CLEANING UP LONDON’S WASTE

A cofferdam was constructed on Blackfriars north foreshore so that a dry workspace could exist below the level of the River Thames. A drop shaft has been designed to intercept both the LL1 sewer located within the listed Bazalgette river wall and the existing Fleet sewer outfall, which is located under Arch 1 of the Blackfriars Bridge, to the new Tideway tunnel. The shaft is now excavated to a depth of 23 metres and when completed will be 53 metres deep (to invert level) with an internal diameter of 22 metres © Tideway

CLEANING UP LONDON’S WASTE

Tideway is an epic civil engineering project. At £3.8 billion, it is the UK’s largest ever water infrastructure undertaking. It includes 25 kilometres of large-diameter tunnel deep below the River Thames, with 23 huge shafts and a workforce of 4,000. To Tideway’s Chief Executive Officer, Andy Mitchell CBE FREng, it represents even more than that. At the halfway point of the project he spoke to Hugh Ferguson about his mission to reconnect Londoners with their great river.

The new Thames Tideway Tunnel will divert the millions of tonnes of raw sewage that flows into the Thames each year, and take it, by gravity, through a new tunnel to Beckton sewage works in east London. Construction started in 2016 with all work due to be completed in 2024. Tideway will supplement rather than replace Sir Joseph Bazalgette’s great network of sewers, completed in 1865 to combat the ‘Great Stink’ from the polluted Thames. Bazalgette estimated that the system, one of the greatest engineering achievements of the Victorian era, prevented around 13,000 deaths a year from cholera and other waterborne diseases.

Bazalgette’s system comprised 2,100 kilometres of brick-lined sewers feeding into 131 kilometres of large interceptor sewers running west to east, parallel to the river. They stretched from Abbey Mills pumping station (and then to Beckton) on the north side of the river, and to Crossness pumping station in the south. He built the tunnels to last – 150 years later, they are still in remarkably good condition, and can continue to transport most of London’s sewage for years to come.

Bazalgette also designed the tunnels so that, unlike some other cities’ sewerage systems, they carry both sewage and storm water run-off, thus avoiding the need to dig up London’s streets with sewage. Bazalgette’s ‘design population’ of four million has increased to nine million and much of London’s space has been transformed from open ground (which can absorb a great deal of rainwater) into buildings or ‘hard standing’.
with water draining directly and immediately into the sewers. Thirdly, a consequence of climate change is more erratic and extreme weather, so that the water engineer’s benchmark of a ‘hundred-year storm’ may now happen three times in five years.

The overflows, initially required about twice a year, are now used 60 times a year, and rising, tipping a staggering 40 million tonnes of sewage a year into the Thames. Worst of all, when heavy rain follows a long dry spell, when the system fills with sewage, the first flush into the Thames is concentrated sewage.

**WHAT TIDEWAY DOES**

Tideway’s job will be to capture all of this overflow and initially store it in its new network of shafts and tunnels, which together form a huge 1.6-million-cubic-metre underground reservoir, releasing it only as fast as the pumps and sewage works can cope. The main feature of the network is a huge 7.2-metre internal diameter tunnel (large enough to fit three double-decker buses) running 25 kilometres from Acton in the west, beneath the Thames through central London, and then veering north to Abbey Mills in the east. Some £1.1 billion of preliminary works have already been completed by Thames Water – including the Lee Tunnel, the easternmost (and deepest) section of tunnel, from Abbey Mills to Beckton.

The tunnel is deep, principally to avoid London’s myriad existing underground services: 30 metres in the west, with gravity flow to 66 metres at Abbey Mills (and deeper still at Beckton). Tideway has 23 sites for constructing its huge shafts that connect the overflows on either side of the river to the main tunnel. Some are also used for lowering and lifting the massive tunnel boring machines (TBMs).

Digging the Lee Tunnel required considerable technical innovation, in part as a testbed for the work on Tideway itself. These innovations included hydrofores (large crane-mounted drilling machines with twin counter-rotating cutters mounted within a steel frame) for sinking panels under bentonite slurry to create the primary concrete linings of shafts and the use of slip forming to build the inner concrete linings of the shafts. Another innovation was the use of fibre optic monitoring to check structural

Blackfriars Bridge work

Tideway’s most visible construction site is at Blackfriars, in the City of London overlooked by people crossing Blackfriars Bridge. It is also prompted a major redesign, undertaken to avoid the risk of damaging the Victorian gas mains. In the summer, this will result in the largest ever structure to be floated on the Thames in Central London.

A combined sewer overflow from the River Fleet discharges under the north arch of Blackfriars Bridge. The plan was to build a twin-walled, sheet-piled cofferdam (a watertight enclosure that enables construction below the waterline). Within that, new concrete culverts would transfer the flow into a new shaft some 200 metres upstream and down the shaft directly into the main Thames Tideway Tunnel.

Analysis showed that the cofferdam and particularly its heavy concrete tie-ins to the river wall, could cause movement to the wall and in turn movement to the Victorian gas mains. Damage to the gas mains could impact the gas supply to the City, while relocation of the gas main would delay the project and, worse, require closure of the Embankment – a major road artery – for several months. Instead, the engineers came up with an ingenious solution. Reducing the twin-walled cofferdam to the upstream end, where the shaft is being sunk, would reduce wall movements enough to avoid damaging the gas main at its critical point further downstream. A large dry dock, drained of water, replaces the central section of the planned cofferdam. Inside the cofferdam, the section of concrete culvert connecting to the Fleet CSO is being prefabricated. Meanwhile, a prepared bed is being created beneath the bridge arch back to the cofferdam using crushed rock cappled with a concrete mattress on which the culvert will sit.

Around May, the dry dock will be flooded to float the culvert. The downstream end of the dock will open and the culvert winched some 190 metres before lowering into position on its bed. It may be only a short float-out, but its massive size – 100 metres long, roughly seven metres square in section and weighing 3,500 tonnes – breaks all records.

Then the culvert will be connected to the CSO (with a temporary gate to allow sewage outfall to release downstream until Tideway is complete), and the dry dock will be re-sealed, locking in the upstream end of the new culvert. With the dock re-drained, the section of concrete culvert linking to the shaft will be built, resting on piles sunk below the Thames.

Finally, the whole Blackfriars site will be backfilled and landscaped to create a new public open space adjoining the river. The new space is Tideway’s largest and its proposed name is ‘Bazalgette Embankment’.

**Map Key**

- White lines = drain site
- Dark lines = sewer site
- Cross hatching = shaft
- Black = culvert
- Blue = CSO
- Yellow = site
- Green = new shaft
- Red = existing shaft
- Yellow = shaft
- Green = new shaft
- Blue = CSO
- Black = culvert
- Yellow = site
- Cross hatching = shaft
- Black = culvert
- Yellow = site
- Green = new shaft
- Blue = CSO
- Black = culvert
- Yellow = site
- Cross hatching = shaft
- Black = culvert
- Yellow = site
- Green = new shaft
- Blue = CSO
- Black = culvert
- Yellow = site
- Cross hatching = shaft
- Black = culvert
- Yellow = site
- Green = new shaft
- Blue = CSO
- Black = culvert
- Yellow = site
- Cross hatching = shaft
- Black = culvert
- Yellow = site
- Green = new shaft
- Blue = CSO

Blackfriars north foreshore. A 100-metre, 3,500-tonne interconnecting culvert will be the largest structure to pass along the Thames (left of the picture). It will be fitted into the central section above and then connected to the CSO drop shaft – below the crane on the left of the picture.
behaviour of the shafts during construction. The ‘Lee Tunnel’ also made widespread use of fibre-reinforced concrete in place of conventional reinforced concrete (see ‘Lee Tunnel article in Ingenia 63’). Most of these innovations have been carried over to the Tideway project. Additional innovations in the construction machine for placing the secondary, inner lining on the east section. This will be similar to the back-end of a TBM, erecting precast segments to form the tube. This promises to be faster, more economical, better quality, safer, and more environmentally-friendly than the conventional method of casting the concrete inner lining in situ. One of the hydrofoils has also been converted to electrical power, demonstrating the feasibility of converting much of the heavy plant on construction sites to electric power, with clear environmental advantages for the future. This electrification was made easier because some shafts already carried heavy duty electrical power for the TBM. The two TBMs on the east section are, as on the Lea Tunnel, slurry tunnelling machines. The other four, with different ground conditions, are air-pressure balance machines. Four TBMs are driving the main tunnel while the other two, smaller but still larger than any of the Crossrail tunnels, are digging connection tunnels. The longest of these tunnels, at five kilometres, due to start construction in June/ July, will carry overflow from the Greenwich pumping station to the main tunnel at Chambers Wharf in Bermondsey. Construction is currently at its peak with just over half of the main tunnel driven. Some shafts are completed; all have been started. Costs were revised upwards last year from the original target of £3.5 billion to £3.8 billion, due mainly to redesign of the works at King Edward Memorial Park in Tower Hamlets and Blackfriars – see Blackfriars Bridge work. As at Blackfriars, work at King Edward involves creating a cofferdam in the river to enable a shaft to be sunk and connected to a local CSO. As fill was being placed inside the steel sheet-pile cofferdam, the piles started to deflect outwards at the top. Further ground investigation revealed an unexpected layer of soft, weak ground near the surface, resulting in the tops of the piles not being properly anchored. Concrete piles were added where necessary to stabilise the cofferdam, enabling backfilling to be completed, but two problems remained: the layer was predicted to settle over time by up to one metre, and the diaphragm walls for the permanent works could not be sunk through the weak ground. The solution was ‘deep soil mixing’. Some 1,500 tubes were sunk up to 13 metres deep, inside which augers were used to stir in a cement/stabiliser.

**LESSONS LEARNED**

Tideway itself has demonstrated how the river can be reimagined as a transport artery. Its barges bring most of the materials into the sites (using offsite construction where possible) and have carried away 95% of the nearly one million tonnes of tunnelling spoil. This represents 130,000 lorry journeys, avoiding, making the barges the largest users of the central London heavy plant on record.

With most of the high-risk work now over, Andy Mitchell CBE FRIng, Tideway’s Chief Executive Officer, is confident that completion of tunnelling – by 2022 – should be free of unpleasant surprises, as will the subsequent commissioning phase. But he considers the positioning of river will last long after Tideway is opened and he has moved on. London’s population is still increasing, more ground is being covered with hard surfaces, and climate changes will make heavy storms more frequent. Even on opening, Tideway will not be able to cope with the strongest storms: it has its own CSOs, which will be used about twice a year, though the sewage released will be much more diluted than it has its own CSOs, which will be used about twice a year, though the sewage released will be much more diluted than it...