Liverpool WwTW

installation of CASS SBR plant for the secondary treatment process that will keep the River Mersey clean

by Jeff Constantine & Nicola Henderson

The United Utilities flagship CASS SBR (Cyclic Activated Sludge System Sequencing Batch Reactor), constructed in the old Wellington Dock heritage site, moves into its fourth, and final year of build. The £200 million Liverpool WwTW upgrade is a state-of-the-art works to improve the quality of the water in the River Mersey. The project is part of the £3.6 billion being invested by United Utilities in AMP5 across the North West, to improve water quality and the environment. This year the project has moved on, with the completion of main construction works and commencement of process commissioning. To date, over 11 million cubic meters of wastewater has been treated in the new plant.

Covers fitted to the upper storey basins improve visual impact and reduce surface water turbulence - Courtesy of United Utilities

'One Team One Aim'

GCA JV, a joint venture between GallifordTry, Costain and Atkins, working in partnership with United Utilities, selected the CASS SBR technology as the secondary treatment process for Liverpool. The CASS technology was selected due to it being a robust, proven and cost effective treatment process.

United Utilities recognised that to successfully deliver this complex project, a different approach was required. A *'One Team One Aim'* initiative was developed, lead by Lorne Large - United Utilities Capital Programme Manager. The team was a special partnership of client, contractor and supply chain, working together to ensure the successful design and build of the new works. All the team are located at the Liverpool site to ensure close collaboration, ownership of the problems and establish a commitment that the team would 'fix' Liverpool together. AECOM's CASS SBR experts were key members of the team, designing the process to treat the wastewater from almost 1 million people.

The key design strategy for the plant was set by United Utilities, and AECOM's technical experts adapted and enhanced the CASS design to suit the project and to meet United Utilities aspirations, bringing innovations to reduce CAPEX, OPEX and programme, improve H&S and buildability, and provide operational flexibility. For example, a high-efficiency aeration system reduces the power required to treat the wastewater, reducing the carbon footprint.

Following the successful performance of the Liverpool team, United Utilities intend to adopt the collaborative one team ethos to spread the 'Liverpool magic' across their upcoming AMP6 major projects.

Minimising impact

Incoming wastewater flows of up to 365,000m^3/d (FFT) flow through the existing inlet works and newly refurbished primary settlement tanks at the existing Sandon Dock treatment works, and then flow to the adjacent Wellington Dock site where the flow is pumped and equally distributed between the 16 (No.) CASS basins.

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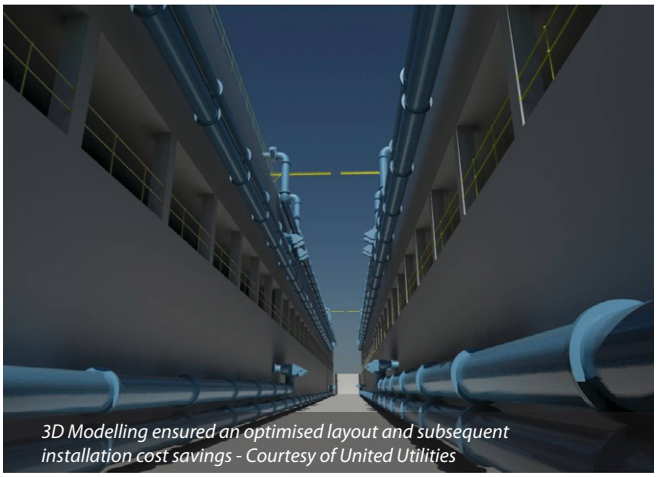
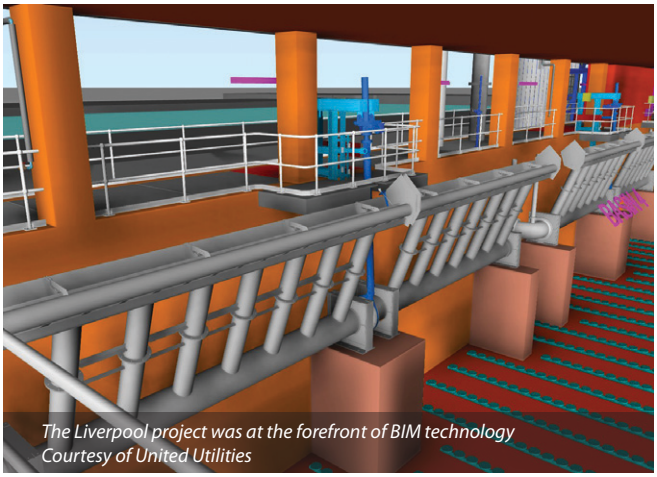
Covers fitted to the upper storey basins improve visual impact and reduce surface water turbulence - Courtesy of United Utilities



3D Modelling ensured an optimised layout and subsequent installation cost savings - Courtesy of United Utilities



The Liverpool project was at the forefront of BIM technology Courtesy of United Utilities

2 (No.) 316SS decanters per CASS SBR basin - Courtesy of United Utilities

Waste sludge (SAS) from the SBR is mixed with primary sludge and thickened in a new purpose built sludge thickening facility on the Wellington Dock site.

The new 16 (No.) basin plant is built within a redundant dock (Wellington Dock) in a world heritage site buffer zone. The plant is being built on two storeys; it is the first multi storey SBR plant and largest in the UK. By stacking in this way, the plant fits within the limited footprint available at Wellington Dock, minimizing the environmental impact on the surrounding area and minimising the impact on the adjacent world heritage site.

Covers are fitted to the upper level to further minimize the visual impact and to prevent the negative effects of the wind on the basin water surface. The innovative design also enables the plant to be decommissioned and taken down at the end of its asset life without damage to the structure of the old dock. The treated water leaving the new plant will be cleaner and greener helping the continued rejuvenation of the River Mersey and ensuring it meets strict European Standards for water quality.

The forefront of BIM (building information modeling) technology

The use of BIM was relatively new in the water industry at the start of the project, but United Utilities recognised it would be invaluable in ensuring the success of this and future projects in AMP6. They therefore pioneered its use, ensuring the Liverpool project was at the forefront of BIM technology, setting the standards for AMP6.

The 3D model of the new facility was created at the outset as a construction and operational model. Design input into the 3D model was undertaken by all the sub-contract design teams and equipment manufacturers, resulting in a truly accurate model that has been used to carry out operator training and HAZOP analysis as well as clash detection. The technology was also used for construction sequencing and planning, and was further developed, using personal iPads with augmented reality and real-time O&M manuals and maintenance management.

An optimised and flexible process solution

To fit an 800,000 PE, secondary treatment plant within the limited existing footprint of the Wellington Dock site left a limited range of treatment options available. A two-storey, 16 (No.) basin CASS SBR was selected to give the lowest whole life cost solution.

Early pilot plant work was undertaken by United Utilities to establish that the SBR treatment process would meet the consent requirements at Liverpool (25mg/l BOD, 125mg/l COD) and to determine the required design parameters. The wastewater contains a high proportion of trade waste and the pilot plant showed that a relative high aerated age of 12 days was required to treat the wastewater due to inhibitory compounds present in the wastewater.

The SBR layout was developed with 8 (No.) basins on the upper deck and 8 (No.) basins on the lower deck with a central gallery. The layout of each basin is common to all 16 (No.) basins.

The plant is sized to treat flow to full treatment (356,000m^3/d) with 14 (No.) of the 16 (No.) basins in operation. The individual basins are configured into 8 (No.) hydraulically linked pairs (process units) which all operate on a fixed four-hour cycle. This simplifies the control system and makes the plant simple to operate. The hydraulically linked basins fill through a common 'Y' chamber fitted with submerged penstocks which ensures that the water level is equal across the paired basins. This is critical for equal process air distribution.

The CASS SBRs at Liverpool are designed to operate either in *batch fill* (i.e. no fill during the decant phase) or *continuous fill* cycles, and can be switched into either mode at the SCADA interface.

The basins operate in a four-hour cycle comprising two hours of aeration, one hour of settle and one hour of decant. The basins are continuously filled during the aeration and settle phases. The treated effluent is removed during the decant phase down to a set bottom water level via a decanting mechanism. The basins can also be filled during decant if required.

The process units are aerated for 50% of the cycle time allowing two process units to share the same blower, as shown below.

Basin	Hour 1	Hour 2	Hour 3	Hour 4
1 & 2	Fill - Aerate	Fill - Aerate	Fill - Settle	Fill - Decant
3 & 4	Fill - Settle	Fill - Decant	Fill - Aerate	Fill - Aerate
5 & 6	Fill - Aerate	Fill - Aerate	Fill - Settle	Fill - Decant
7 & 8	Fill - Settle	Fill - Decant	Fill - Aerate	Fill - Aerate
9 &10	Fill - Aerate	Fill - Aerate	Fill - Settle	Fill - Decant
11 &12	Fill - Settle	Fill - Decant	Fill - Aerate	Fill - Aerate
13 &14	Fill - Aerate	Fill - Aerate	Fill - Settle	Fill - Decant
15 &16	Fill - Settle	Fill - Decant	Fill - Aerate	Fill - Aerate

Table 1 – CASS SBR cycle times

Blowers configured for maximum efficiency

A total of four sets of blowers are installed, each set has an individual header pipe feeding a total of two process units. This allows efficient control of dissolved oxygen.

To achieve lowest whole life cost, centrifugal blowers were selected at Liverpool, configured in four dedicated sets. To achieve lowest energy costs and also provide sufficient turndown capability, each set contains two sizes (2 x 16,000m^3/hour and 1 x 8,000m^3/hour) of blowers.

During the aeration phase, the blowers are controlled at achieve a pre-set dissolved oxygen profile with manually adjustable set points. This system, together with the combination of different blower sizes in each set, enables significant power savings to be made through optimised energy usage.

A robust and low maintenance decanter

One of the key components of an SBR system is its decanting mechanism. The CASS decanter is very robust and easy to maintain with a simple design and support structure. It is manufactured from stainless steel. The Liverpool decanters are manufactured in 316SS to due to the corrosive nature of the coastal environment.

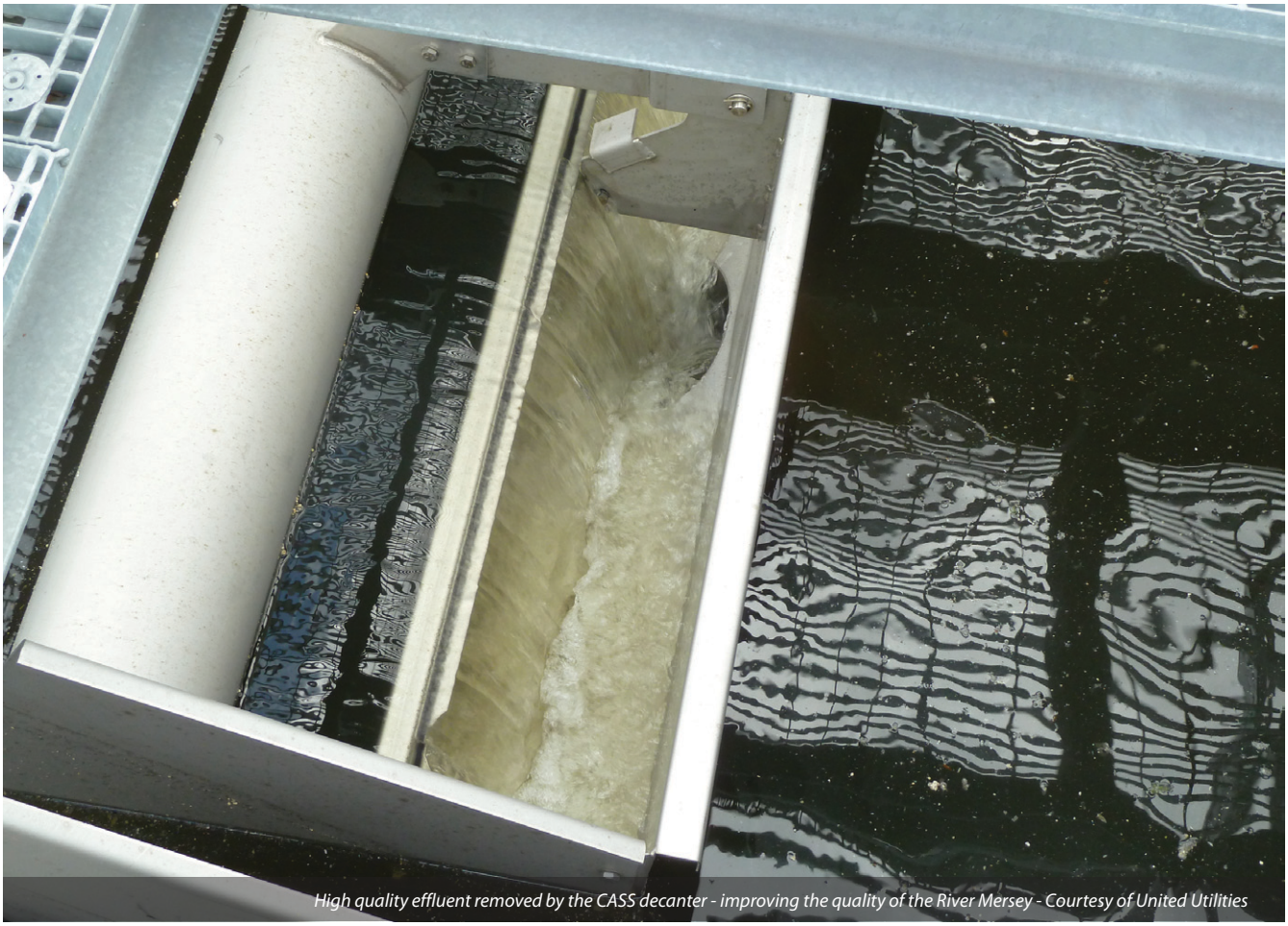
Each CASS basin at Liverpool is fitted with 2 (No.) 16m long decanters which can decant up to a 2m depth of treated effluent. One of the key design challenges with multiple decanter installation is to ensure that the decanters operate in parallel. The CASS design experts used a proven method from other CASS installations which ensures that the decanters are synchronised within a basin.

Reducing TOTEX through innovation

Value engineering utilising BIM brought significant CAPEX and OPEX savings to the project. For example, the initial design brief specified three separate pipework systems on each basin:

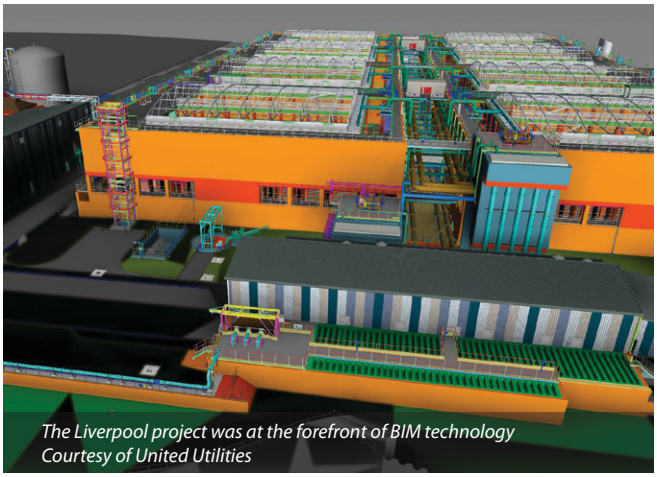
- RAS (return sludge)
- SAS (surplus sludge)
- Basin drain down

The design team developed an innovative common ring main system which incorporated all three pipework systems. This system enables mixed liquor to be transferred from one basin to another or for a basin to be drained down completely using the RAS pump. This system reduced the amount of pipework required and provides great operational flexibility.



High quality effluent removed by the CASS decanter - improving the quality of the River Mersey - Courtesy of United Utilities

Seeding the SBRs with BAFF sludge - Courtesy of United Utilities



The Liverpool project was at the forefront of BIM technology Courtesy of United Utilities

Aerial View of CASS SBR - Courtesy of United Utilities

Table 2
CASS SBR plant performance

Parameter	SBR Feed (mg/l)	SBR Effluent (mg/l)	Consent (mg/l)
COD	388	38	125
BOD	158	5	25
TSS	108	15	250
Ammonia	64	2.7	N/A
Phosphorus	7.4	2.3	N/A

Data courtesy of United Utilities

Commissioning in mind from the outset

The commissioning programme was developed early in the design phase using data established from an SBR pilot plant study undertaken by United Utilities in 2010. This established the suitability of utilising the BAFF/Actiflo sludge from the existing Sandon Dock works as an inoculum for seeding the CASS SBR plant.

The use and availability of this seed sludge eliminated the requirement to import significant amounts (~200 tanker loads) of waste activated sludge from other works, eradicating tanker movements and associated environmental impact.

Process commissioning was undertaken in a phased manner to enable process capability within the existing BAFF plant to be maintained and managed in such a way to permit controlled transfer of treatment capacity between the old and new treatment facilities.

Retaining treatment capacity within the existing BAFF permitted the initial cycle times of the CASS SBR to be extended up to 24 hours. This ensured effluent compliance during early phases of commissioning when mixed liquor levels were considerably below design. As mixed liquor concentrations rose, the cycle times were gradually reduced until the desired 4-hour cycle could be implemented.

From previous experience, provision was made for dealing with foam during initial process start-up, but foam generation was never an issue even during the first 24-hour cycles.

The benefits of the innovative combined ring main system (one ring main per floor level) were fully realised during commissioning. The individual ring mains allowed transfer of sludge not only between basins but also between the upper and lower deck, making commissioning of individual process units more efficient and less labour intensive.

Process commissioning is due to be completed in 2015 and the plant will then undergo a series of 28 day performance tests.

Exceeding plant performance requirements

The new CASS SBR plant has been in operation for approximately 6 months, and is treating 50% of the Liverpool wastewater flows. To date, the effluent quality is exceeding everyone's expectations.

The pilot plant showed that it would be very difficult to nitrify and remove ammonia due to the inhibitory compounds present in the influent. After a few months of operation, the CASS plant started to nitrify and is currently removing approximately 96% of the ammonia load with eleven basins in operation.

Conclusions

United Utilities *'One Team One Aim'* ethos has ensured that the Liverpool WwTW upgrade project has been delivered under budget and ahead of programme.

AECOM's CASS SBR team brought an innovative and flexible approach to the project, providing an optimised TOTEX solution. The SBR plant is simple to operate, flexible and robust and exceeds all expectations.

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