

Phosphorus Removal Schemes

phosphorus removal to meet new environmental consent concentrations for final effluent discharges into Carmarthen Bay

by Nathan Walding MEng CEng MICE

The Habitats Directive Review of Consents, March 2010 identified four waste water treatment works (WwTWs) discharging into Carmarthen Bay, South Wales that required phosphorus removal - Gowerton, Llanelli, Parc-y-splott & Pontyberem. New environmental discharge consents imposing the total phosphorus (P) concentration limit of 1mg/l for each works' final effluent came into force on 31 March 2015. The main intervention and technical solution for the WwTWs to meet this standard is the provision of chemical dosing facilities for P removal. The process of adding chemicals to the waste stream will have an impact on the capacity of the works sludge treatment process as it increases sludge production; hence new sludge treatment facilities are required at each site to manage the increased sludge arising from chemical dosing and projected population growth figures within each catchment.



FST precast wall sections at Gowerton WwTW by Carlow Precast - Courtesy of Dŵr Cymru Welsh Water

Process design

Ferric sulphate solution dosing was implemented across the four sites for chemical precipitation of total phosphorus (TP) to comply with a final effluent consent limit of 1 mg/l TP Annual Average. The Dŵr Cymru Welsh Water (DCWW) process specification requires two dosing locations, referred to as primary and secondary dosing points.

The locations for primary and secondary dosing varied across the four sites, due to the process configuration and existing treatment facilities, but typically primary dosing was carried out at the inlet works (prior to primary treatment) and following the biological treatment stage (prior to tertiary treatment).

Following addition of the ferric sulphate solution the pH of sewage flow typically drops and this can affect the nitrification process of sewage treatment (biological oxidation of ammonia). To correct the pH levels of the sewage flow, sodium hydroxide solution dosing was required at some of the sites prior to the biological treatment stage.

The scope of the new sludge treatment facilities required to meet the demand as a result of increased sludge production varied across the sites, but typically included the provision of new raw sludge holding tanks, centrifuge units, strain presses, final settlement tanks (Gowerton only), upgrading sludge pumps, de-sludge pump stations and other sludge related pipework and mechanical/electrical fittings.

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Outline design and target cost

Following initial process design at each site, Morgan Sindall plc (DCWW AMP5 and AMP6 framework design and build contractor) and Arup (lead designers) completed outline designs in consultation with DCWW Operations to confirm the scope of upgrade works required for each site.

Civil, mechanical and electrical drawings and documentation was produced to 'target cost' level (typically 30%-50% design stage) and issued to Tier II Framework Contractors and the wider supply chain in order to confirm the overall scheme costs or budgets for each site.

Following receipt of costs and compilation of overall scheme budgets it was realised that the scope of works for a number of sites, in particular Llanelli WwTW and Parc-y-Splott WwTW, was not achievable within DCWW's budget plan allowance; hence, the scope of works needed to be significantly challenged in order to reduce costs for scheme viability without undue impact on residual risks or consent compliance.

Value engineering

Emphasis was placed on value engineering to challenge the initial process design in terms of the requirement for new plant or if reuse/refurbishment of existing assets was a feasible alternative. This process was carried out through liaison with DCWW Operations as they held valuable knowledge on the performance of the existing assets. Some examples of savings achieved across the sites are described below:

- Agreement reached with DCWW that the 5 minute contact time following the addition of ferric sulphate solution at Pontyberem WwTW could be achieved in the existing primary settlement tanks (PSTs), removing the proposed serpentine channel arrangement at the inlet works and

grit collection facilities due the calculated low velocities and settlement predicated within the channels.

- Refurbishment of the existing rapid gravity filter (RGF) tanks at Pontyberem WwTW to remove the requirement to provide a new Dynasand unit to improve the performance and output of the existing tertiary treatment plant.
- Reuse of existing strain press feed pumps at Llanelli WwTW and the provision of an enlarged raw sludge storage tank on the footprint of the existing tank through reuse of the existing tanks foundations (height of new tank increased in comparison to existing).
- DCWW Operations acceptance of the risk of damage to the flocculation at Gowerton WwTW associated with the proposal to pump RAS from a new FST de-sludge pump station to an existing RAS pump station. This removed the requirement for a single combined (larger) RAS pump station and new 500m long 800mm diameter rising main back to the anoxic zone. Due to the size of the pumps at Gowerton damage to flocculation was considered unlikely as only a small proportion of the RAS would be exposed to shear caused by the pump impeller. In addition, the presence of large anoxic and aerobic zones at the site would enable the flocculation structure to be rebuilt, in the event of any damage.

In addition to the above construction methodologies and DCWW technical specifications were challenged for efficiency. Some further examples of measures taken to reduce scheme costs across the sites are described below.

DCWW Specification challenge - Resizing existing pipework at Gowerton WwTW to meet minimum pipework velocities

Following implementation of the new FSTs at Gowerton WwTW, flows to the existing FSTs will be reduced from 153l/s per tank at flow to final treatment (FFT) to 61l/s. This will reduce the velocities



Installation of temporary works for FST construction
Courtesy of Dŵr Cymru Welsh Water

Excavation to formation level for FST construction
Courtesy of Dŵr Cymru Welsh Water

in the existing feed and outlet pipework below the minimum self-cleansing velocities defined in DCWW Specifications. The original scope of works proposed downsizing of the outlet pipework to meet minimum velocities ($>0.6\text{m/s}$ in normal operation at FFT) to include:

- Replacement of 2 (No.) 22m lengths of 686mm internal diameter concrete pipework with DN350 ductile iron pipework.
- Replacement of a 57m length of 991mm internal diameter concrete pipework with DN500 ductile iron pipework.

A technical query (TQ) was submitted to DCWW's technical governance team to challenge the requirement to resize the existing outlet pipework since the risk of solids settlement in the FST outlet pipework was considered negligible (as final effluent should not cause significant amounts of solids to settle out under low velocities) and DCWW Operations reported no problems with solids settlement in periods of low flow at the site.

In addition, the replacement of the existing pipework was viewed as a significant risk to the condition of the existing FSTs (excavation depths of up to 4m, approximately 1m away from the existing tanks), which could result in settlement and cracking in the existing tanks. The TQ was subsequently accepted on the basis that the cost/benefit ratio of replacement did not warrant the risks associated with this construction activity and this scope was removed from the scheme.

DCWW Specification challenge - High level fittings to chemical storage tanks

DCWW's Mechanical Specification: Coagulants and phosphate removal, storage & dosing equipment (MS154) stated that all chemical storage tanks are to be fitted with level probes as well as analogue level measurement devices e.g. ultrasonic devices to mitigate against the risk of tank overflow and chemical spillage. These fittings would be provided at a high level within the tanks and therefore permanent fixed access to the top of the tanks for inspection and/or maintenance would be required - a significant cost across the four sites.

A TQ was submitted to DCWW's technical governance team to remove the need for ultrasonic measurement by providing low level pressure sensors (transducers) and other physical measures e.g. visual cat and mouse indicator, fill panel and bund level alarms to measure and monitor the level of chemical within the tanks. The TQ proposal to remove any high level maintainable equipment was accepted following review of the residual risks at a HAZOP workshop between Morgan Sindall plc, Arup and DCWW Operations. The outcome not only reduced scheme costs but also removed the health and safety risks associated with working at height.

Construction methodologies - Precasting and prefabrication of civil structures and ancillaries

Early engagement with the supply chain was undertaken to determine the feasibility of precasting/prefabrication of the structures to be provided across all sites for cost, programme and health and safety benefits during the construction phase. Contracts were awarded to:

- Carlow Precast for the design and build of the reinforced concrete structures using their precast wall sections 'stitched together' with in situ cast concrete infill panels (these were successfully used to form the final settlement tanks at Gowerton WwTW, where each precast wall section incorporated the launder channel).
- Pipex Px for the supply of the catchpit/catchpots that were required on the chemical dosing pipework lines. These chambers were manufactured in robust thermoplastic materials e.g. polypropylene which was suitable to resist



Temporary works at Gowerton WwTW
Courtesy of Dŵr Cymru Welsh Water



Kijlstra precast MCC chamber being lifted into place at Gowerton WwTW - Courtesy of Dŵr Cymru Welsh Water



Prefabricated catchpit/catchpot chambers by Pipex Px
Courtesy of Dŵr Cymru Welsh Water

chemical attack (as opposed to concrete) in the event of a burst in the dosing pipelines.

- Kijlstra Precast for the supply of smaller precast concrete chambers e.g. the new 5.4m x 1.4m x 1m deep (internal) MCC chamber required at Gowerton WwTW, which was fabricated in one piece and lifted into place in less than 1 hour.

Challenges

The main challenge at each site was how to accommodate the required upgrades (new plant and equipment) within the footprint of already heavily congested wastewater treatment works sites that had already undergone several rounds of upgrade works in previous AMP cycles. Some examples of the challenges faced at the sites are described below.

Gowerton WwTW - Final settlement tank (FST) locations: As previously discussed 2 (No.) new FSTs were required at Gowerton WwTW to reduce the demand on the existing FSTs and provide capacity for future growth. Physical space to accommodate the new FSTs was limited at the site and confined to a corridor of available land immediately to the west of the existing FSTs that was bounded by an existing medium pressure gas main owned by Wales & West Utilities.

The diameter of the tanks (27.1m internal diameter) was fixed to satisfy process design calculations and there was insufficient budget to relocate the existing gas main to free up sufficient working space that would typically be required for construction. The available space for the southernmost FST (FST B) between the gas main and the existing FST pipework was 33.2m, which provided only 3.6m total clearance from the outside of the FST launder channels (29.6m external diameter).

Discussions were held with Wales & West utilities, Morgan Sindall's temporary works designers and Carlow Precast (the tank design and build contractor) to arrive at a temporary works solution that satisfied:

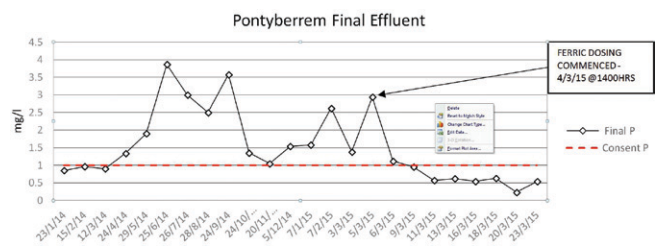
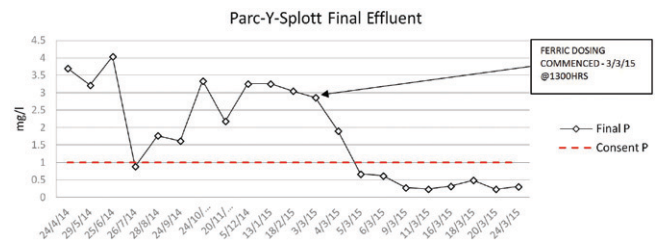
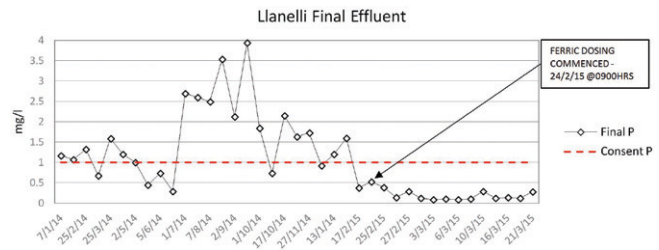
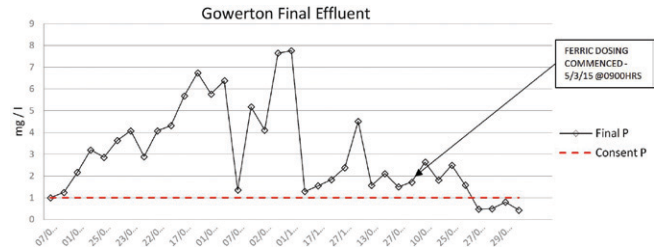
- Easement requirements imposed by Wales and West Utilities - minimum 1m clearance required from back edge of temporary works to gas main.
- Installation (and width) of temporary works.
- Working room requirements for installation and compaction behind precast wall segmental units and casting of in situ concrete in-fill panels.
- Sufficient clearance from existing structures to minimise risk of damage during installation of temporary works.

A king pile post and panel temporary works system was selected to meet the above criteria, in combination with locally reducing the height of the temporary works around the tightest positions of the services before more room was provided where the tank returns on the radius.

Llanelli WwTW - Sludge treatment area: The scope of works at Llanelli to manage existing and increased sludge loads comprised the provision of a new sludge stream building (to contain new centrifuges, polymer dosing plant, MCC and associated mechanical equipment), a new strain press gantry with 2 (No.) new strain presses, a larger raw sludge holding tank to replace the existing and associated pipework and fittings.

The available space for the new building, plant and equipment was confined to the existing sludge management area to the south of the site, already occupied in part by existing tanks, pumps, strain presses and a centrifuge building.

Significant liaison with DCWW was required in positioning of the building and determining the vehicle type and size that would be



*P trends following implementation at the 4 sites
Courtesy of DCWW*

used for existing and proposed sludge management. Autotrack software was used to demonstrate to DCWW that turning circles for proposed vehicles could be achieved for the range of vehicle loading/unloading permutations involved to arrive at agreement for the final position of the new building, plant and equipment.

Conclusion

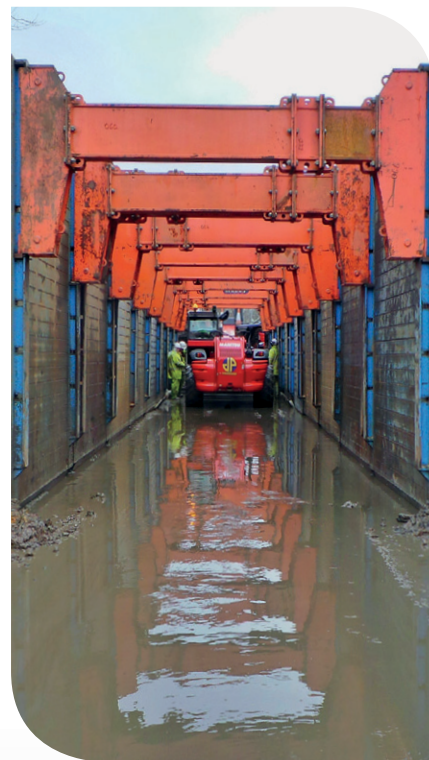
The implementation of chemical dosing plant for P removal and associated impacts across the 4 sites provided significant challenges in terms of overall budget management and the constraints imposed by working within heavily congested and operational WwTWs operating at or near capacity.

However, due to the focussed approach and collaborative working between all of the design, contract, sub-contract, commercial, operational and process teams, the required P trending and environmental consent status to allow DCWW to comply with the Natural Resources Wales consent at the year-end (31st March 2015) was achieved.

The P trends following implementation of chemical dosing for each of the sites is displayed for each site in the graphs above.

The editor and publishers would like to thank Nathan Walding, Water Engineer with Arup, for providing the above article for publication.

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