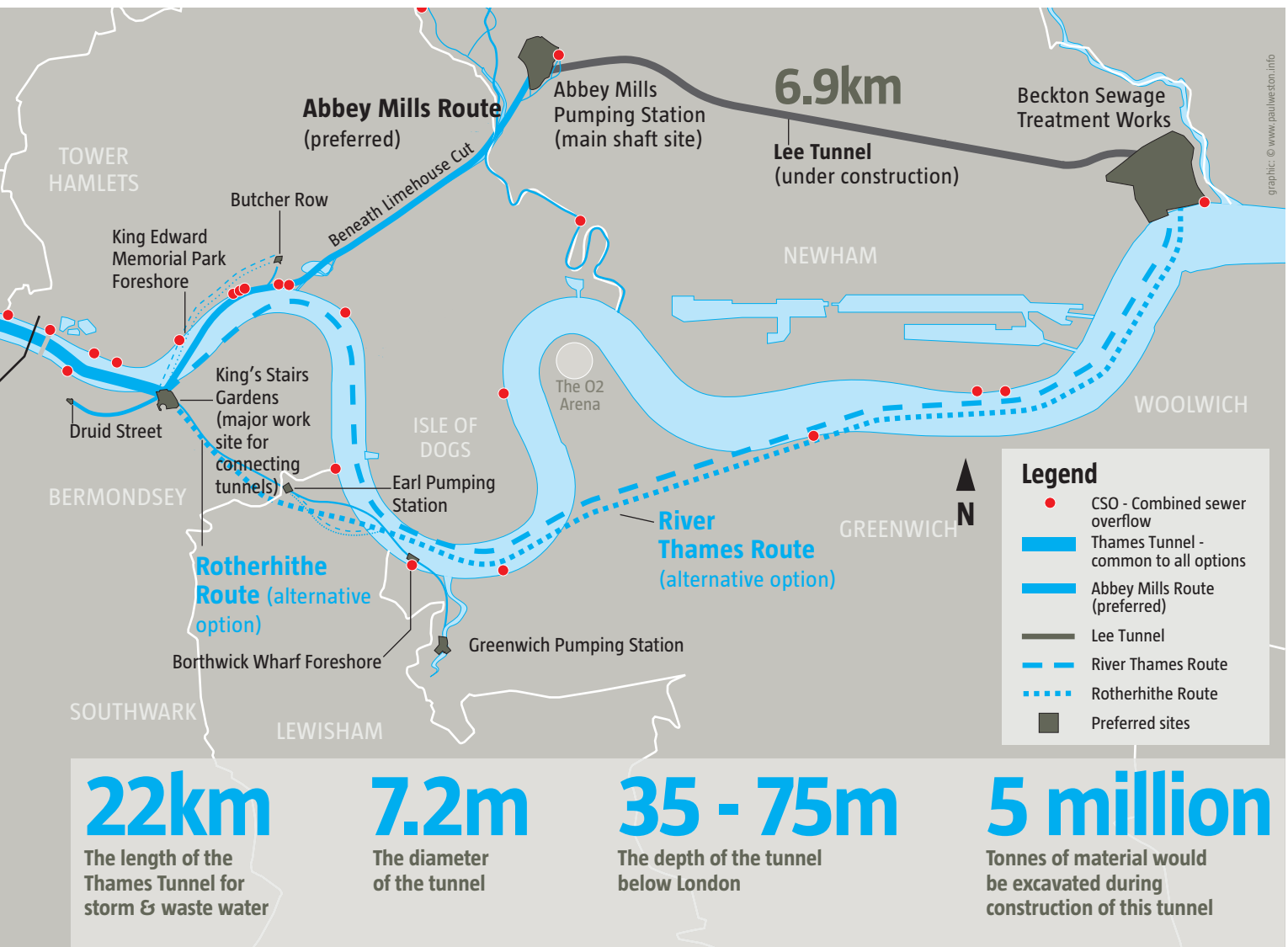
"The preferred route option is 9km shorter and about £700M cheaper in relative terms," says head of London Tideway Tunnels Phil Stride.

The proposed project fundamentals remain unchanged. The 7.2m internal diameter tunnel would start in West London and run beneath the River

"The preferred route option is 9km shorter and about £700M cheaper in relative terms"

Phil Stride, head of London Tideway Tunnels

Thames, collecting the sewage from the worst polluting combined sewer overflows (CSOs) along the way. All three routes will deal with 34 of the 36 CSOs that were identified as a priority by the Environment Agency, the other two CSOs being dealt with by separate Thames Water projects. And all three routes will ensure that London is compliant with the requirements of the European Union Urban Wastewater Treatment Directive.





"The interceptor sewers collect flow from the 'lost rivers' of London"

Phil Stride, head of London Tideway Tunnels

However, the routes which the three proposals take to achieve this are slightly different. The original scheme proposed over three years ago began at a depth of approximately 35m in West London and followed the route of the Thames through the City of London, Greenwich and all the way to Beckton Sewage Treatment Works in Barking. At this point it could be as deep as 75m. "At £4.3bn, this is the most expensive option and captures 96% of all sewage overflowing into the river," says Stride.

The original 2006 plan also required direct interception of all 34 CSOs, which would also have required 34 drop shafts, and involved the construction of 11 major work shafts.

Following extensive analysis a second route was then identified that reduced the tunnel length by 1.8 km. The new proposal follows the original scheme as far as the Rotherhithe peninsula where, instead of following the river, it takes a land based route to Greenwich and then continues on to Beckton. By shortening the route the tunnel bypasses two CSOs that lie east of the Tower of London in Tower Hamlets. "So this option requires connection tunnels to capture these flows," says Stride.

Building on the efficiencies developed so far, the Thames Tunnel team then began considering a third route that would see the Thames

CSOs: Polluting the river

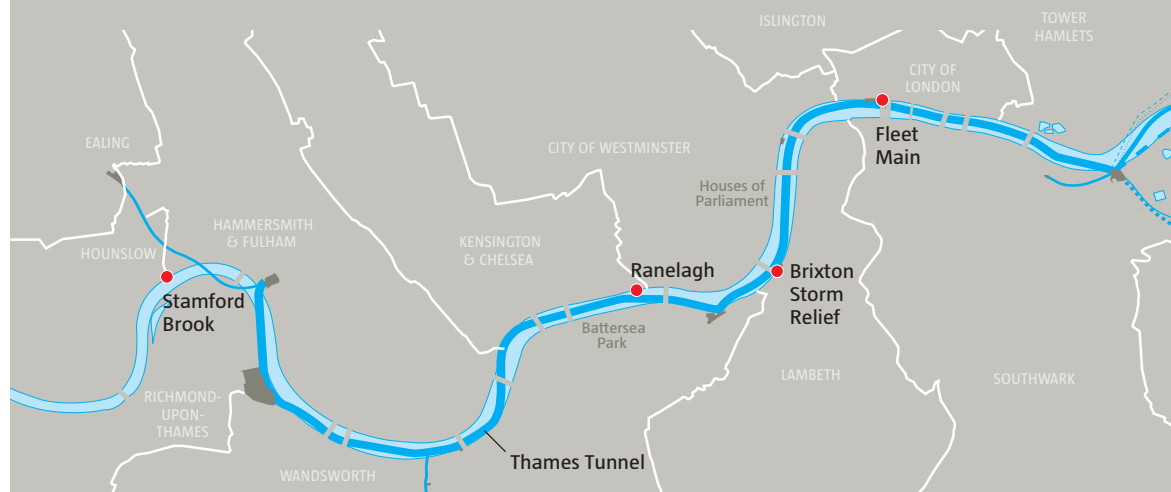
BRIXTON



RANELAGH



STAMFORD BROOK

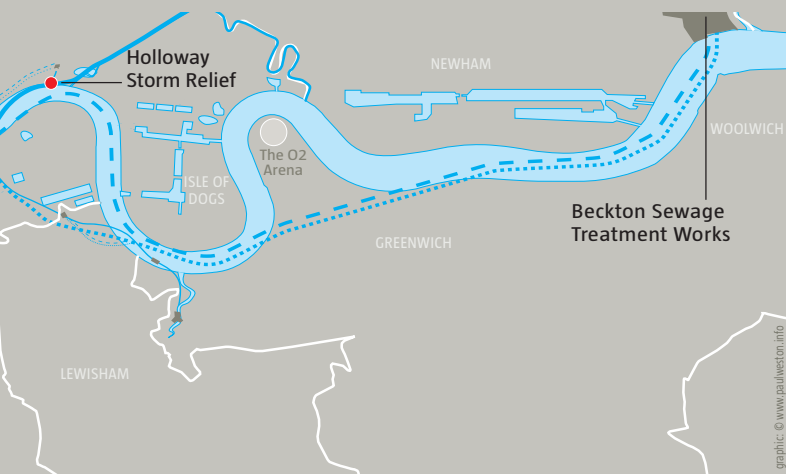


Albert Embankment: Work on the foreshore at the Albert Embankment would enable two CSOs at Clapham and Brixton to be directed into the Thames Tunnel

FLEET MAIN



HOLLOWAY



Barn Elms: Proposed TBM launch site



King Edward Memorial Park: Proposed site for North East Storm Relief CSO

Tunnel follow the original alignment but with a major diversion at Limehouse leading the tunnel into the newly constructed Lee Tunnel beginning at Abbey Mills in Stratford and running along to Beckton Sewage Treatment Works. This option only emerged following design changes to the 6.9km Lee Tunnel. "Initially the design for the Lee Tunnel at Abbey Mills was not low enough to take flow by gravity from the Thames Tunnel," says Stride.

"A geological feature known as a graben, the German word meaning ditch, was discovered during the investigations for the Lee Tunnel. This feature consists of a series of down-faulted blocks of ground creating an area of potentially disturbed ground and variable face conditions.

"We realised that it would be better to lower the Lee Tunnel by 10m to minimise the length of tunnel through this disturbed zone," says Stride. "This then presented us with the option of shortening the main Thames Tunnel and connecting it in at Abbey Mills."

Having developed a possible route that is only 22km long, approximately 9km shorter than the original proposal, the team then set about rationalising the design and minimising the construction impacts. "There was concern that by potentially taking this route we would miss out the CSO at Charlton, but we would deal with this using other measures," says Stride.

These "other measures" are in fact being used on a number of the CSOs along the routes and include things like connection tunnels and hydraulic adjustments to the existing system to prevent overflows. Part of the effort to minimise disruption means reducing the number of work sites at the surface and the design team has had great success in eliminating the need for surface work. "This is great news from an engineering design development perspective. The original route looked at six main shafts with five intermediate shafts. We have potentially narrowed this down to just three main tunnel drive shafts and a further drive site for the most significant connection tunnels in the east" says Stride.

The main drive shafts are the sites at which the tunnel boring machines (TBMs) would be launched and these sites would operate 24 hours a day to maintain tunnelling operations.

"There are significant construction

facilities required at the main tunnel drive sites. In total we are going to be handling 5M.t of excavated material arising from the TBMs. So there is a massive amount of work to do, and planning out the logistics strategy at this stage is essential," says Stride.

The major work sites will require up to approximately 20,000m² of land take and involve 25m diameter shafts that will potentially be driven to depths of up to 75m in the east.

By reducing the number of principal main construction sites to just five the team has potentially reduced the disruption on the surface. In determining the possible location of these five sites a rigorous site selection process was followed, beginning with examining land 500m either side of the River Thames. Immediate exclusions were applied to World Heritage Sites, existing concentrated residential areas, the Palace of Westminster, Westminster Abbey, St Margaret's Church, the Tower of London and Maritime Greenwich.

The second step was to create a long list of potential sites within the 500m zone using desktop surveys, aerial photos and Ordnance Survey maps. These sites were then evaluated using environmental, planning, engineering, property and community impact assessments leading to a draft shortlist of sites. Further scrutiny led to a final shortlist and after site suitability studies were carried out, a preferred shortlist was created. "The four drive shafts proposed for the preferred scheme are at Barn Elms, Abbey Mills, Tideway Walk for the main tunnel, plus significant connection tunnel construction from King's Stairs Gardens (see map). We envisage construction at these points will be ongoing for around seven years," says Stride.

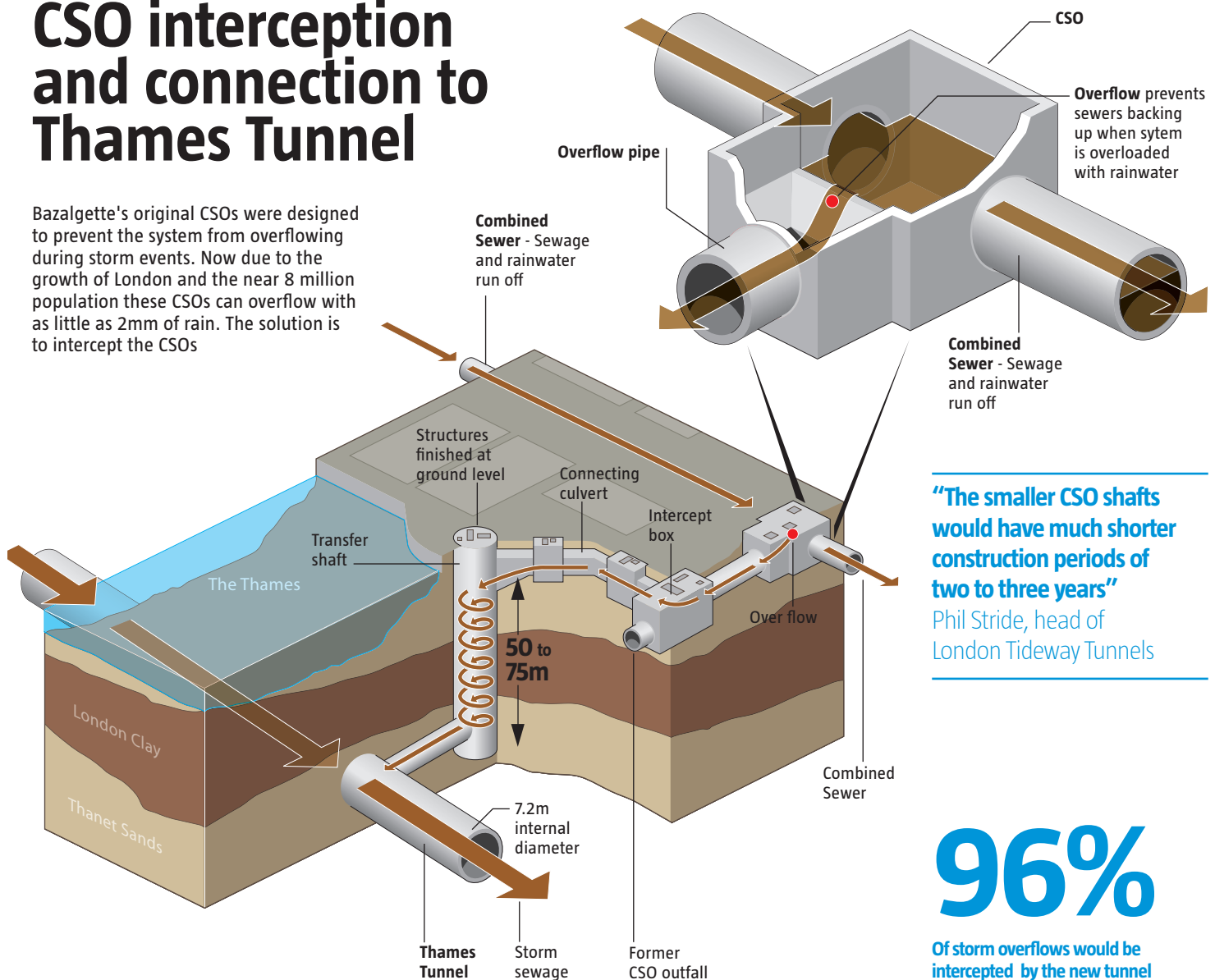
The same methodology was also applied to the CSO connection shafts which will divert the overflows from the CSOs into the new tunnel.

"Lowering the Lee Tunnel by 10m at Abbey Mills presented us with the option of shortening the main Thames Tunnel"

Phil Stride head of London Tideway Tunnels

CSO interception and connection to Thames Tunnel

Bazalgette's original CSOs were designed to prevent the system from overflowing during storm events. Now due to the growth of London and the near 8 million population these CSOs can overflow with as little as 2mm of rain. The solution is to intercept the CSOs



"The smaller CSO shafts would have much shorter construction periods of two to three years"

Phil Stride, head of London Tideway Tunnels

96%

Of storm overflows would be intercepted by the new tunnel

"The smaller CSO shafts will have much shorter construction periods of two to three years. These sites typically vary in size from 300m² to 3,000m²," says Stride.

"The key difference between the main shafts and the CSO shaft sites is the amount of activity and materials storage required. The smaller shaft sites would have working hours of typically 8am to 6pm," explains Stride.

The team has developed alternative ways to collect the sewage from the 34 CSOs, which has been achieved with only 22 shafts in total, with CSOs combined where possible with the main tunnel shafts. For the majority of the overflows the shaft would sit adjacent to the CSO and once the sewage has poured into the new shaft

a connection tunnel at the base would divert the flow into the Thames Tunnel.

For the CSOs that do not have single dedicated shafts, longer connecting pipes are proposed to connect two or three CSOs into one shaft. In other locations some hydraulic adjustments are proposed to prevent overflows from occurring.

"It is not really a sewer, even though it collects sewage. It is really a vast underground storage tank"

Phil Stride, head of London Tideway Tunnels

Low level interceptor sewers run along either bank of the Thames and are known as the North and South Low Level Sewer.

By making a number of strategic connections into the northern low level interceptor sewer, additional hydraulic capacity in this existing sewer can be created, allowing CSO flows to then be conveyed through the existing system. This significantly reduces the number of CSO interception shafts required.

"It [the low level interceptor] really acts as a hydraulic conduit. In some areas we have been able to prevent CSOs from overflowing by increasing the weir height," says Stride.

"This keeps flows in the sewer instead of overflowing. Then we connect to the low level interceptor at

key CSO drop shaft locations. By adding three connections into the low level sewer and relieving pressure on the system with the other drop shafts we are diverting the same number of CSOs with the least amount of disruption," says Stride.

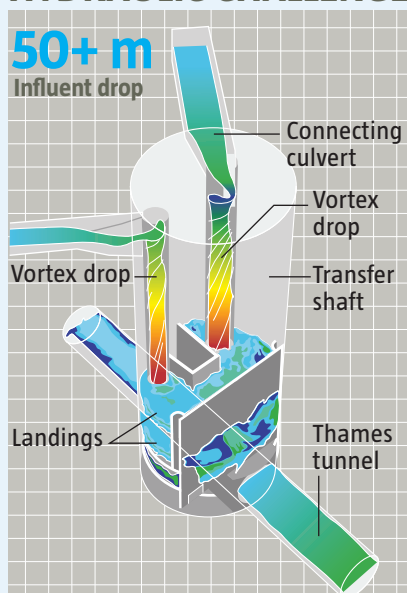
The project requires a significant number of sites to be in the foreshore and is a key reason for the rise in the cost estimate for the scheme (see intro). At many locations no viable land-based locations were identified. However work in the foreshore massively reduces work on the surface, for example, service diversions. It is also considered to be much less disruptive. Work in the foreshore would require some heavy engineering and creates the need for some permanent

The hydraulic challenge

ANALYSIS

One of the great challenges of this project was what to do with the energy and turbulence caused by the 50m + drop to the Thames Tunnel. The designers used extensive 3D modeling and computational fluid dynamics modeling to explore a number of solutions

HYDRAULIC CHALLENGE



The vertical shafts that would transfer storm sewage into the new Thames Tunnel present a range of hydraulic challenges to the designers working on the project.

As the influent is set to drop as much as 50m, the team has to contend with the turbulence created when the water reaches the bottom of the shaft. "There is a lot of energy created when a mass of water drops over this distance," says design manager Gareth Thomas. "And we have two main options for dealing with this."

The first involves the construction of a series of steps within the shafts, referred to as a cascade. The water drops onto a series of landings designed to allow the water's energy to be progressively dissipated. "This obviously involves a lot of construction and it has operational challenges as all these landings need to be inspected and maintained," says Thomas.

The second method favoured by the team is the use of vortex drops, where the sewage is introduced to the shaft in a way that encourages it to spiral downwards around the outside walls of the vortex tube. To create the swirling motion required for the sewage to flow correctly, the connection sewers will taper on approach to the shaft creating a

rotational effect. "The floor of the channel also drops to accelerate the flow before entering the tube," explains Thomas.

"Both types of drop structures need to control the amount of air entering the tunnel," says Thomas.

Essentially, air that gets into the system could build up into significant air pockets that Thomas likens to "big springs". The pressure of these could be enough to force water back up to the surface of the ground, if not properly designed. "Clearly this is totally unacceptable and we have to ensure that there will be no significant air pockets in the system," says Thomas.

The first step was to use a 2D catchment model built using Info-works software platform. "This models the catchment characteristics and gives the flow rates into the new system and allows us to check the levels so that there is no flooding or surcharging," says Thomas.

The next step was to develop 3D models using a computational fluid dynamics package to replicate how the water will move through the drop shafts and tunnels. This was followed by the creation of physical models of some of the larger drop structures and shafts, which is allowing the team to see how the water and air in the system are behaving. "

structures once construction is completed. For example at Blackfriars Bridge, the Fleet Main CSO must be intercepted but the area is home to a network of existing infrastructure making this a highly congested area.

Along with the road and rail bridge are the District Line, Waterloo & City Line, EDF's Bankside cable tunnel, the Victoria Embankment (A3211) and the Blackfriars Underpass.

To prevent disruption here the team is proposing to carry out the work along the foreshore but this would result in the need to realign the river wall and install long term structures for ventilation and air filtration facilities. Views are to be sought from the public and stakeholders on site location, and how these structures should look. The

team envisages extending the river wall and creating a new hard standing area to support the required structures. Construction at this location would take in excess of three years.

A key concern for the team when excavating in such locations is the potential for archaeological finds that could delay the project and increase costs. "We obviously have to incorporate some contingencies in the event that we do find something and further investigation is required," says Stride.

The result of the design team's efforts is a slightly smaller, but much cheaper stormwater storage system that prevents 96% of sewage from overflowing into the River Thames. Recommendations originally made by

the Environment Agency were for a storage system with a capacity of 1.6M.m³ and, although the new route gives a cumulative storage capacity (including Lee Tunnel) of just less than this at 1.5M.m³, the Agency has reviewed the preferred option and says that it meets the threshold levels for dissolved oxygen.

"It appeals more to the market to make the packages a manageable size"

Phil Stride, head of London Tideway Tunnels

Dissolved oxygen is a crucial measure as a certain level is required to sustain aquatic life. Stride says that the reduced volume is not going to cause bottlenecks or system constraints. "It is not really a sewer even though it collects sewage and has a gradient from west to east. It is really a vast underground storage tank. It is not being designed as a conventional conveyance pipeline," he explains.

After its progress on developing a preferred route the team is now focused on the next major milestone for the tunnel: achieving planning permission. Extensive public consultation is now underway and the first round of this will last for 14 weeks.

The feedback will be used to modify the plans and address any concerns

before a revised design is published for consultation in mid 2011. A planning application would then be made to the Major Infrastructure Planning Unit at the Planning Inspectorate in 2012.

Construction of the Thames Tunnel is then expected to begin in 2013, with the expectation of four or five major contracts. As with the neighbouring Lee Tunnel and fellow giant tunnelling project Crossrail, the Thames Tunnel team leaders expect that consortiums of international and UK based tunnelling experts will bid for these enormous packages of work.

"It appeals more to the market to make the packages a manageable size and from a client's perspective it means that you don't have all your eggs in one basket," says Stride.

Stride says that the extensive design work and reduction of site disruption is due to the dedication of the team of international experts based at

Paddington. "We have worked very hard to develop what we believe is the optimum solution according to the challenge that was set by government. By engaging with stakeholders and working as a team we have come up with what I believe is a feasible and buildable scheme in terms of land required and getting disruption to a reasonable level. I do not think this would have been the case with the original scheme proposal."

Although the public consultation is just beginning the tunnel team has already conducted extensive initial engagement with stakeholders in a bid to seek the best way to design and build this much needed environmental solution. "There isn't a wastewater project anywhere in the UK that has gone through such an urbanised area and dealt with so many local authorities. To date we have done over 200 presentations and the vast



"Both types of drop structure need to control the amount of air entering the tunnel"

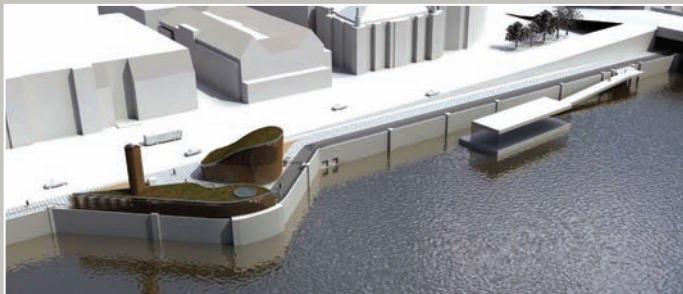
Gareth Thomas,
design manager

majority of people see that this project is really needed," says Stride.

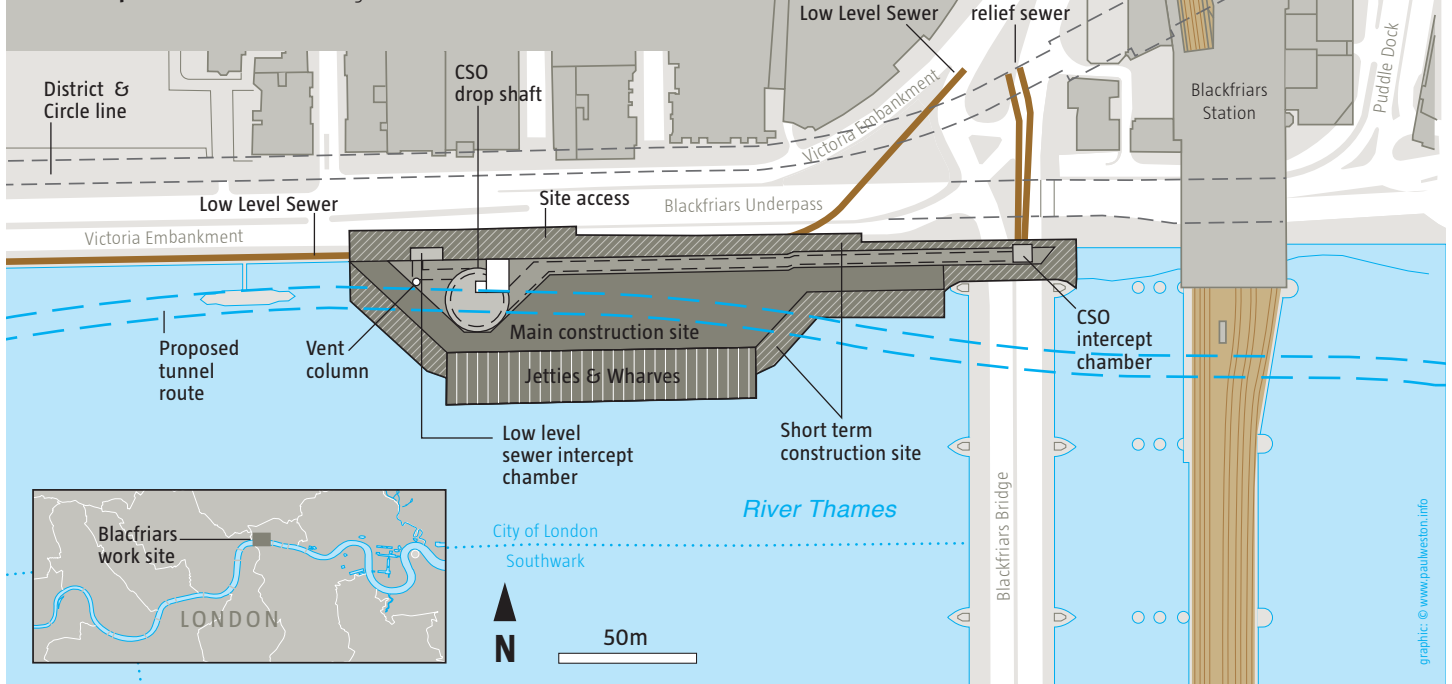
"While a lot of work has been done in developing a preferred scheme, no final decisions on tunnel route or site locations have been made. The first phase of public consultation will be the start of a major engagement that will help us decide the selected scheme that we will be then submit for planning consent.

"Although nothing is set in stone at this stage, if London wants to remain a key international city, then something has to be done about the sewage overflows," says Stride, who is keen to ensure that all stakeholder concerns are heard and considered carefully. But at the same time he and the team are excited about building the UK's longest and deepest ever tunnel. "In the history of the UK water industry there has never been a larger or more exciting scheme."

Blackfriars: A typical work site



Artist's impression: How the above ground structures will look



Multiple methods for variable ground

The boring challenge

Bernadette Redfern

Running from west to east, the Thames Tunnel would bore through all major geological formations in the London basin from London Clay, to the Lambeth Group and Thanet Sands in the middle and fairly quickly through into the chalk layers of the east.

The variable ground conditions naturally give rise to different boring techniques and although contractors bidding for the tunnel sections will suggest the methods that they think are most effective, two options stand out. Slurry tunnel boring machines (TBMs) and earth pressure balance (EPB) TBMs. "There are many opinions on what is the right sort of machine to use in the different geological strata," explains tunnel design manager Derek Arnold. "But the consensus seems to be, and the assumption that we are making, is that in the chalk you would use a slurry-type TBM."

This is because of the different mechanisms used by TBMs for cutting and supporting the face of the excavation. A slurry machine is likely to experience less cutting tool wear because the face is supported by the slurry under pressure. In an EPB machine the face pressure is largely transmitted through the cutting tools. This is particularly the case when the chalk is likely to contain flints.

Another indicator that the eastern section of the bore will require a slurry machine is that this method is about to be used for the shorter Lee Tunnel.

Maintaining the condition of the face of the TBMs is set to be a key



Test drilling: A rig tests ground conditions under the Thames

challenge for the contractors. Cutter heads must be maintained and replaced throughout the bore requiring access to the face of the machine. At the huge depths that the Thames Tunnel is boring at this will not be easy.

"In deeper alignments there is also higher ground water so those interventions are going to be challenging," says Arnold. "We are at a very early stage in terms of planning our intervention strategy but I think we

"There are many opinions on what is the right sort of machine to use in the different geological strata"

Derek Arnold,
tunnel design manager

will be looking for areas where we have ground conditions that will allow us to enter the face with minimal ground treatment or dewatering or even compressed air."

"The variable ground conditions will also have an impact on the shafts required for TBM launches and CSO flow diversion. The design team expects that in the deeper eastern shafts, which will be driven into chalk, diaphragm walls will be used for the full depth of the shaft, running to beneath the base of the tunnel to allow formation of a concrete plug. This plug will then enable the placement of the secondary lining without water ingress.

"In the clay we can use a number of construction methods, including using segmental linings with either the caisson or underpinning methods, or



"In deeper alignments there is also higher ground water so those interventions are going to be challenging"

Derek Arnold,
tunnel design manager

using sprayed concrete linings. In the middle sections we may also use secant piling for shallower shafts in more difficult ground conditions. Extensive effort has gone in to investigating the ground conditions to create a detailed picture of the underground environment. In summer 2009 three boring rigs were sent to the River Thames to begin taking 76 cores at depths of up to 100m. A further 120 sites along the river bank have also been investigated and more boreholes will be taken at the central section between Wandsworth and Lewisham.

This information was collated by Fugro and Norwest Holst and over 5,000 core boxes are now being stored at Abbey Mills creating a soil library that tells the team about the properties and behaviour of the strata beneath the River Thames.

Overcoming challenges

Learning from the Lee Tunnel

Bernadette Redfern



"We engaged with MVB early and have held risk meetings throughout"

Nick Butler, Lee Tunnel

By the time boring of the proposed Thames Tunnel is due to begin, in 2014/2015 the 6.9km long Lee Tunnel will be complete. This will provide the Thames Tunnel engineering team with valuable information to help mitigate project risks.

From the outset the Lee Tunnel project team has worked hard to mitigate potential problems. "We engaged with MVB early and have held risk meetings throughout. We identified some really critical issues from managing and removing spoil to reducing wear on the cutterheads," explains Nick Butler tunnel construction manager on the Lee Tunnel project.

Butler credits the broad expertise of the project team in putting measures in place to mitigate potential problems before they arise. "Empirical evidence from the team told us that larger disc cutters have a higher longevity. We had nominally identified 17 inch cutters in the original specification and are now using 19 inch. Our studies show that this will give us 40% extra life on the tools," he says.

Another challenge identified by the Lee Tunnel "TBM task force", which included members from contractors MVB, TBM manufacturer Herrenknecht and Thames Water, was the potential for high pressure water to enter the tunnel when unblocking the grouting system. The water pressure on the face of the TBM will be 7.5 bar at maximum depth, so any pathway could expose the TBM crew to dangerous, pressurised water. The two part grouting system uses a chemical

accelerator (sodium silicate) which means that the grout leaves the unit as a gel. However blockages of this thicker grout can occur and the usual method to deal with it is to push a mechanical reamer and a high pressure hose through the lines. However, this has water ingress risks, and to prevent this Butler says the team has created a Y-shaped piece that can be screwed into the accelerator additive location on the tailskin, so the reaming machine can be inserted through a stuffing box while controlling the flow of water through the other branch of the Y piece. This allows the blockage to be cleared without allowing in water.

"The same techniques should be of benefit to the chalk tunnelling in the eastern end of the Thames Tunnel. It should provide excellent experience as by the time the Thames Tunnel starts we will know how successful our methods have been," says Butler.

The design team planning the Thames Tunnel will still have big challenges of their own to overcome. Preparing the sites for the arrival of the TBMs means allocating sufficient space for the access shaft, excavated material storage and segmental ring storage. "Ideally, the main work site for the slurry machine needs to be around 20,000m². Smaller sites are feasible if space is limited," explains Thames Tunnel design manager Derek Arnold.

"For the EPB sites we don't need so much space as the spoil does not need

to be processed once removed, so the optimum for these work sites is 18,000m²," he says.

In terms of removing the excavated spoil the Lee Tunnel team is using a filter press system to separate the fine chalk particles from the water. Derek Arnold says that this could also be used on the Thames Tunnel at the chalky eastern bore, but that the management team is looking at options and would listen to contractors' suggestions. The chalk is then being removed on the Lee Tunnel project by barge and this is another option open for excavated material on the Thames Tunnel but economic and impacts analysis must be carried out to discern whether or not the river route is most sustainable. "We are committed to using the river wherever economic and practicable as it may lend itself to high volume movements of material. But smaller volumes of materials coming in to the sites may need to come in by road," says Maurice Gallagher, construction and logistics planner.

In addition to the main bores anticipated for the Thames Tunnel, on the preferred route 10.6km of connection tunnels would also be driven to provide a route for the sewage into the new main tunnel.

These would range in size from 2.2m internal diameter to the largest at 4.5m internal diameter at King's Stairs Gardens in Southwark running for 4km along to Greenwich Pumping Station.

Construction of the new Thames Tunnel with its major work sites and connecting tunnels is a number of years away, but experience from sister project the Lee Tunnel will be a key tool in ensuring that the UK's biggest ever waste water project is delivered on time and to budget.

40%

Greater life expected for cutting tools following risk analysis

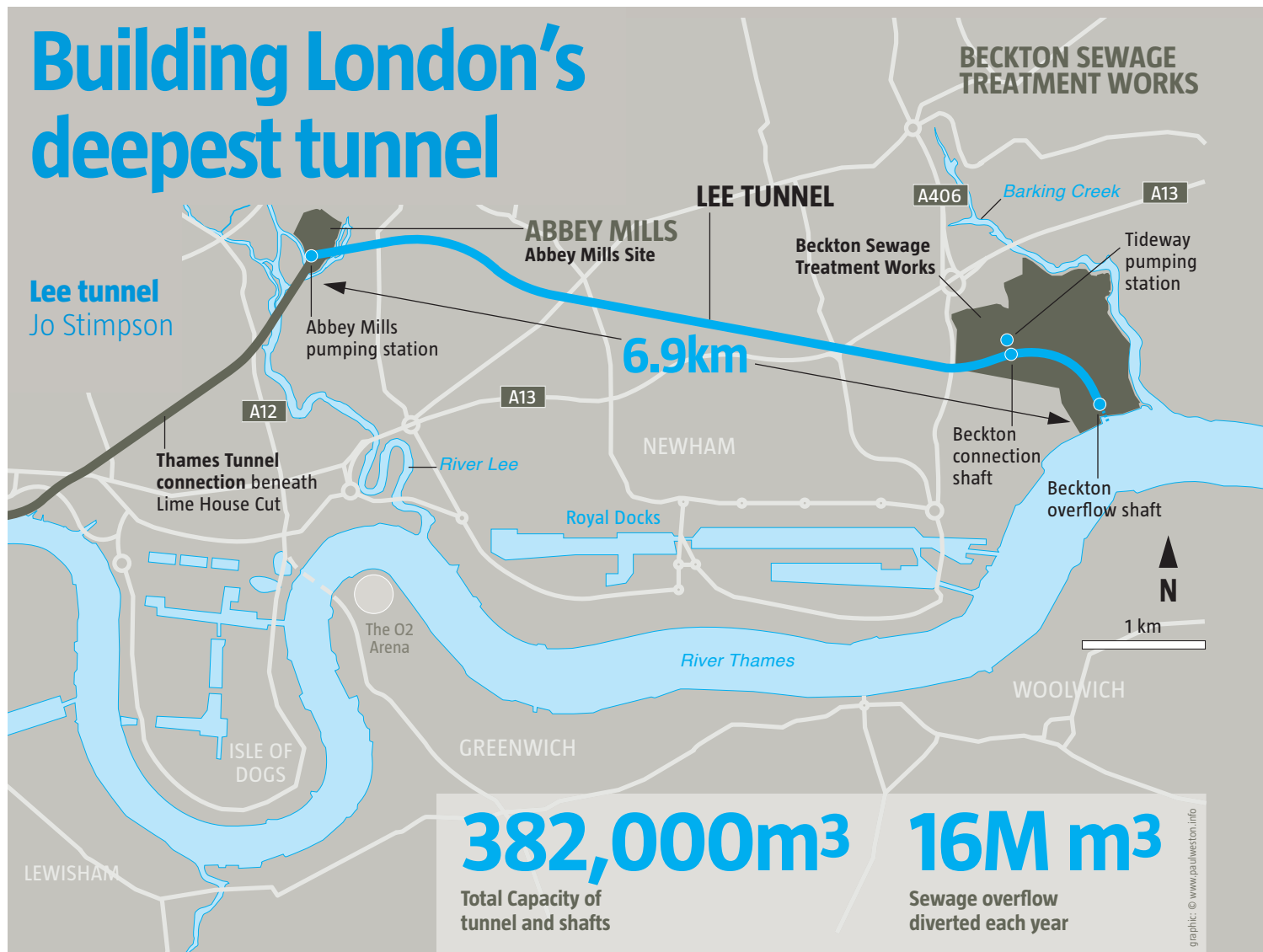
6.9km

Length of the Lee Tunnel

"The same techniques should benefit the chalk tunnelling in the eastern end of the Thames Tunnel"

Nick Butler, Lee Tunnel

Building London's deepest tunnel



The main construction phase of the Lee Tunnel will begin this Autumn creating the deepest tunnel in the capital diverting 16M.m³ a year of sewage overflows into the Thames.

The Lee tunnel may only capture discharges from one combined sewer overflow, and it may only run for 6.9km, but the smaller of the two tunnel projects certainly packs a punch, and its benefits will be significant.

In diverting the discharges from the combined sewer outfall (CSO) at Abbey Mills pumping station in Stratford the Lee tunnel will prevent a massive 16M.m³ of untreated storm sewage from pouring into the River Thames via its major tributary the River Lee. This is

equivalent to over 60 spills every year, meaning that the CSO is needed on average more than once a week.

Designing and building the Lee Tunnel is the Morgan Sindall/Vinci Construction Grand Projets/Bachy Solanche partnership known as MVB. In extreme storm events, the £635M sewer will act as an underground storage tank until the Beckton Sewage Treatment Works has capacity free to treat the additional load. Stored overflows are then pumped out more than 6km south east to the sewage treatment works. At the moment the sewage treatment works is being expanded to deal with these increased volumes. This involves increasing capacity from 1,426M.litres/day to 2,333M.litres/day. "In principle this is a massive storage tank that transfers flows to Beckton," says MVB enabling works and tunnel manager



"Each pump will have a pump out rate of 3m³/second. They will have a vital role in the functioning of the project"

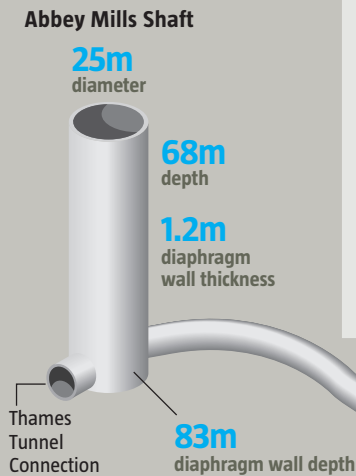
François Pogu, Lee Tunnel project director, MVB

John Corcoran.

In exceptional circumstances, when the entire storage space of 382,000m³ provided by the tunnel and shafts is filled with storm sewage, additional overflows will continue 0.85km further down the Lee Tunnel to an overflow culvert that will empty directly into the Thames. It is anticipated that it might happen six to eight times per year on average. This would reduce further once the Thames Tunnel is completed.

The Lee Tunnel will total 6.9km in length, with an internal diameter of 7.2m. But the most remarkable thing about it is the depth. At its lowest point the tunnel dives down to 75m below ground and its shafts will boast what MVB believes are the deepest diaphragm walls in the UK. This extreme depth is designed to enable the storm sewage to flow downwards

LEE TUNNEL ABBAY MILLS

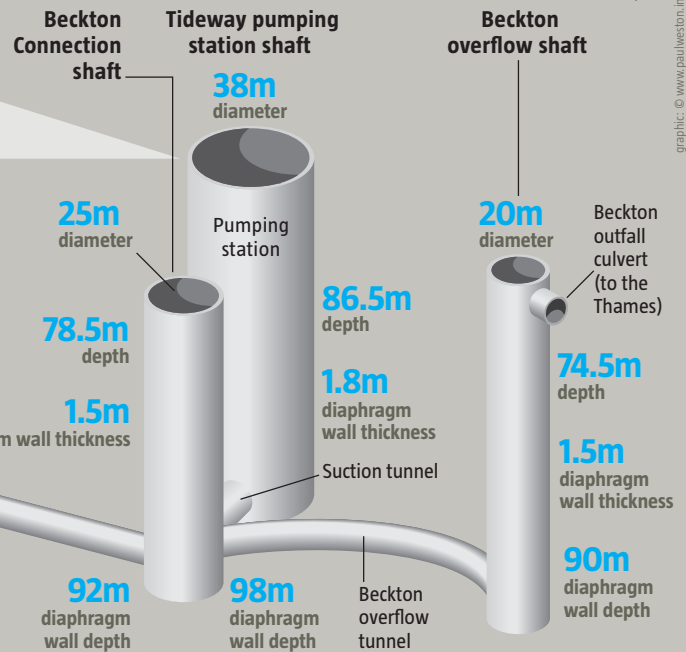


PUMPS

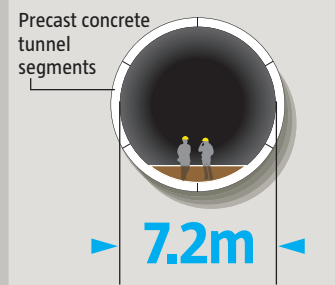


4 or 5 Number of pumps
3.5MW Power of each pump
3m³/s Pump out rate of each pump

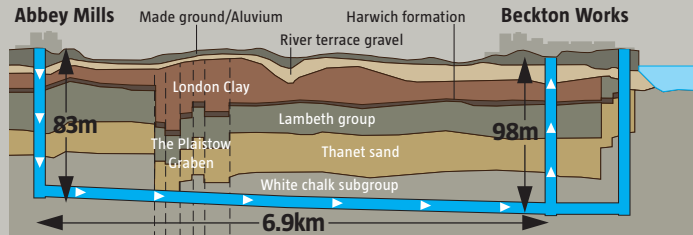
BECKTON SEWAGE TREATMENT WORKS



TUNNEL SECTION



GEOLOGY of the deepest tunnel in London



1.7M t

Material removed
boring the Lee Tunnel

to Beckton while also avoiding the warren of tunnels, pipelines and cables that exists under London, particularly the Olympic Park cable tunnels. "We're below the normal obstacles or utilities that you might encounter on a transport tunnel," says CH2M HILL Lee Tunnel project manager Robert Hayden.

The tunnel will feature four shafts: a connection shaft at Abbey Mills to take overflows from the CSO down to the tunnel; a connection shaft at Beckton to take flows from the tunnel to the pump station shaft; a pumping shaft adjacent to that which will pump the sewage up to the treatment works when appropriate; and an overflow shaft which overflows into the River Thames. The scope of works also includes two culvert systems at either end of the Lee Tunnel – one set connecting the CSO to the Abbey Mills

connection shaft, and another connecting the Beckton overflow shaft to the River Thames.

Tunnel and pump shaft work sites will be limited to Abbey Mills and Beckton, meaning that the main construction phase will take place on land already owned by Thames Water. "The Thames Tunnel is a vast project which needs considerably longer to plan and build, whereas the Lee Tunnel could be procured and developed in advance because we own the launch site for the tunnel boring machine (TBM) and the finish site," says Thames Water head of capital delivery Lawrence Gosden.

Abbey Mills, where the tunnel ends, will house one work site, while Beckton will have three – one at the overflow shaft, which will be the starting point for tunnelling; one at the point where the connection and pumping shafts

will be located; and a third site to house two new batchers that will supply concrete for the entire works from within the Beckton site. "That will limit transport movements around the site," says Corcoran. Meanwhile, precast concrete sections for the tunnel will be cast at Ridham Dock in Kent.

Enabling works are underway at Beckton which include clearing the work sites and preparing access roads, as well as extensive coring to remove

existing structure obstructions ahead of shaft construction.

"We have removed the old Victorian infrastructure underneath the first shaft site as it could have affected the excavation of the diaphragm wall which has extremely tight verticality tolerances," says MVB project engineer Martin Stanley.

For example a 19th century pumping station was previously housed at Beckton, and after the station was demolished its basement was filled with foam concrete. It is part of the basement that MVB has removed with the coring. A listed masonry chimney designed by Bazalgette as part of the improvements to the northern outfall sewer at Beckton between 1887 and 1889 was previously positioned over the area where the overflow shaft is to be built. So this has also had to be temporarily

"We're below the normal obstacles and utilities that you might encounter on a transport tunnel"

Robert Hayden, CH2M HILL,
Lee Tunnel project manager



Getting ready: Site preparation works for the diaphragm walling of the drive shaft

“Counter rotating wheels dig into the ground and a pump within the cutter sucks solids away”

Martin Stanley, project engineer, MVB

removed from the site. English Heritage protection means it has been put into storage to be rebuilt in the same location after the completion of the works. An existing modern building, Bazalgette House, also had to be part demolished to create the necessary storage space for plant and slurry tanks ahead of the main work getting underway.

“Autumn’s bringing some exciting changes to the project,” says Hayden. Challenges include mobilising the diaphragm wall equipment and starting work at Beckton for the three shafts. “It will be exciting to see that,” says Hayden. “The project is really ramping up.” Other milestones for the project will be the shaft excavation and construction, and tunnel boring machine (TBM) arrival and assembly, all in 2011; the start of TBM work in 2012; TBM breakthrough in 2013; and construction completion in 2014.

The four shafts will be supported with diaphragm walls – concrete retaining walls built by excavating a trench using bentonite slurry for support, installing reinforcement and then pouring concrete from the bottom of the trench. It is a technique for which Bachy Soletanche is recognised worldwide, says Hayden.

Logistical Challenge

Beckton Sewage Treatment Works is the largest such works in Europe, and is located next to the River Thames. Unfortunately, that means that establishing three sizeable work sites and carrying out a major tunneling project present significant logistical challenges.

Carrying out construction on three different sites in the middle of a constantly working sewage treatment plant would be difficult enough, but because maintenance work on the existing treatment works is currently ongoing, Beckton was a hive of activity even before MVB’s arrival. “We are the new boys on the block; we’ve got to integrate into the running of the plant,” says Corcoran.

Site access is a delicate issue. There is only one road into Beckton Sewage Treatment Works, says Hayden, and the site is already constrained and busy.

“We’re going to be adding a massive amount of people and plant,” he warns. A logistics centre on site will take on the challenge of co-ordinating deliveries. The strategy, he says, will involve maximising river transport and bringing

in road deliveries in bulk by night.

The peak of the project will see 450 MVB staff including labour on site, with a further 50 staff in the project management team led by CH2M HILL. That peak of activity will happen in 2012, when tunnelling will be at its peak. MVB is further engaging with the local community through Newham Workplace, a recruitment centre that was established to help workers in the London Borough of Newham make the most of regeneration in their area. MVB, keen to employ local people, is in discussion with Newham Workplace to ensure skilled workers can be trained to find employment on the project.

MVB is also taking health and safety seriously, to the point of enforcing random drug testing for all staff. Pogu says the ultimate aim is for MVB workers to take ownership of their own safety, and to that end some workers have volunteered to become “safety champions” who take the extra responsibility of monitoring health and safety throughout the project. “Our health and safety starts with putting on your seatbelt on the bus coming into the site,” says Hayden.

Bachy Soletanche specialises in the Hydrofraise system, a reverse circulation drilling rig with two cutter drums that rotate in opposite directions. “Counter-rotating wheels dig into the ground and a pump within the cutter sucks solids away,” says Stanley. As it is excavated, the trench is topped up with bentonite slurry to maintain the stability of the sides. The slurry is continuously cleaned during the excavation process and the solids separated away before the bentonite is re-used. “If you’re sending dirty slurry down it won’t be as effective,” says Corcoran. The Hydrofraise will work its way systematically around the edges of the shafts, which range in internal

diameter from 20m to 38m.

The pumping shaft at Beckton is the largest and deepest of the four shafts – and the one that will have to work the hardest when the tunnel is in operation. It will house 3.5MW pumps weighing 40t each – investigations are still ongoing into whether the number of pumps needed will be four or five. “They have to pump [sewage] 85m high,” says MVB Lee Tunnel project director François Pogu. Each pump will have a pump-out rate of 3m³/second. In a storm event, the pumps will gradually empty the Lee Tunnel which stores sewage, and when full it could take up to two days for its contents to be pumped out. The design of the

pumps is part of MVB’s contract, and has been an area of early focus due to its vital role in the functioning of the whole project. MVB has also been able to draw on the considerable pumping expertise within Thames Water, says Pogu.

All spoil from the Beckton works will be taken away by river, from a jetty just 300m from the main work site at the overflow shaft. The jetty was historically used to take sludge away from Beckton. Now it will be upgraded to serve the Lee Tunnel project. A conveyor will take material to the jetty’s end and an incline conveyor will then be used to load ships. A new lighting system will also be installed.



Getting going: MVB will start work on three of the four deep shafts that will be built for the project in 2010



Testing: 80 cores were taken to prepare for construction of the drive shaft

"We are tied into a lot of existing planning conditions," says Corcoran, one of which is an obligation to establish measures to reduce road movements. "1.7M.t of material will be removed by barge instead of road. That can make a real difference to traffic," says Pogu.

The Lee Tunnel will for the most part be bored through the south of England's upper chalk formation. Due to the extensive tunnels already existing below London, Pogu says, the geological conditions of the area are well established. "It is a soft rock and it's quite well known – this is not the first tunnel in London!" he says. "We should know what we will face." One section of the tunnel also passes through Thanet Sand, which is equally well known – although this contains abrasive flint within the Bullhead Beds which can wear the equipment.

Still, despite the familiarity of the area, MVB has elected to undertake site investigations to confirm its

expectations, as although the area has been repeatedly tunnelled before, those tunnels were less deep. "It hasn't been done at such a depth [before]," says Pogu.

"At this depth nobody knows." MVB will use a slurry shield tunnel boring machine (TBM) with a diameter of 8.88m. The machine offers a completely enclosed working environment, suited to soft ground with high water pressure. "It has an advantage over an earth pressure balance machine," says Pogu. "There

"The Lee Tunnel is deeper than the Thames Tunnel but many of the ground conditions are similar"

Lawrence Gosden,
head of capital delivery,
Thames Water



Corcoran: "It's a great job to be on"

is nowhere for the water to go." The £15M Herrenknecht TBM is 100m long, requires a crew of 10 men and can progress 17m per day. Pogu says that at depths of 70m to 80m water pressure on the tunnel from the water table will be 8 bar.

MVB is working under an NEC3 contract, which Pogu says he would recommend as "a good tool".

The relationship with MVB is governed by a spirit of co-operation and mutual trust, says Hayden.

"We collaborate to find a solution rather than writing ugly letters to each other. Francois and I have informal discussions on how things are going. I expect him to share his issues with me." A Lee Tunnel project charter, signed by members of the MVB staff and the project management team, sets out key values, objectives and success factors for the project.

The charter is the product of a partnering workshop that was led by consultant EC Harris to establish a

"The Lee tunnel could be procured and developed in advance because Thames Water owns the launch site for the TBM"

John Corcoran, tunnel manager, MVB

shared outlook for MVB.

The procurement process to award the design and build contract – the largest ever awarded by Thames Water – was "vigorous", says Thames Water head of capital delivery Lawrence Gosden. "We wanted value for money and real confidence in the delivery." Procurement started in October 2007 and lasted until November 2009. Two firms were shortlisted: MVB and a Hochtief/Murphy joint venture. "Both sets of JVs are very good, we would be happy doing business with all of them," says Gosden.

Pogu says specialist expertise is key to MVB successfully completing the work. Morgan Sindall and Vinci have "broad experience in tunneling", he says, and he describes Morgan Sindall as "one of the best UK contractors. It is an advantage to be in a joint venture with such partners," he says.

But while the Lee Tunnel is a major and complex project in itself, it is also a prelude to something much bigger. Does Thames Water feel there are lessons here to be learned ahead of the Thames Tunnel?

"Absolutely," says Gosden. "The Lee Tunnel is deeper than we anticipate the Thames Tunnel being, but many of the ground conditions are similar, and so are the logistics of a project in a working city. We will be monitoring the project closely as the Thames Tunnel is developed."

On site, enthusiasm for the project is evident. "It's a massive job and big thinking is needed. It's a great job to be on," says Corcoran, while Hayden says the Lee Tunnel comprises multiple big projects in one.

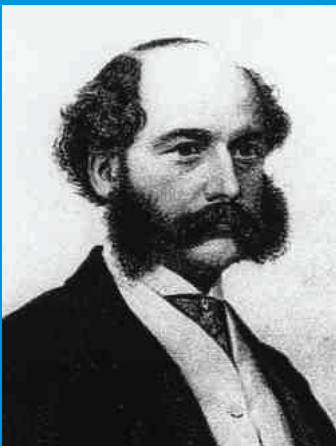
"You have tunnels at the deepest depths in London's history and a pumping shaft with some of the largest pumps on the market.

"We're committed to delivering a world class project for Thames Water. That means on time, on budget, and safely," he says.

The man who stopped the stink

The historical context

Jo Stimpson



In 1859 Bazalgette proposed a network of huge underground brick sewers to intercept sewage outflow

15

The number of years it took to build Bazalgette's sewer network

Ground breaking Victorian construction created a sewerage system for London that has endured for over a century but more innovation is required to secure its future.

Sir Joseph Bazalgette is widely recognised as a Victorian pioneer in civil engineering. As the chief engineer of the Metropolitan Board of Works he created the sewers, pumping stations and treatment works that have allowed Londoners to enjoy a reliable sewerage system for 150 years.

However until Bazalgette's intervention in the mid 1850s the city's sewerage system was in a grim state. In medieval London, which existed as the City of London, with Westminster still just a town a few miles up the river, waste was simply jettisoned into the street. This led to the development of a fleet of rakers, who collected street waste on carts and took it to 'laystalls' outside the city. In the late 14th century rakers were taken on by the government at public expense, marking the beginning of an organised industry for the disposal of waste.

At that time, the word 'sewer' referred to any water course in the city, whether it contained human waste or not. It was only later, when these rivers and streams became constantly used as channels for waste that the word 'sewer' took on its modern meaning. Accordingly, in 1531 the Statute of Sewers created Commissions of Sewers which had the authority to oversee maintenance of London's water courses, protecting flows and dealing with damage.

Cess pits were the first chambers built specifically as receptacles for

waste. First appearing in the medieval era and growing steadily more ubiquitous over the following centuries, cess pits stored sewage until being emptied by rakers.

Some were designed with culverts to channel overflows into the street or into a water course – which was illegal but still common. For those without such a culvert, backed-up cesspits led to overflows on their land that not only threatened public health and damaged buildings, but were extremely unpleasant.

By 1850 it was made legal to connect cesspits to sewers but London's population was by now growing at an alarming rate. The city had expanded into surrounding rural areas, tripling its land area between 1802 and 1832. Building companies began to construct man-made sewers that channelled away household waste. These were built speculatively by private companies, resulting in poorly planned and constructed – and often open – sewer systems.

By the mid-18th century, all public waterways had become foul and contaminated, compounded by the growing popularity of flush toilets, introduced in the 1780s.

All sewage was eventually channelled into the Thames, from which water companies pumped it back into the water supply. The situation climaxed in the 19th century with the infamous Great Stink of 1858 forcing action from government.

"In 1855 the Thames was noxious; it was almost septic, black and bubbling"

Isobel Bain,
Environment Agency

Unusually hot summers in 1855 and 1858 made the Thames' stench of untreated sewage unbearable. By this time more than 400,000t of sewage flowed into the Thames each day, totalling around 150M.t a year.

The warm weather caused bacteria to thrive – but left the river otherwise ecologically dead. "It was devoid of life," says Environment Agency tideway strategy project manager Isobel Bain. "It was noxious; it was almost septic, black and bubbling." Cholera had also become widespread and was at the time believed to be caused by airborne 'miasma' from the sewage in the Thames. While the disease was actually caused by bacteria which spread through the contaminated drinking water, its association with the foul rivers was accurate.

Parliament, being housed next to the river, could not fail to notice the growing problem. Limited action had been taken through the Metropolitan Commission of Sewers Act 1848 which had created a commission to survey London's sewerage system. The Commission decided to close the open cesspits, but its work was disrupted as the Commission was repeatedly disbanded and reorganised before being superseded in 1855 by the Metropolitan Board of Works led by Joseph Bazalgette.

In 1859 Bazalgette proposed the construction of a network of huge underground brick sewers to intercept sewage outflows, diverting them to where they could be more safely deposited in the Thames downstream from London. The city's topography made pumping stations necessary to maintain the flow, so Bazalgette planned for major ones to be built at Deptford, Crossness, Abbey Mills and Chelsea Embankment. Beckton and

Sewer History

By the mid 1800s the Thames was little more than an open sewer, devoid of fish or wildlife and was an obvious health hazard. Bazalgette's solution was to construct 134km of underground brick main sewers and 1,770km of street sewers, to intercept the raw sewage

134km

Length of underground brick main sewers

1770km

Length of street sewers which linked into the main sewers

1800

Extent of urban area.
Population c. 900k

1900

Extent of urban area.
Population c. 4.5million

TODAY

Extent of urban area.
Population c. 8million

SIR JOSEPH BAZALGETTE'S INTERCEPTING SEWERS

Bazalgette devised a network of sewers to intercept sewage outflows



TIME LINE

1844-47

Metropolitan buildings act requires all new buildings be connected to common sewers

1848

Various commissions looked at the problem of pollution in the Thames

1849

Fish had disappeared from the Thames

1858

The Great Stink forces action by government

1865

First phase of Bazalgette's system is opened

Crossness sewage works were also part of Bazalgette's scheme, but were only intended to store sewage and discharge to the river on the ebb tide – treatment facilities would not be introduced there until 1882. Other treatment works would be built over the following century as treatment methods developed.

Parliament accepted the scheme, which was enormous in scale and would cost £3M.

Water companies were instructed to move their intakes upstream while Bazalgette designed five main intercepting sewers alongside the river, with ancillary branches.

The project spent two years in the design phase as Bazalgette tried to bring costs down. But increasing complaints by MPs as the stink continued meant additional funds were soon made available.

Bazalgette designed his sewers generously, recognising that population growth would likely continue

Construction of the new sewers took 15 years and was the largest British civil engineering project of the 19th century boasting some of the world's finest brickwork – sadly hidden underground.

The northern low level interceptor sewer lay inside new embankments designed to reclaim land from the river and boat yards. The Thames embankment on the north bank contained a railway as well as a sewer, and featured a road and walkway on top. In total, the scheme reclaimed

89,000m² of land from the river. The beginnings of the new sewer system opened in 1865 – although the whole project was not completed for another ten years.

Bazalgette designed his sewers generously, recognising that population growth would likely continue. But actual growth outstripped even his expectations. He estimated London's population would be 4.5M by the 1900s. In fact, it reached 6M by that time, and hovers around 8M today. Despite Bazalgette's generous allowances today's sewer network is struggling and one of the cleverer aspects of the Victorian system is causing intolerable damage to the River Thames today.

Combined sewer overflows (CSOs) were incorporated into the network to provide relief for the system in times of very heavy rainfall. Rather than allow

the system to back up and flood the streets and people's homes, these overflows discharged excess flows into the river.

At the time the overcapacity of the system meant that such overflows into the Thames were a rare result of severe rainfall, but today CSOs typically discharge into the river once a week. With London's population forecast to grow by another 1M as soon as 2029, the city's sewers are only going to face more flow in the future. The London Tideway Improvements project will not be easy to deliver, nor is it cheap but Thames Water says that work undertaken now will quickly prove itself as vital for London and will continue the tradition begun by the Victorians of delivering new capacity and facilities that will safeguard water quality in the River Thames for many decades to come.

Other major treatment works upgrades

Wastewater plants
Adrian Greeman



“We have drawn lessons from the Olympics construction site nearby”

Lawrence Gosden,
head of capital delivery,
Thames Water

A critical element of the London Tideway Improvements is the significant upgrade programme of the five sewage treatment works discharging to the tidal River Thames. This includes Beckton, the largest in Europe.

Thames Water’s upgrade programme for London’s treatment plants, while not of the same scale and complexity as the Tideway tunnel projects, is a major capital programme in its own right with a huge £675M being spent on upgrades at five wastewater treatment works over the next five years. This programme will increase capacities by up to 60% during storm flows, reduce odours and extend the sustainability of the plants with better use of generated heat or gas and the addition of wind power.

Roughly half of that spend goes on the two giant plants which flank the Thames estuary on the east side of London at Beckton on the north bank and Crossness on the south. These are the legacy of the original Bazalgette sewerage scheme to clean up Victorian London. Beckton, covering 132ha, is Europe’s largest treatment plant, and will have a through flow of 27m³/sec when work finishes in 2014. Crossness has just over half the capacity of its northern sister.

Each is getting a significant expansion to its treatment capacity, ranging from initial grit removal and screening through primary sedimentation to secondary treatment.

New aeration tanks will allow much

greater volumes of sewage to be handled, lifting the threshold above which overflow and storm discharge takes place during periods of high rainfall. Like most Victorian cities, London has mainly a combined sewage system. Only very dilute flows, satisfying much more stringent “consent” levels for pollution, will now go directly into the river.

“The increased capacity also means there is a need for some additions to sludge handling and to pumping and other ancillary equipment buildings,” says Thames Water’s capital programme delivery team head Lawrence Gosden.

The most complex of the construction works is at Beckton, not only because of its size but also because it is the end point for the new 7km long Lee Tunnel, now in construction, and with some of its site operations at Beckton, including the 75m deep tunnel start shaft.

The other construction work taking place and the fact that the treatment plants must all remain fully operational throughout the expansion programme means logistical and site coordination questions are paramount for Beckton. “We have drawn lessons from the Olympics construction site nearby,” declares Gosden. First the site has set up a “site integration team” formed from members of Thames’ own capital works team, from the senior operations staff, and then from the consultants and contractors. These are primarily C2HM HILL and Tamesis, a Laing O’Rourke-led consortium with water specialist IMTECH. Tunnel contractor consortium MVB comprising Morgan Sindall, Vinci Construction Grands Projets with Bachy Soletanche is also represented.

“The team meets frequently and

considers the plans for proposed operations from all the parties to assess the impact they might have,” says Gosden.

Beckton has also established a marshalling centre for deliveries, similar to that used on the Olympics works and also, initially, for the Terminal Five construction project at London’s Heathrow airport. The centre is a common delivery point for site vehicles and materials for all the contractors. Deliveries are coordinated and go to site immediately but have to check in and be instructed on routes and times.

“The centre is just inside the site with its own buildings, access, barrier control and security,” says Gosden. “It has been under construction in the early work which began in April and will begin to operate towards the end of this year when the main construction really takes off.” That construction is essentially for “more of the existing process, which works well,” explains Gosden. Beckton uses a plug-flow activated sludge treatment for the secondary sewage, which passes through 80m long aeration tanks and then into final settling tanks where the solids are removed before the clarified liquor passes into the river.

“Essentially we are adding a third stream to the secondary treatment process,” says Thames Water project contracts manager Jaymin Patel.

There will be new grit removal and screening channels, primary sludge settlement, new aeration tanks and then 16 new final settlement tanks, each 44.5m in diameter. Additional pumping is also required, as is a blower house for the feed to the fine bubble diffusers at the bottom of the 7.5m deep process tanks.

Most of this is being built within the

£675M

The amount being spent on upgrades at five wastewater treatment works over the next five years

60%

Increase in capacities during storm flows created by the programme



so-called Beckton Rectangle, an area of spare land within the 1.1km by 1.2km Beckton boundary. Being relatively soft ground of alluvial deposits overlying gravels, nearly all the structures will be piled to a depth of up to 20m, with a mixture of driven and bored piling. The area has also needed a detailed survey for unexploded Second World War bombs before construction could start.

Further helping the logistics and the construction process is a proposal by Laing O'Rourke to use precast concrete construction, taking advantage of a new production factory it has just set up in the Midlands.

"Unit sections of around 40t will be brought in for the tank walls by low loader," explains Gosden. They will be directed to the required area by the marshalling centre.

Aside from speeding the work – and producing significant cost savings, the use of precast, where possible, will also be much safer, says Gosden, a key requirement for the client. "Factory production gives better quality control and avoids some of the dangers of site work," he says. Other work at Beckton includes the provision of additional sludge treatment and enhanced anaerobic digestion, which will provide around 4MW of renewable energy to power site equipment. This will complement the existing "Sludge Powered Generator" incineration plant. This facility uses heat from sludge incineration to power a steam turbine, which currently generates approximately 5.5MW of electricity to

Sewage Works Upgrades		
	Current capacity M.l./day	Upgrade capacity M.l./day
Beckton	1,426	2,333
Riverside	216	216
Mogden	690	1,064
Long Reach	230	250
Crossness	733	1183
Total	3,395	5,045

offset demand from the National Grid and power site equipment. Further power is to be generated by a wind turbine on the site providing up to an extra 1.5MW, subject to final wind assessments currently underway.

Work at Crossness is pretty much a repeat of the expansion at Beckton, says Gosden, though in proportion to its slightly smaller size and without the additional odour reduction work required at Beckton to cover the primary and secondary tanks. Because there is to be no additional flow from a new tunnel at Crossness, the overall capacity increase will be 44% from 733 Ml/day to 1182Ml/day and will cost £220M.

This excludes a second project at Beckton which will cover the currently open primary settlement tank area, to reduce odours. An extra £67M is to be spent on this work.

Since Crossness does not have the additional complexity of the tunnelling to contend with, it does not need the extra management structures for site co-ordination, nor a dedicated marshalling centre. "The contracting consortium will manage its own site delivery and co-ordination," says Gosden, although close contact will again be required with the operation team on site, as the plant must obviously continue operating.

"Factory production gives better quality control and avoids some of the dangers of site work"

Lawrence Gosden,
Thames Water

Crossness, like Beckton, features some landscaping work as part of the contract, although there is also work to be done on the Crossness Nature Reserve and Southern Marshes area.

Third largest of the projects is for the west London plant at Mogden, where another £140M is to be spent, again on much the same kind of upgrade, increasing capacity by around 50%. This will greatly reduce the number of times when the storm tanks will need to be used for short term storage. A major constraint here is that the plant sits in close proximity to surrounding neighbourhoods and construction will be tightly controlled for noise and disruption. There will be no wind turbine here but there will be a capacity increase from 790M.l./day to 1,064M.l./day.

The last of the two schemes at Long Reach and Riverside are similar, but on a smaller scale to Beckton, Crossness and Mogden. Long Reach will not need additional final settlement tanks though the rest of its processes will be extended in a £40M project. Riverside involves £85M worth of work on new inlet, primary and aeration tanks and just two new final settlement tanks. In addition an advanced sludge treatment plant is being installed.

Work at Long Reach and Riverside is due to come on-stream in 2012. Crossness and Mogden will finish a year later in 2013 and work at Beckton, with the additional complications of the Lee Tunnel to incorporate, will continue until 2014.

Cleaning up the River Thames

Environmental drivers

Bernadette Redfern



"A CSO incident at the wrong time can wipe out a whole load of fish that are less than one year old"

Yvette de Garis, head of environment and quality strategy, Thames Water

Preventing sewage from overflowing into the River Thames is set to ensure London meets European legislation and will significantly improve the waterside environment.

The three major engineering projects that make up the London Tideway Improvements scheme are set to provide a raft of environmental benefits to the tidal River Thames.

The Beckton and Crossness catchments, which serve central London, discharge 39M.m³ of untreated storm sewage into the Thames in an average year.

By preventing sewage from discharging into the waterway from the 36 most polluting combined sewer overflows (CSOs), aquatic life will benefit from reduced depletion of dissolved oxygen, currently depressed as a consequence of untreated storm sewage entering the river and triggering bacteriological activity.

Reducing sewage derived litter is also a very welcome outcome, as is the expected reduction in potential health problems related to exposure to untreated stormwater discharges.

"There has been concern over the impact of the combined sewer overflows on the Thames Tideway for some time, but what has brought it to a head is the issue of compliance with the Urban Waste Water Treatment Directive," explains Thames Water head of environment and quality strategy Yvette de Garis.

The Urban Waste Water Treatment Directive is a wide ranging piece of European legislation that came into force in May 1991. It requires that all wastewater collecting systems and

treatment facilities for large towns and cities must put in place adequate treatment facilities by December 2005.

The legislation does allow discharges from the system under storm conditions. Unfortunately not all of the CSOs in the River Thames need storm conditions to overflow. "There has been much debate as to whether the current system is compliant as the situation with regard to discharges from CSOs is far from clear cut," says de Garis.

Following extensive research the Department for the Environment Food and Rural Affairs (Defra) and the Environment Agency decided that remediating the 36 most polluting CSOs was necessary if the directive's requirements are to be met.

"In 2007 the minister at Defra wrote to Thames Water and required us to progress with the development of a scheme to remedy the situation," says de Garis.

Thames Water had also been studying the impact of the CSOs on the river. "What we found was that discharges from the CSOs led to an increased risk of health-related illnesses, an increased risk of sewage derived litter in the river and an increased risk of fish kill," says de Garis.

"A CSO incident at the wrong time can wipe out large numbers of fish fry – fish that are less than one year old."

The main reason for the damage to aquatic life is the increased competition for dissolved oxygen created when untreated storm-combined sewage is introduced to the river. This contains bacteria which compete with the natural demand for oxygen from fish and other aquatic life and increases what's known as the biochemical oxygen demand (BOD).

Environment Agency tideway strategy project manager Isobel Bain

says that the sewage causes other problems too.

"The tidal Thames is an important habitat for juvenile fish, and these are adversely affected by sewage discharges. Regular CSO discharges could inhibit or prevent juveniles joining adult populations in the North Sea, including sensitive species such as salmon, sea trout and smelt," she says.

In determining the extent of the problem, Thames Water created a hydraulic model of the network, which was then verified by field based investigation. In doing this a range of assumptions surrounding the effects of the CSOs were made, including that 10% of the litter in the river is caused by sewage discharge.

"We would then look at the proportion of that 10% that would be linked to the CSOs by volume," says de Garis.

"Similarly we built a model that made predictions on how water quality would change under a CSO event and varied the parameters to reflect the increased load expected in the future, including climate change effects. This model would then predict the variation of dissolved oxygen in the river as a result of the discharges."

Another key issue that Thames Water's research identified concerned the quality of effluent being discharged from the five major sewage works along the river.

"When we modelled the Tideway we found that the problem wasn't just about the discharges during storms but there were also underlying problems with the discharge quality coming from sewage treatment works. This showed that the estuary was already under stress when storms occurred."

In response, a £675M programme of upgrading the sewage treatment

10%

Of the litter in the Thames is caused by sewage discharge

120

Species of fish recorded in the Thames

Thames Tideway environment at risk



CSO DISCHARGE

As little as 2mm of rain can be enough to trigger a sewage discharge from the 36 most polluting CSOs



300

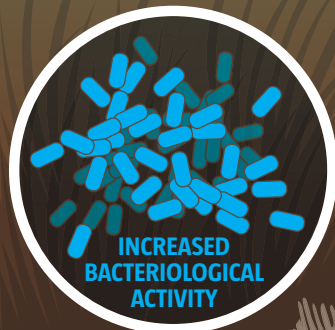
The number of plant species found along the Thames

MIGRATORY FISH

Particularly affected are migratory fish such as salmon, sea trout and smelt

BIOCHEMICAL OXYGEN DEMAND

Untreated sewage discharge depletes the dissolved oxygen in the water killing fish and increasing bacteriological activity



INCREASED
BACTERIOLOGICAL
ACTIVITY

Cormorant

Salmon

38

Species of birds supported by the tidal Thames

350

Species of invertebrates found in the Thames

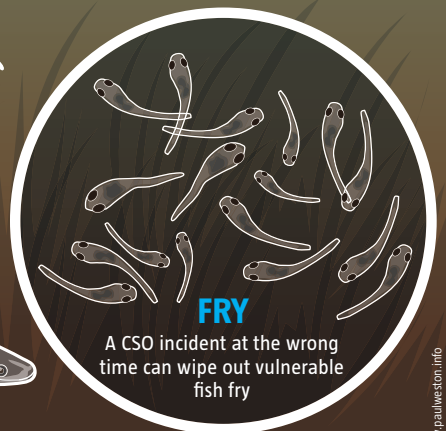
Sea trout

Smelt

Eel

120

Species of fish recorded in the Thames



FRY

A CSO incident at the wrong time can wipe out vulnerable fish fry

39M.m³

Average volume of untreated sewage discharged into the Thames each year

57

The number of sewage outfalls along the tidal Thames

10%

Of litter in the Thames caused by sewage discharge

works through expanding the facilities was commissioned to improve the baseline condition of the estuary.

As for the CSOs in the sewer network, the proposed Thames Tunnel will capture discharges from 34 of these by 2020. But the biggest offender, a CSO at Abbey Mills responsible for 41% of the annual discharges, will be collected by the Lee Tunnel.

"The Lee Tunnel has been developed first as Abbey Mills CSO is a key overflow, causing significant pollution to the River Lee," says Thames Water environmental impact assessment manager for the project Suzanne Burgoyne.

Although the final route of the Thames Tunnel is still under consultation, de Garis and Burgoyne say that all three options offer virtually the same environmental benefits in terms of

An army of volunteers

Over the past 15 years a small army of 8,000 individuals has been working away to clean up London's waterways.

These volunteers are part of the Thames21 initiative dedicated to improving water quality in London's waterways. They clear rubbish from the River Thames and tributaries, and organise educational activities. But riverside events have to be cancelled if sewage has been discharged into London's waterways. Preventing overflows would allow Thames21 to continue its efforts. "Our volunteers are thrilled that something is finally being done," says Thames21 chief executive Debbie Leach.

"As a world class city, London needs a clean and healthy river"

Isobel Bain, Environment Agency tideway strategy project manager

sewage capture.

"Because the driver is compliance with the Urban Waste Water Treatment Directive interpreted as a set of dissolved oxygen standards for the estuary, all of the options have been designed to meet these standards as a minimum," says de Garis.

"So environmental gains come with the preferred option of building a shorter tunnel that reduces disruption,

congestion, air quality impact, waste generation and noise."

An additional factor is that the River Thames is currently failing to meet challenging water standards that were ushered in by the Water Framework Directive 2000. As a heavily modified watercourse, the River Thames is required to meet good ecological potential by 2027. The Thames Tunnel is a positive step towards meeting this standard.

The importance of The River Thames to London cannot be underestimated and although European Law is driving the need for change, there is also an undercurrent of support from stakeholders and users of the waterway who want a better aquatic environment and see economic benefits stemming from a cleaner river.

"As a world class city, London needs a clean and healthy river," says Bain.

Getting the best from the best

Procurement

Bernadette Redfern



"We have a very challenging project and we will be seeking as much innovation and creativity as we can get out of the market"

Jim Otta, project director,
London Tideway Tunnels

Extensive engagement with the construction industry is key to the Thames Tunnel team's plans to successfully deliver the UK's biggest ever wastewater project.

There are many variables to consider when planning the UK's largest ever wastewater project and Thames Water plans to use the best available knowledge in the construction industry to deliver the proposed Thames Tunnel. To do this the company will launch an initial market consultation exercise in January 2011 that the company hopes will see the most experienced firms in the construction sector offering their thoughts as to the best way to build London's new 'super sewer'.

"We have a very challenging project and we will be seeking as much innovation and creativity as we can get out of the market," says London Tideway Tunnels project director Jim Otta. "We have a large network of companies on our technical framework agreements. Between them they have been involved in every major tunnelling job in the UK over the last decade, so there is all kinds of technical expertise here and we now need to reach out to firms that will actually build the project to seek their input."

In fact Thames Water already has around 50 firms working for it on its existing £5bn capital investment programme for asset management plan period 5 (AMP 5) that runs from 2010 to 2015. This should give it a considerable head start when it comes to consulting the industry on the best and most cost effective way to build the

UK's biggest ever sewer tunnel.

So far a number of major contracts have already been awarded. The construction contract for the Lee Tunnel was awarded in January 2010, representing a major milestone for the UK water sector as the industry's largest single construction contract to date. The NEC3 contract was let to the MVB consortium of Morgan Sindall, Vinci Construction Grands Projets and Bachy Soletanche following a six month tender process and a 12 month evaluation period.

"The criteria were weighted between technical competency and commercial terms, so we weren't looking solely at cost but for the best combination of technical and cost – this gives greater certainty that we have the right skills to deliver the project and minimise risk," says Otta.

"The commercial section was kept locked up until after we had done the technical ranking and scoring, and then we took two of those bidders into the final round where we opened the commercial packages. This was to avoid any bias that might creep in the technical evaluation due to cost differences." In addition, Otta says that the complex nature and large scale of the scheme demanded careful evaluation of the technical proposals.

"The project is the deepest and largest tunnel that has ever been constructed in London. It is in the chalk

and we had to make sure we had the right technical solution in place and the right cost to go along with that to minimise risks during delivery."

Construction of the 7km, 7.2m internal diameter sewer is now underway and Otta and the London Tideway Tunnels team must now focus on the next set of contracts. The proposed Thames Tunnel will require up to 60 enabling works packages, as well as four or five main tunnelling contracts. Enabling works contracts could start to be awarded as soon as 2012.

With 22 engineering framework contractors already working for Thames Water, there is seemingly no shortage of potential delivery partners, but Otta says that they could be awarded outside the framework if current partners have capacity constraints. "It depends on the ability of the existing framework contractors to actually do more work because they do have quite a bit of work under the existing agreement, but the contracts do lend themselves more to companies that are already here and have done work in London – whereas the tunnelling construction contracts are typically multinational consortiums."

In terms of timing and structure, Otta says that the Thames Tunnel will be split into four or five major packages. "We think that is about the right size to attract the maximum amount of competition. If we go bigger than that we think it might be too big and limit the number of firms who could bid," he says.

Of course the final contract packages will only be determined once planning permission for the tunnel is obtained, and at the moment there are potentially three routes. So the timing of the awards will depend on the progress the

£3.6bn

Forecasted cost of proposed
Thames Tunnel

£635M

Lee Tunnel project cost

"We had to make sure we had the right technical solution and the right cost"

Jim Otta, project director,
London Tideway Tunnels



Big spend: Construction is already underway on the Lee Tunnel Project

scheme makes through the planning system. The team is planning for construction to start in late 2013.

"It really depends on consultation and planning. We make our planning submission in 2012 and in mid-2013 we are going out for the main tunnel contract awards with the idea that they would start somewhere in late 2013 for completion in 2020," says Otta.

An interesting conundrum exists for consultants who must choose where to focus their efforts. For each of the tunnel contracts the Thames Tunnel team will require a reference designer, a role carried out by Aecom for the Lee Tunnel. Consultants may opt to continue in the frameworks, do the reference design, or alternatively work in consortiums with contractors on the tunnelling packages.

As for the contract types to be used, Otta says there is a range of options. "We tend to use NEC as it is what the market prefers for this type of project, but we will be using a suite of contracts for the enabling works. Some of those will be under the existing Thames Water contracts, which tend to have specific terms and conditions," he says.

Going into AMP5 Thames Water changed its approach to procurement, mainly driven by the new CEO Martin Baggs, who was formally appointed in March 2010. "Traditionally we awarded on a project by project basis, but when you look at the rest of the industry they

Thames Tunnel: the contracts

Contract	Anticipated award date
Enabling works – 50 to 60 packages	Contract bids begin mid-2012 and run through until 2013/2014
Thames Tunnel reference designers	Contract bids to begin 2012
Thames Tunnel main contracts – 4/5	Contract bids to begin 2013

"For a capital programme of this size, health and safety has to be at the top of the agenda at every meeting,"

Martin Baggs, chief executive officer, Thames Water

have moved on and more of a programme management approach so the whole aim of the new approach is to give contractors more flexibility to deliver," says Baggs.

What this means is that contractors are given design responsibility and therefore more freedom to deliver their schemes in the most efficient way.

As for the Thames Tunnel itself, this could also go down the NEC route, but Otta says this is not yet decided, nor is the final delivery structure. "There will be a whole range of new contracts

going forward, but in terms of final contract arrangements they have yet to be determined," says Baggs. "It is a possibility that our own capital delivery team will manage the construction phase, but it will need a much larger team than the smaller works. It is going to be significantly different to the construction of a sewage treatment works," he says. Until October 2009 the entire project was managed under the NEC project management contract executed by CH2M Hill in association with Halcrow. But as the Lee Tunnel entered the construction phase it was integrated into Thames Water's own capital delivery team's programme. "This aligns it with the resources and expertise inside Thames Water," says Otta.

The Thames Tunnel project team continues to manage the works with a 150 strong team, which includes staff from some of the 30 framework consultants. "We operate as an

integrated team pulling the best out of the framework partners," says Otta.

Thames Water is looking for several key attributes in potential future partners.

"We will be encouraging contractors to be good community partners and that involves trying to employ as many locals as they can, responding to the public and being open and honest about what is happening," says Otta.

Just as important is ensuring that health and safety is at the top of the agenda. "For a capital programme of this size, health and safety has to be at the top of the agenda at every meeting. The last thing that we want to see is any accidents. We want everyone involved to go home safe at the end of every day," says Baggs.

In March, Thames Water launched its AMP5 programme with a health and safety conference to emphasise the importance of this issue in the coming years. "We now have a joint health and safety board. I'd like to see that same approach develop further on project and programme delivery," says Baggs. Firms wishing to work with Thames Water in the future certainly have a lot to prove, from technical excellence, to health and safety, extensive community engagement and cost efficiency. But with investment of over £10bn within the next decade, the benefits for the industry will most definitely flow in both directions.

Working on the tunnels

Skills & jobs

Adrian Greeman

4000

Employees to work on project construction

600

Consultants to be engaged in design

The large-scale engineering required for the proposed Thames Tunnel means that it is set to take over from Crossrail as London's major civil engineering and tunnel employer.

The Thames Tunnel project is the largest waste water project in Europe in terms of capital expenditure and will demand labour and skills on a corresponding scale. An estimated 4,000 people are expected to be employed on the Lee and Thames Tunnel during its construction. This will be complemented by several hundred professionals, project managers and design engineers employed directly and in consultancies and specialist advisers.

"Most of those will not actually begin work until late 2014 but the design, investigation and preparation teams have already been gearing up," says Thames Tunnel project director Jim Otta. He comes from consultant CH2M HILL and has himself garnered experience on big tunnels from Singapore's deep sewer scheme to a similar project in Sydney.

But although there are a few more expatriates in the core management team, the majority are drawn locally or from 50 or so firms currently working on the scheme. These are primarily selected from the Thames Water's framework consultants.

"We currently have a team of 150 based in Paddington," says Otta "which has grown from an initial start-up group of around 25 starting out from offices in Richmond." He expects the central team to climb to around 600 during reference design of the various packages, including those drawn in by the various consultancy firms. Most of

the extra engineers will work from their own offices however.

The big demand is for skilled construction work and fortunately for the scheme, a pool of labour has built up recently in London in the past period. Terminal Five at Heathrow had a large workforce, and the Olympic Park has become a major employer. Some of that workforce at least is likely to move over to the Crossrail tunnel project which is picking up momentum with preparatory site work and design now underway.

That scheme will help with the core needs of the Thames Tunnel project by supplying experienced tunnelling workers. "There was some tunnelling for the Olympics but there is a greater amount on Crossrail," says Otta.

So much tunnelling is happening in fact, with major power tunnel projects underway for EDF and the National Grid, London Underground improvements, and other schemes, that a new training facility, the Tunnels & Underground Construction Academy is being formed. It was initiated by the Crossrail project but is supported either financially or with resources by contractors. The scheme got underway with £8M from Crossrail's London Mayoralty funding in 2009 and had an additional £5M boost from the previous Labour government's Learning & Skills Council in March this year.

Permanent premises are under construction near Ilford in the London Borough of Newham, in a facility which will include a simulated tunnel boring machine (TBM) environment and one for the back-up train. There will also be a sprayed concrete facility and classrooms and workshops. It opens in March 2011 and should put through at least 1,800 trainees each year, learning operational and safety skills.

That number may not be enough however, especially when the "churn" or turnover of workers is taken into account over the lifetime of a project, a factor which could multiply the numbers actually employed on the scheme by a factor of 10.

Otta says the project team has also been making visits into Europe to assess skills and availability overseas. "There is a small highly skilled workforce that tends to move to where the projects are," he says. Most recently the team had a look at a tunnel project underway in Amsterdam.

Certainly the European tunnelling and mining community could provide some of the very highly experienced workforce needed for the main sewer tunnel. But even so, as much as possible the aim is to recruit locally and the team plan to engage with the 14 boroughs along the route to see what the availability is for labour and the need for employment. From 2011 the Thames Tunnel will also offer work experience opportunities to at least 30 people from across the local boroughs each year to encourage awareness of opportunities in engineering.

"For the Lee Tunnel we have engaged with the local borough to identify available skills and we are trying to match the needs of our project with it," says Otta. "We want to engage the local employment market and identify the sets of skills that could come from various areas."

All this could be of major significance in the coming period. The economic downturn has created an ever greater need for employment and with the prospect of 4,000 site staff and hundreds of designers over the coming years, the Thames Tunnel project is set to give a significant boost to London's construction industry.

"Most of those will not actually begin work until late 2014 but the design, investigation and preparation teams have already been gearing up"

Jim Otta, project director, London Tideway Tunnels