Willenhall UID

major water quality improvements to the River Tame catchment, delivered with a focus on innovation and sustainability

by Ian Merrill MSc CEng MICE

Severn Trent Water's £9.3m Willenhall Unsatisfactory Intermittent Discharge (UID) Project was developed to deliver environmental improvements within the highly urbanised Black Country region of the West Midlands. The specific project driver was one of water quality, with an aim of improving the standard of river water in the upper reaches of the River Tame catchment, which covers an total area of nearly 150km^2 and holds a population of approximately half a million people.

Storage tank excavation at bottom frame level, September 2010 - Courtesy of NMCNomenca

The solution agreed with the Environment Agency (EA) was to provide 20,000m^3 of storm sewage storage. In the event of a major rainstorm, the Willenhall storm tank is designed to provide capacity within Severn Trent Water's (STW) sewerage system, to reduce the threat of storm sewage overflowing into the River Tame. By storing excess flows within the sewerage system, the annual spill volume to the River Tame will be reduced from 153,000m^3 to just 33,000m^3.

Extensive site investigation works were carried out to gain a thorough understanding of the chosen construction site's underlying geology. This was found to consist of made ground up to 4m deep, overlying alluvium classified as sands and gravels. Below the alluvium, middle coal measures strata were encountered to the full depth of the proposed excavation; the stratum generally consisted of fine grained sandstone and grey mudstone.

The confirmed presence of historic deep coal mining operations below the site and a high groundwater table added complexity to design constraints. The study also identified the presence of various contaminants on the site, plus a small population of great crested newts, both of which would need to be considered as the design was developed.

Innovation through design

The multi-disciplinary project team was led by the STW Asset Creation, Sewerage East and their framework contractor NMCNomenca, with support from supply chain partners comprised of Eastwood and Partners (structural engineers), Ivor King (sheet pile wall contractor), OGI Groundwater Specialists Limited (dewatering contractors), STAM Construction (FRC contractors) and Keller Ground Engineering (tension pile contractors).

Further support was given by Grontmij (environmental consultants) as solution buy-in was sought from both the EA and Walsall Metropolitan Borough Council in an effort to reuse all excavated materials within the bounds of the existing site.

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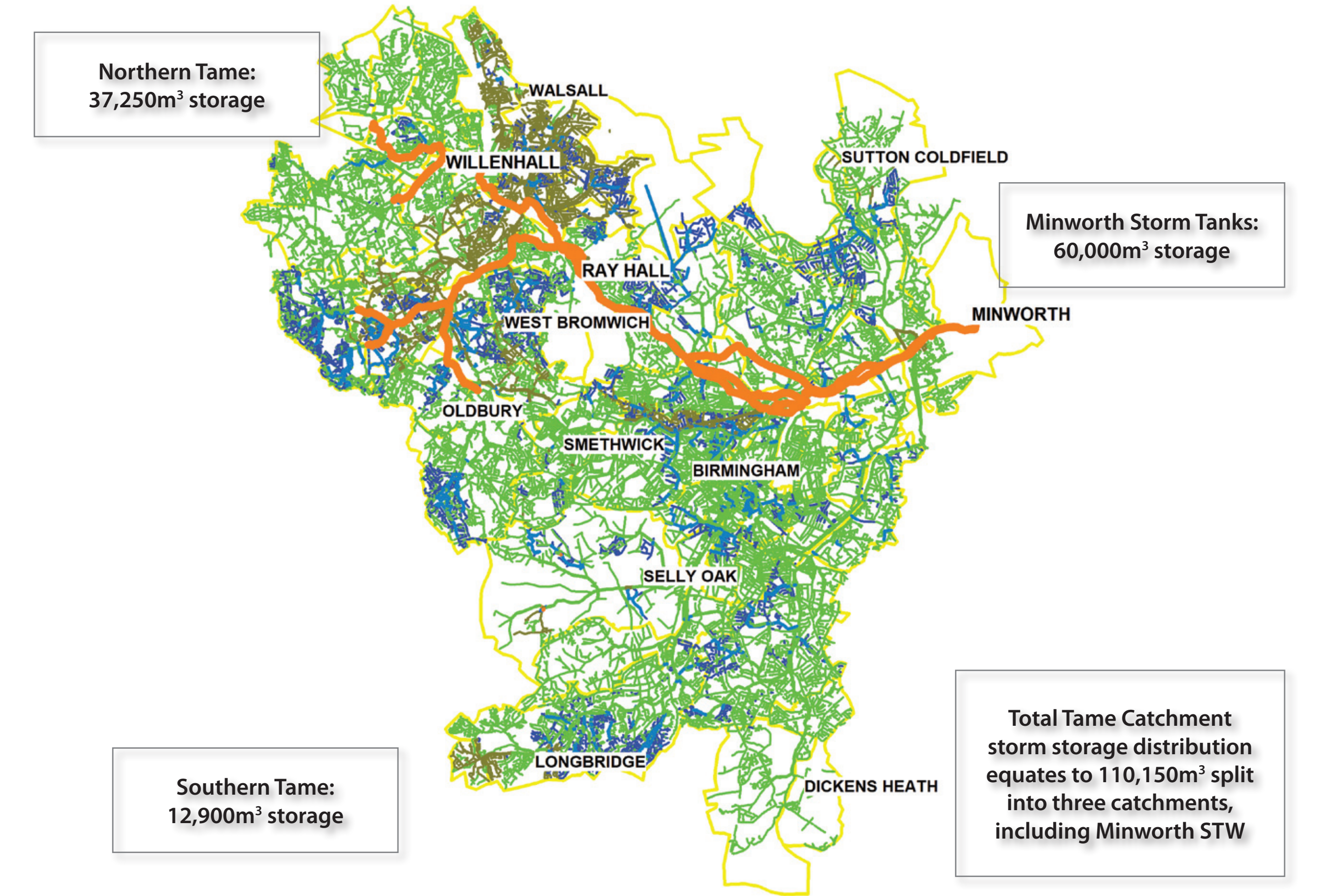


River Tame Catchment showing storage distribution - Courtesy of Clear Ltd

Feasibility studies and modelling

From its very conception the project drove forward innovative thinking, as advanced feasibility work by STW Asset Creation created the largest hydraulic sewerage system model in the UK.

Twenty-one drainage area plans were 'stitched' together to produce a 40,000 node InfoWorks model covering a catchment area of 145km^2. The model encompassed 1,500km of sewers and 152 combined sewer overflows, and within the Northern Tame Sub-catchment alone generated peak dry weather flows of 2,000l/s and peak storm flows of 9,000l/s. The scale of the modelling exercise meant that it took up to four weeks to run certain time series rainfall simulations!

The outputs from the verified hydraulic model were utilised as part of a SIMPOL water quality modelling exercise, carried out in conjunction with the Water Research Council. This water quality analysis demonstrated to the Environment Agency that only 20,000m^3 of storage was required, as opposed to the 30,000m^3 originally planned, in order to deliver the requisite water quality improvements. The initiative delivered a cost saving of £3.75m, in terms of storage volume reduction across the entire Tame Catchment.

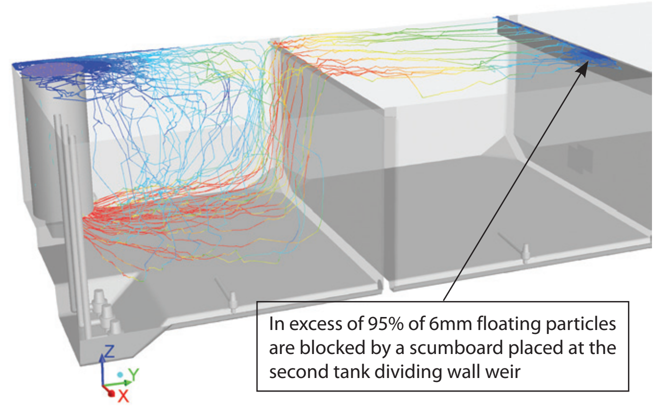
As the feasibility studies progressed, a number of below-ground storage tank options were considered in order to deliver the required 20,000m^3 volume, including various segmental shaft tank arrangements. The eventual design selected consisted of a single in-situ reinforced concrete tank, which was best aligned to the prevailing geological conditions.

The tank itself was further subdivided into twelve compartments which would fill sequentially through a weir arrangement and empty via pumped return. Not only did this tank subdivision

Storage tank structure late in construction phase, prior to the installation of GRP roof, March 2011 - Courtesy of NMCN

Storage tank structure late in construction phase, showing temporary inter-tank opening at base level, March 2011 - Courtesy of NMCN rationalise the cleansing regime, the internal dividing walls also provided structural support which increased the efficiency of the structural design as a whole.

CFD modelling was utilised to establish that the proposed storage tank geometry and mixer pumps would provide the requisite cleansing outputs, but was also developed to demonstrate that only one inter-tank scumboard would be required, rather than the eleven originally planned. This innovation delivered a nett cost saving of £53k, with CFD modelling expertise provided by Ansys UK Ltd.



CFD floating particle tracks demonstrate the efficiency of scumboards Courtesy of Ansys UK

The storage tank

The 174m long x 21m wide x 13.5m deep reinforced concrete storage tank is designed to fill by gravity, with a full 20,000m^3 capacity being provided before the first spill from the Willenhall Combined Sewer Overflow. Dilute sewage fills the twelve tank cells sequentially, in order to minimise energy use through the automated cleansing regime. The stored effluent is returned by pumps, as soon as remote monitoring dictates that flows in the receiving sewer have fallen sufficiently.

Because the storage tank will generally remain empty under normal operating conditions the risk of floatation, in-ground conditions characterised by a high water table, remained a primary risk throughout the design process.

In addition to the self weight of the tank structure, the floatation risk was countered by the use of a shear key, projecting from the tank base slab, to mobilise the maximum amount of soil in resistance to uplift. The structural design also relied heavily upon the presence of 204 tension piles, to provide permanent floatation resistance for the tank.


GRP roof installation on completed tanks, June 2011 Courtesy of Severn Trent Water

GRP roof

As a cover to the storage tanks, a GRP roof was installed rather than a traditional reinforced concrete slab design. This not only delivered substantial cost savings in terms of the roof itself, but also enabled the slimming down of the section of the supporting walls.

The total cost saving of this innovative measure was £277k but, importantly, additional construction phase health and safety benefits were realised in terms of the omission of the soffit formwork required by an in-situ slab and a much less onerous lifting regime. Adams Hydraulics Limited designed and produced the GRP storage tank roof of a scale never before seen on a project of this type.

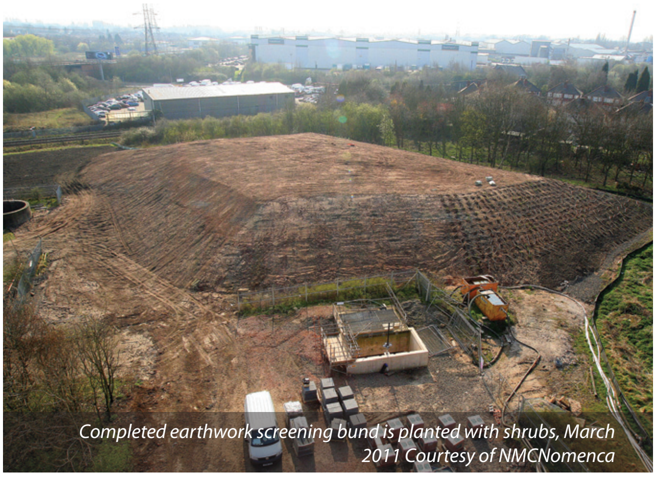

Cofferdam of interlocking sheet piles Courtesy of NMCNomenca

Innovation at construction phase

Due to the high groundwater levels, which were proven through advanced site investigation works, a cofferdam of interlocking sheet piles was used in conjunction with a complex deep well dewatering system in order to create a watertight environment in which construction of the reinforced concrete structure could be progressed.

Early installation of the pumping station electricity supply meant that electric dewatering pumps could be utilised, as opposed to diesel, thus delivering significant energy-saving and environmental benefits.

Excavation works were carefully programmed in order to allow precise tracking of excavated materials and thus comply with EA permitting stipulations. With the large excavation volumes associated with this project, planning of site traffic routes was extremely important and played a significant role in the exemplary health and safety record delivered through the construction phase.


Completed earthwork screening bund is planted with shrubs, March 2011 Courtesy of NMCNomenca

Sheet piled cofferdam

The installation of the sheet piled cofferdam and supporting frames was carried out over three phases. After the driving of the sheet piles, excavation was completed to top frame level, at which point the upper frame structure was welded into place. Upon reaching bottom frame level the excavation was halted to allow installation of the tension piles, followed by the construction of the temporary bottom frame. Finally, the excavation was completed to formation level, carefully avoiding the tension pile heads already in-situ.

From this point the construction of the reinforced concrete structure was a relatively straightforward operation, with an innovative system of pulley-mounted external shuttering and sectionalised internal shuttering permitting rapid progress; heated shutters were deployed during the cold winter months in order to adhere to the tight construction programme.

Temporary works included inter-tank openings at base slab level, of sufficient size to allow access for scissor lifts, personnel and small tools. This innovation drove substantial health and safety benefits through greatly reduced access/egress and lifting operations between individual tank cells.

Sustainability

As the entire project focussed on environmental improvement, a sustainable solution was always a primary driver. In light of this consideration, the push to achieve on-site disposal of all material excavated during tank construction, a total of approximately 40,500m^3, was always of paramount importance.

The agreement with the EA to proceed with this exercise, under license, not only delivered a financial saving of £584k, it also realised a carbon emission saving of 1,358t. Furthermore, this on-site disposal regime meant that 16,000 vehicular movements on and off site were eliminated, vastly reducing potential impact upon the local community.

Carbon savings and other benefits

Additional quantifiable carbon savings achieved in the course of the project were as follows:

- Using local staff and skilled labour, plus car sharing, saved 165,000kg of CO_2.
- Design efficiencies associated with the GRP roof saved 214,000kg of CO_2.
- Providing an early mains electricity supply instead of diesel generators saved 1,293,000kg of CO_2.

In addition to river water quality improvements, which will benefit the entire River Tame Catchment, the project has also benefited the endangered great crested newt by habitat creation as part of a mitigation strategy agreed with Natural England.

In recognition of the project's contributions to sustainable development, a Green Apple Environmental Award was presented in November 2011 at the House of Commons. Further recognition of project benefits to the local community came in the form of a Considerate Constructors Award presented in March 2012.

Conclusion

In spite of a significant array of technical and environmental challenges, the Willenhall UID Delivery Team was able to engineer a sustainable and innovative solution. The project was successfully delivered to an agreed programme and budget in July 2011, and is already providing tangible river quality improvements in a region historically beset by environmental deprivation.

The Editor & Publishers thank Ian Merrill, Solution Manager with Severn Trent Water, Waste Water Services, Asset Creation - Sewerage East, for preparing the above article for publication.

Storage tank cell late in construction phase, March 2011
Note integral 'letterbox' at crest of inter-tank weir (prior to fitting of GRP baffle plate) and drain-down channel to pump sump (bottom left) - Courtesy of NMCN

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