Hampton Advanced WTW

three steps to ensure resilience

by
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Thames Water's Hampton Water Treatment Works (WTW), in west London, is part of the city's critical infrastructure. The UK's largest WTW Hampton provides a safe, dependable water supply for one third of London's inhabitants; 3 million people. Between June 2006 and April 2010 Thames Water undertook a trio of large-scale projects with the goals of ensuring resilience of supply and enhancing the WTW's operational efficiency. The projects were wide in scope: refurbishing 32 rapid gravity filters (RGFs); replacing the disinfection system; constructing a 38m-deep pump-out shaft connected to the London Ring Main.

Hampton, the UK's largest WTW, provides a safe, dependable water supply for 3 million people *Courtesy of Black & Veatch Ltd*

In an indication of the importance of the enhancements at Hampton, and the skill with which they were executed, the projects received three Institution of Civil Engineers (ICE) awards. The projects' diverse nature meant Thames Water worked with a number of consulting and contracting partners. Only one company however, Black & Veatch, played a major role in all three projects; providing both professional services and construction expertise.

In both solution and execution, sustainability was at the heart of the RGF project; a fact recognised by the ICE in 2009 when the institution awarded the project both the ICE London Merit Award for Conservation and the ICE London Merit Award for the Greatest Contribution to London.

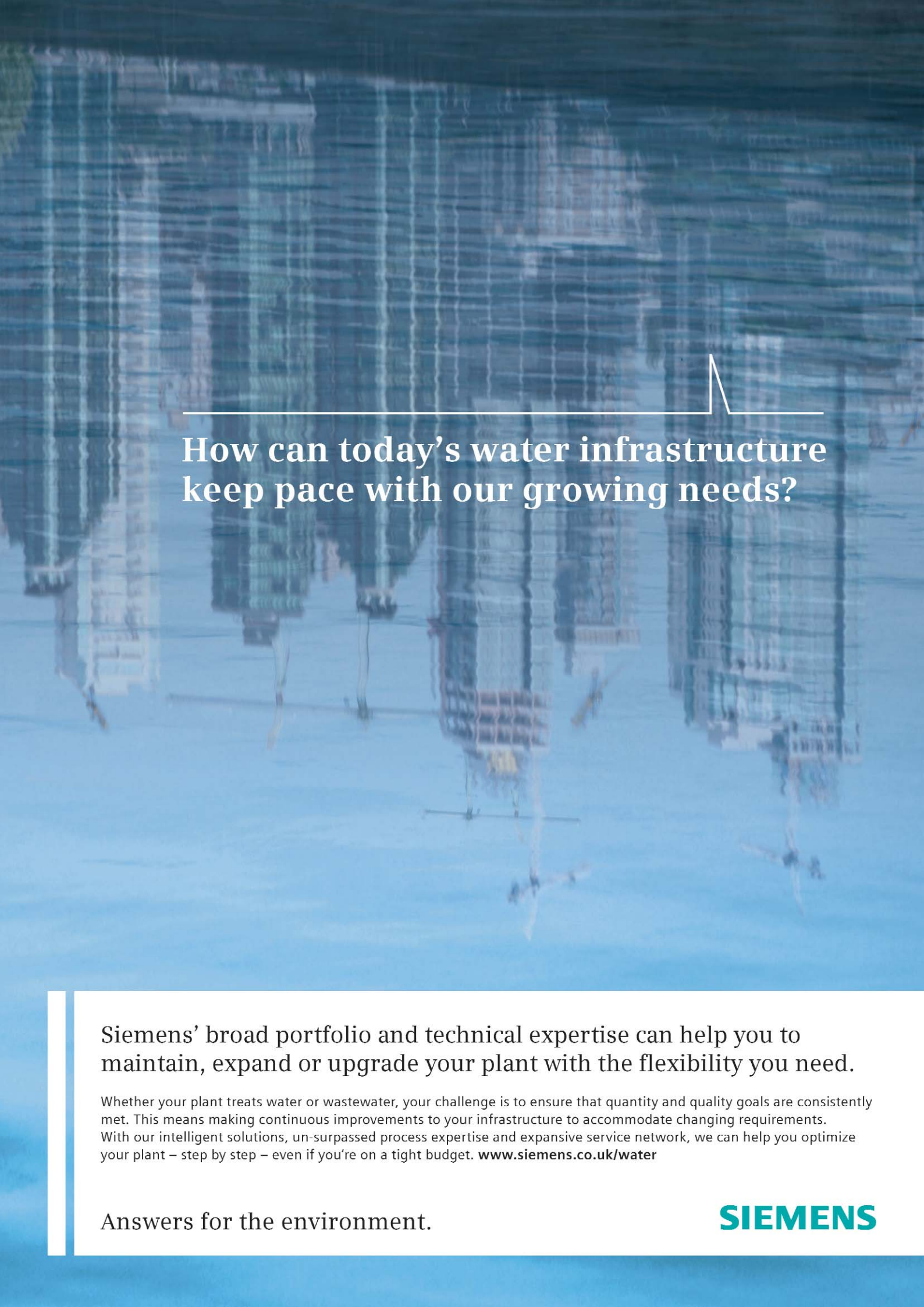
Rapid gravity filters (RGFs)

The 32 RGFs are critical to Hampton's 800 Ml/d output; and a number of factors led Thames Water to assess ways of ensuring the WTW's RGF performance remained at the level desired.

Both the mechanical and electrical (M&E) and control systems were nearing the end of their asset life; and the need for media replacement was ongoing. In recent years the algal burden in the storage reservoirs that feed Hampton resulted in worsening raw water quality which had a significant impact on the RGFs' performance.

A solution was required that would improve output during periods of poor raw water quality, but would not require significant reductions of output during execution. Thames Water originally considered construction of a new RGF block. The cost was estimated at £130 million and the project would have had a significant environmental impact.

Thames Water then investigated the possibility of upgrading and remodelling the existing RGF block. After undertaking numerous studies, producing concept designs and inviting proposals addressing concept design ratification, buildability and methodology, Thames Water selected Black & Veatch to provide and deliver the remodelling solution. The total cost of the refurbishment project was estimated at £27 million.



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Phase 1

The project was executed in two phases. Year one was dedicated to the enabling work required to allow the remodelled filters to operate. This offline preparatory work included the construction of a 1,700m^3 reinforced concrete backwash tank within an existing 120-year old covered reservoir. Black & Veatch suggested this solution rather than the original compliant bid of refurbishing the existing elevated gravity-feed backwash tank. The benefits of this were numerous:

- The existing cast iron tank was 70 years old. It was elevated 13m above the filter block in a confined location. Refurbishment was considered very difficult and potentially hazardous;
- There would have been increased risk to the process had problems arisen during refurbishment of the cast iron tank;
- There were doubts about the long-term integrity of the tank and whether it would remain serviceable for the additional 20 years specified;
- A fully pumped low-head level system with a new tank rather than a combined pumped/gravity system to an elevated tank is ultimately more robust in terms of control.

In the filter block new air blowers, backwash pumps, waste pumps and pipelines were installed as well as new electrical panels and a new control system. These were all commissioned alongside the existing equipment.

Phase 2

With enabling complete the second phase of the project saw the sequential remodelling of all 32 filters. Each filter was stripped to its concrete shell, the central reinforced concrete wall was re-built and the shell was fitted with modern filtration equipment. All of the actuated valves and penstocks, as well as flowmeters and instruments, were replaced and re-cabled.

The 32 filters were remodelled in sequence, allowing customers' supplies to remain unaffected by the project *Courtesy of Black & Veatch Ltd*

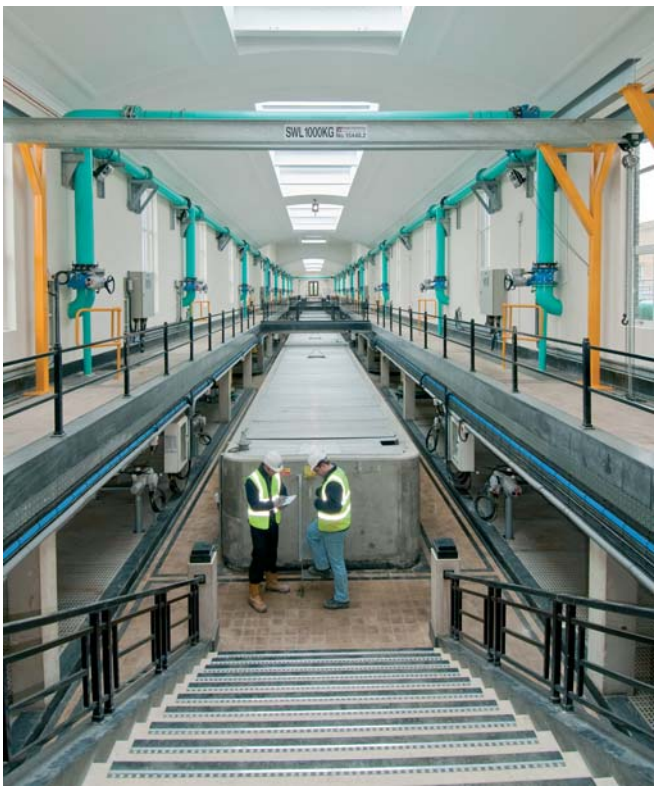
A key success during this phase of the project was the temporary connection of the existing and new control systems. The establishment of a hybrid control system allowed both remodelled and existing filters to operate as one system giving the WTW's operations team the opportunity to gain confidence in the new system while being able to revert to the old one.

Given the importance of Hampton it was important the WTW's operations team had trust and confidence in the refurbishment team's ability to undertake with the project without affecting supplies. This was achieved through detailed planning, coupled with extensive communication and liaison. A pre-agreed and regularly updated shutdown schedule was produced. This augmented the main programme and assisted with the management of the significant number of shutdowns and process inhibits without affecting the output of the plant.

An illustration of Thames Water's growing confidence in the Black & Veatch team was the steady increase in the number of filters operators felt confident to release for refurbishment at the same time. The result of this was that the project was finished six months ahead of schedule, and £1.4m under budget.

The success of the refurbishment project was demonstrated in September 2008 when a large Melosira algal bloom occurred in several of Hampton's supply reservoirs and was drawn into the WTW. Prior to the project these conditions could have had potentially adverse effect upon the WTW's performance. The remodelled filter run-times exceeded expectations against the design figures, however, as the upgraded wash system prevented algal fouling of the media bed and ensured effective and sustained cleaning.

The decision to refurbish RGFs rather than opt for new-build greatly reduced the project's environmental impact. In fact ensuring the project was executed in a sustainable manner was a significant feature of Black & Veatch's approach. Disused clay core reservoirs were brought back into service for backwash wastewater attenuation, and part of a 130-year old concrete reservoir was re-used in the construction of a new backwash tank. In addition a 250m section of disused 36" main was turned into a conduit for a new waste pipeline.



During refurbishment a hybrid control system allowed both remodelled and existing filters to operate as one system *Courtesy of Black & Veatch Ltd*

The original filter block was retained, cutting cost and environmental impact, pipework and control equipment was all replaced *Courtesy of Black & Veatch Ltd*

Other aspects of the work which reduced the project's environmental impact included harvesting and chipping of 14km of unplasticised polyvinyl chloride piping and 92,000 polypropylene nozzles for reuse in the plastics industry and 800-tonnes of waste concrete that was crushed and reused as hardcore in construction. 14,000-tonnes of existing media was reused as pipe bedding.

In presenting the Hampton team with their ICE London Merit Awards Robert Sharpe, chair of the judging panel commented, "The recipients … have excelled in delivering projects which combine a commitment to innovation, creativity and social value with a culture of safety and sustainability."

The disinfection system

Replacing the disinfection system was the second project Black & Veatch undertook in support of Thames Water's programme to optimise efficiency and increase resilience of supply at Hampton.

As with the RGF refurbishment one of most significant challenges for the disinfection system replacement project was the interface with the live works. Both construction and commissioning of the new disinfection system, however, were achieved without disruption of supply to Thames Water's customers. Achieving this not inconsiderable feat required close cooperation with Thames Water's operations and production planners to carry out risk assessments for the supply to the whole of London.

Thames Water Engineering undertook the outline design for the new disinfection system; detail design and construction support was carried out by Black & Veatch. Costain, the Principal Contractor, began site work in December 2006. The £18 million project was completed in September 2009.

The existing disinfection system comprised chlorination, contact, partial decolourisation and terminal ammonisation; drivers for the system's replacement were threefold. Due to their age the chlorinators and sulphonators had to be replaced to ensure a satisfactory level of serviceability. Changes to water quality regulations meant a more refined control system was required for the ammoniation system. The upper tier of the Control of Major Accident Hazards (COMAH) applied to Hampton due to the quantities of liquid chlorine, sulphur dioxide and ammonia stored on site. Despite the increased cost Thames decided the health and safety benefits of switching from liquid to gas disinfection chemicals, which meant the works was no longer subject to COMAH regulations, was justified.

New process

The new disinfection process utilises chemicals delivered as liquors in place of liquefied gases. The points of application are in similar locations to the old system but subject to improvements to the dosing, mixing and sampling arrangements. This project also provided a facility for chlorinating the water for the RGF backwash.

The new chemical requirement is sodium hypochlorite liquor [15% by weight as Cl_2], sodium bisulphite liquor [20% by weight as SO_2] and ammonium sulphate liquor [40% by weight].

Sodium hypochlorite is metered by peristaltic pumps and dispensed by vacuum eductors driven by motive water supplies; while sodium bisulphite and ammonium sulphate is dosed by piston-hydraulic diaphragm pumps into carrier water streams.

Dosing of all chemicals is flow paced. Existing flow meters have been utilised for primary dose control and secondary dose control to the London Ring Main but new multi-path ultrasonic flow sensors and cables have been installed for secondary dose control in the two 78" outlet conduits from the contact tank to the high-lift pumping station.

A more resilient supply of motive water has been provided by dual redundant pumps from the high lift suction manifold with a full backup capability from a high pressure main. The sodium hypochlorite motive water supplies are softened by base exchange. The ion exchange resin will be regenerated using brine obtained from salt saturators. The carrier water for sodium bisulphite and ammonium sulphate dosing does not require softening.

To ensure mixing in the 60" diameter low-lift pumping conduits achieves the required 0.05 coefficient of variation (CoV) an additional array of mixers were installed in each conduit.

New mixing arrays have also been installed in each 78" outlet conduit between the off-takes to the new London Ring Main pump-out shaft and the off-takes to the existing London Ring Main connection, shaft no. 3. These shorten the previous loop times and ensure mixing prior to the flow division at the off-takes to shaft no. 3. Mixing in the 1.8m diameter main that feeds the London Ring Main via the new pump-out shaft will be by turbulent diffusion in the pipeline to the shaft and the down-pipe within the shaft.

Water sample delivery systems in each process stream are duplicated where they supply critical instruments including triple-validated chlorine residual analysers.

New facilities include a tank farm for storage of the chemicals and salt saturators. Sodium hypochlorite is chilled to restrict the degradation. A new chemical building, with a separate room for each chemical, houses water softening plant and chemical dosing plant. New analysers have a dedicated sample room in the new building. There is also a control room housing the motor control centre and PLCs that manage the new disinfection plant.

Approximately 5,000m of chemical dosing and water sample pipes were laid in new concrete troughs to the points of application.

The 38-metre deep pump-out shaft permits pumping directly from the London Ring Main into the local distribution network *Courtesy of Black & Veatch Ltd*

A high volume of existing buried services added to the challenge of pump-out shaft connections *Courtesy of Black & Veatch Ltd*

The pump-out shaft

The most recent element of Black & Veatch's support for Thames Water's enhancements of Hampton is the new pump-out shaft that connects the WTW with the London Ring Main. The work, due for completion in early summer 2010, has already received a special award in the ICE's London Civil Engineering Awards for its role in a suite of projects to expand the ring main's capacity.

The aim of the pump-out shaft is to improve the resilience of supply for people who receive water directly from Hampton. Currently 300,000 people take their supply from local network mains fed by the WTW's existing high-lift pumping station. Should problems develop with the pumping station those supplies could be affected.

To prevent this the new pump-out shaft houses a dry well high-lift pumping station to replace the existing high-lift pumping station and permit pumping directly from the London Ring Main into the local distribution network. In addition the shaft will increase potential transfer from Hampton to the ring main. The pump-out shaft is capable of transferring more than 400Ml/d of water into local supply.

Black & Veatch's role in the pump-out shaft project began with detailed design encompassing design moderation through value management, value engineering, formal design reviews and Health & Safety design reviews. Civil construction was by Costain; this was followed by Black & Veatch's MEICA fit-out of the 15-metre dia., 38-metre deep shaft and connection to the local supply network and the London Ring Main. Within the shaft the MEICA contract included pipework, a surge column, pumps, valves, electrical and ICA equipment, ventilation, monitoring and access facilities.

The network connections proved among the most challenging aspects of the project. The tendered specification required relining the existing mains manifold. This necessitated confined space working at a depth of 5m, beneath live services. Promoted by concerns regarding safety and cost the detailed design review proposed replacing the manifold.

Confined space working at depth, with a live main above, also led to a design review of the tendered specification proposal that a section of main be relaid from the existing depth of 5m to a new depth of 8m. Remodelling led to the incorporation of a vacuum rather than gravity system; with a cost saving in the region £650,000.

Further cost savings were achieved by revising the original plan to house both high and low voltage switchgear in a listed Victorian structure on the site. An alternative, easier to adapt location, was identified in a more accessible, unlisted building.

The project team anticipates cost savings in the region of £1.6 million will be achieved. This has been possible to a significant degree because of the nature of the Black & Veatch team. A wide range of engineering disciplines - M&E, design, procurement and civils - from a single business have been working together on the scheme from its early phases through to commissioning. This results in a close and ongoing dialogue to ensure detailed designs deliver the outputs desired, while remaining safe and cost-effective to build.

As with the RGF and disinfection work the pump-out shaft project required close liaison between the project team and Thames Water's operations staff. Because the project necessitates establishing connections with eight live mains, including the London Ring Main and several local network mains, establishing good communications and trust between the project team and the utility's network personnel has been important.

The pump-out shaft project has achieved all water into supply beneficial dates, and is forecast to achieve final handover ahead of schedule.

All of the projects described in this article have been delivered on or ahead of schedule, and all have yielded savings for Thames Water; more than £108 million compared to one of the earlier solutions in the case of the RGF project. More importantly water supplies to 3 million Thames Water customers have remained unaffected during four years of complex, challenging engineering projects; projects which will help ensure the quality and quantity of supplies for several decades.

Note: ***The editor and publishers thank Andrew Greenway, Contracts Manager, Black & Veatch Ltd and Neville Cowton, Technical Director, Black & Veatch Ltd for preparing the above article.***■

One arm of a starfish can regenerate into a whole new organism as long as a portion of the central disk is attached.

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