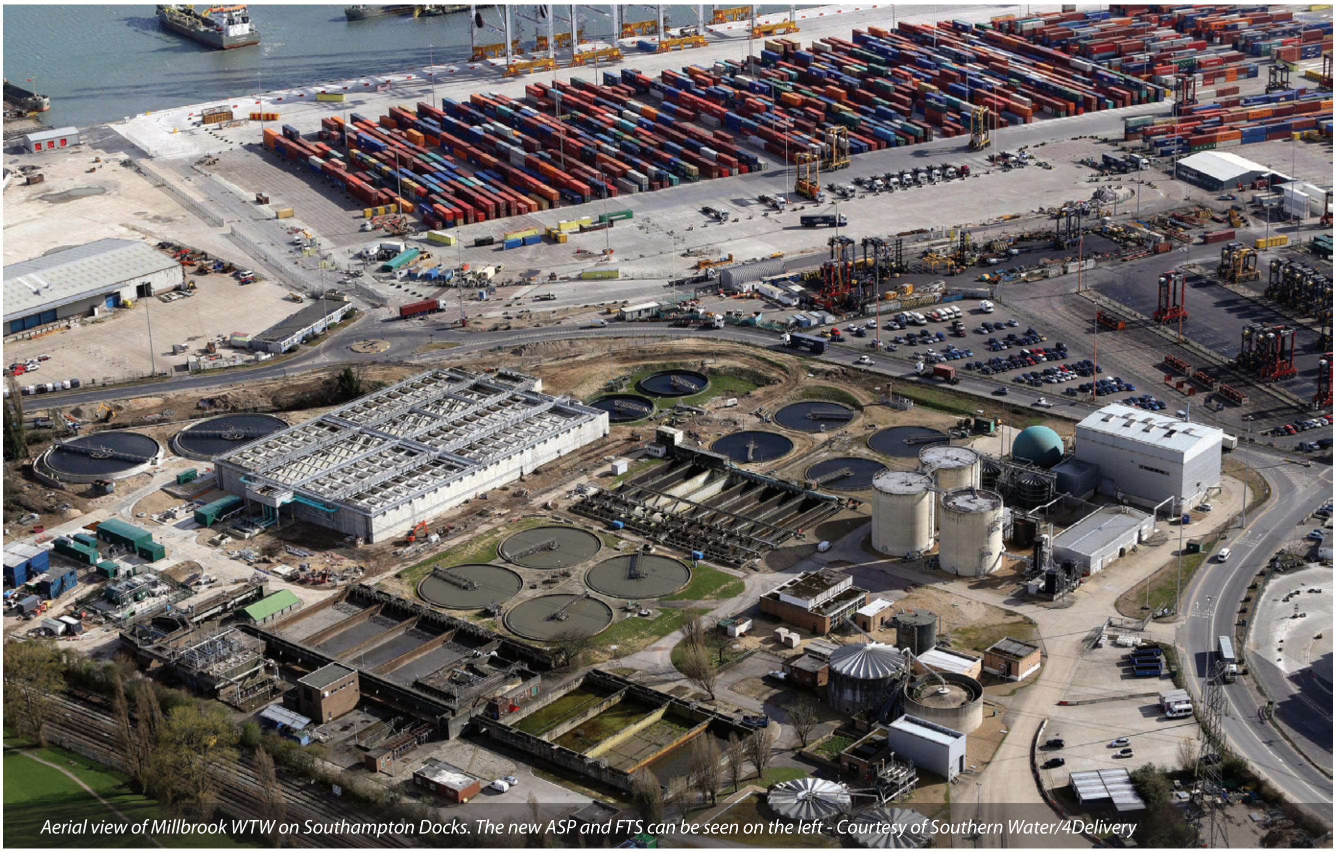
Millbrook WwTW

overcoming challenging site constraints through careful construction planning to deliver a robust process solution and reduced nutrient emissions

by Martin Tresidder & Paul White MSc

When originally constructed in the 1930s, Millbrook WwTW comprised only of a series of rectangular storm tanks. Upgrades were undertaken in the 1960s and 1990s with the addition of a carbonaceous activated sludge plant (ASP) to provide secondary treatment. The site receives wastewater from the Southampton area with a current population equivalent (PE) of approximately 135,000. Located within the Western Docks, the site is sized to treat a Flow to Full Treatment (FFT) of 850l/s before discharging into the River Test estuary.



Aerial view of Millbrook WTW on Southampton Docks. The new ASP and FTS can be seen on the left - Courtesy of Southern Water/4Delivery

Project need

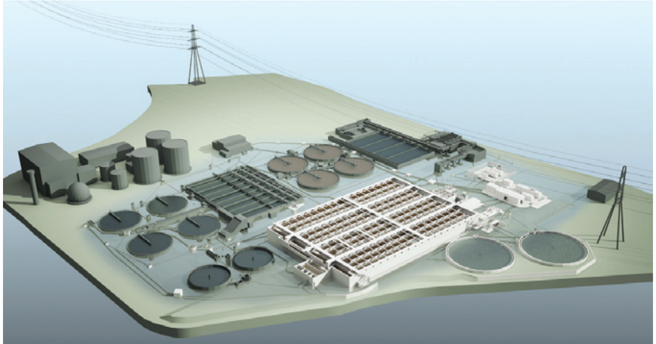
As part of the National Environmental Programme (NEP) the Environment Agency has introduced a new discharge permit condition of 10mg/l of Total Nitrogen (TN). This satisfies the requirements of the Habitats Directive. The existing ASP was not designed to produce effluent which meets this standard, thus a significant upgrade to the works was identified in Southern Water's AMP5 investment plan. This gave rise to the £25m capital works scheme currently being delivered by 4Delivery and is scheduled for completion in September 2014.

The process solution

The treatment technology selected to provide the TN removal function was a 4-stage BARDENPHO ASP process, which differs from conventional carbonaceous ASP in its ability to remove nitrogen through denitrification to produce nitrogen gas. This is achieved through two alternating stages of anoxic and aerated zones. Nitrified liquors are returned to the upstream of the process where anoxic conditions and influent carbon enables denitrification to occur. Further reduction of residual nitrogen occurs in the secondary anoxic zone, but due to depletion of carbon in the mixed liquor (BOD/COD reduction), an external source is provided in the form of methanol dosing. For removal of biomass from the secondary effluent, an additional 80% of settlement tank capacity (surface area) was provided to ensure clarity of the final effluent.

Sizing of the BARDENPHO ASP process had to consider the projected PE figure of 155,000 (2020/21 horizon). Further consideration was given to the high-strength centrate and filtrate liquors generated from the on-site Sludge Treatment Centre (STC) that are returned into the wastewater process. Analysis showed that in terms of ammonia concentration, these combined liquors contributed approximately 125,000 PE in addition to the crude influent load.

A detailed optioneering exercise was carried out to select the most efficient way of treating this non-crude influent. A dedicated high-rate treatment process was considered to treat the liquors at source; however a whole life cost assessment showed that the most cost-effective and lowest carbon approach was to combine the liquors with the crude load and treat in the BARDENPHO process. This meant that the site would comprise of a simple, robust process with an overall lower number of assets, thus representing best-value for the client. This would also allow replacement of the existing, shallow ASP tanks. However, accommodating 33,500m^3 of



A detailed 3D model of the existing site was developed together with the proposed new works. This helped the team to plan and manage asset interfaces; in particular buried services. The model was also used to assess feasibility of the construction sequence given significant site constraints. Courtesy of Southern Water/4Delivery

New pipework - Courtesy of Southern Water/4Delivery

A new final settlement tank, under construction, spring 2012 Courtesy of Southern Water/4Delivery

process volume into this constrained site presented a significant design challenge.

Design

The design involved the development of a detailed 3D model, including that of the existing site and including below ground services. This was particularly useful for planning new pipeline routes and avoiding clashes. Modelling of new structural assets was instrumental in evaluating the construction sequence and phasing activities. By including external constraints such as the overhead HV cables, the model was also used to help plan safe methods of working.

A significant proportion of the overall design effort was focused on the optimum civil and structural arrangement for the large BARDENPHO ASP structure. Physical constraints included: an irregularly-shaped area of available footprint; a shallow groundwater table; poor ground strength (made ground); overhead HV cables; existing buried services. The physical geometry of the structure had to satisfy all these aspects whilst also being in accordance with the governing process design. To minimise the footprint, the process depth was set at 7m which is at the upper limit for typical ASP plants. This still entailed a structure 92m long and 62m wide. A total of 4 (No.) lanes were selected to provide operational flexibility and arranged in a 3-pass serpentine arrangement to ensure optimum plug-flow conditions.

As the structure was being designed for construction in reinforced concrete (RC), great effort was made to ensure an efficient design. The draft outline design involved a simple 700mm thick base on a precast concrete (PCC) piled foundation and 500-700mm thick walls. A coordinated approach was applied for development of the design, involving group discussion between the teams, civil, structural and geotechnical engineers. Early contractor involvement was key to these discussions.

These design workshops culminated in agreement on the following design approach:

i. Treatment of the made ground layers using vibro-stone columns. As well as being more cost effective than PCC piles, the technique is far less noisy. However, their use required the structural design to allow for up to 50mm of potential settlement.
ii. To avoid excessively thick walls, the structural design adopted a propped cantilever system with tie-beams between opposing walls at coping level. This meant that the 7.5m high walls could taper in thickness from 500 to 350mm, as the beams help resist the moment generated in the walls by the hydrostatic load.
iii. The base slab design was also more efficient as a result of adopting this solution, being only 300mm thick and 500 mm thick below the main walls.

Use of the innovative propped cantilever design helped save a significant volume of in situ concrete. Settlement was anticipated but the structure was designed to withstand the effects.

The tie beams were designed to make installation as quick and simple as possible, without need for connection into the wall reinforcement. For longevity, given the coastal environment of the site, the beams were designed in RC and included overhangs at each end for a simple hooked connection. These specialist items were fabricated by Banagher Precast Concrete in Ireland. In total, 64 (No.) 16 m long beams were made, each weighing 8 tonnes.

Construction

To generate sufficient space for the new BARDENPHO ASP, 2 (No.) existing primary settlement tanks and an ASP structure had to be demolished. However, the site had to maintain consent compliance throughout construction. It was decided to adopt a phased approach to construction of the new RC tank. The overall sequence was as follows:

i. Clear the greenfield area, treat the ground and construct 2 (No.) of the 4 (No.) new ASP lanes and 2 (No.) new 33m diameter conical final settlement tanks.
ii. Install all associated process pipework, mechanical and electrical plant to enable commissioning for carbonaceous treatment of a proportion of FFT.
iii. The additional process capacity then allows the redundant assets to be decommissioned and demolished.
iv. The remaining 2 (No.) ASP lanes are constructed in the newly available space.
v. The full structure is commissioned for full biological nutrient removal (BNR), enabling decommissioning of the other ASP. By phasing the construction in this way, the existing site was given a significant boost in terms of available treatment capacity during construction.

During construction, over 10,000m^3 of concrete has been placed, as well as 1500 tonnes of reinforcement. Over 1.5km of new pipelines up to 1.2m in diameter have been laid together with over 3km of cable ducts. In addition, over 100 tonne of new above-ground steelwork has been installed. All of this work has been undertaken in a working site with limited space and overhead HV cables.

The use of crawler cranes was the primary method employed to enable construction of the major structures, with further mobile cranes of various sizes in support.

Installation of the propped cantilever tie beams for the new ASP structure was particularly challenging due to the site logistics and involved the use of a 350 tonne mobile crane to enable lifting of the 8 tonne beams into position.

Health, safety and the environment

The following summarises the achievements during construction:

- Zero reportable accidents or environmental incidents to date during 250,000 man-hours worked over 30 months.
- Zero compliance issues throughout construction and commissioning.
- Over 90% of waste materials either reused on site or recycled off site.

Summary/conclusion

The Millbrook WwTW upgrade is one of the largest capital non-infrastructure schemes being delivered on behalf of Southern Water during AMP5. 4Delivery brought knowledge and expertise from its joint venture partners Veolia Water, Costain and MWH. Delivery of the scheme was a challenge given the scale of the new infrastructure required and myriad of physical constraints.

Innovation in the design was required to overcome these, helped by a collaborative approach with early input from the construction team. This avoided need for revisions on the ground. The delivery team meticulously planned the 2-staged schedule to ensure construction could proceed with the utmost heed to health and safety, existing plant operation and the environment.

The plant is programmed to become fully operational by September when effluent discharge will see a reduction in nutrient input into the Solent. This forms part of a regional environmental programme that safeguards the quality of local waters for the benefit and enjoyment of local communities.

The Editor & Publishers would like to thank Martin Tresidder, Construction Manager with 4Delivery, and Paul White, Civil Engineer with 4Delivery, for providing the above article for publication.

The completed ASP, spring 2014 - Courtesy of Southern Water/4Delivery

The completed ASP, which is now taking flows - Courtesy of Southern Water/4Delivery