Ulley Reservoir Rehabilitation Scheme

new £3.5m spillway to replace storm damaged overflow structure and prevent risk of dam wall failure

by Matthew Jenkins MEng MICE

Ulley Reservoir is located to the south of Rotherham town centre and was originally built to provide a water supply to the town. It was constructed between 1871 and 1875 and comprises an earth embankment with a puddle clay core. The embankment is 205m long and the maximum height is 16m, retaining a reservoir of 580,000m^3. Ulley is owned by Rotherham Metropolitan Borough Council (RMBC) and forms part of a country park providing public recreational facilities. During a storm on 25th June 2007, a masonry wall on one of the three reservoir spillways failed. This resulted in a large scour hole forming on the downstream shoulder of the embankment, threatening to breach the dam itself. Local residents in Rotherham were evacuated and the nearby M1 motorway was closed for 48 hours as a precaution. Following the incident, the embankment was stabilised by 2,500 tonnes of imported coarse limestone fill. The rehabilitation works were designed to address the conclusions and recommendations of the Section 10 Report. In the interests of safety, areas of focus included work to the spillways, core, wave-protection and drawdown facility.

Aerial photograph of the completed Ulley Reservoir *Courtesy of Arup and Peter Smith Photography*

Arup was called in by Rotherham Metropolitan Borough Council on the day of the incident and managed the immediate incident response activities. A Section 10 Inspection under the Reservoirs Act was called for by the Supervising Engineer.

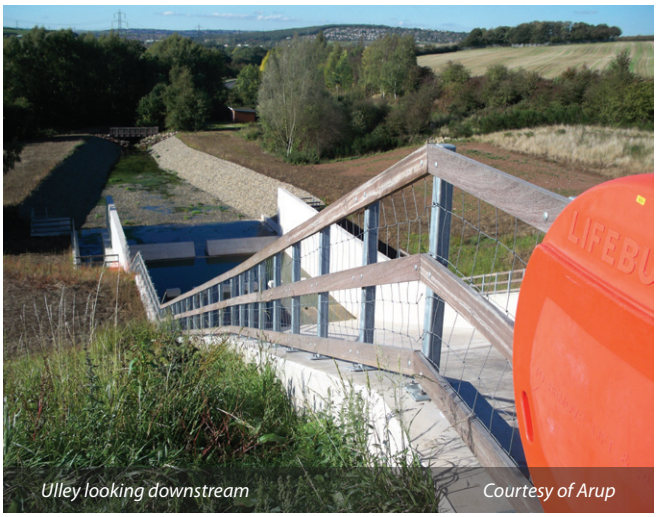
Design considerations

Construction safety issues were continually assessed against long-term reservoir safety benefits in evaluating the design options. There was also strong public support for the rehabilitation of the reservoir. The project team worked with local groups and parish councils to develop the final design and mitigate the impact of the work on the Country Park.

Arup was engaged to undertake the feasibility study and detailed design. This included geotechnical investigations, re-calculation of the Probable Maximum Flood (PMF) and physical hydraulic modelling of the chosen spillway design. The modelling enabled the spillway design to be optimised, tapering from 20m to 15m and for wall heights to be reduced.

Managing reservoir outflow during construction was a key factor in the consideration of 3 main new spillway options. On the left hand abutment, it would clash with the undamaged existing 1943 spillway, which still allowed for discharge of storm flows during construction. On the right, there was steep sidelong ground,


Ulley spillway sheet piles Courtesy of Arup


Ulley looking downstream Courtesy of Arup

which would have presented major geotechnical challenges. The width of land available was also limited here which would have required a less efficient and more expensive weir arrangement. The decision was made to line the new spillway up with the receiving watercourse. This avoided any bends, provided an efficient weir and removed the water quickly away from the toe of the embankment.

The spillway design was based on a re-calculated PMF of 123m^3/s and incorporated articulated joints with waterbars to allow for potential settlement. Underdrains were installed at each joint to monitor performance and ensure that any seepage did not affect the dam fill material. V-notch measuring chambers were also constructed to enable future seepage monitoring.

The original puddle-clay core of the dam had been raised in 1969 by provision of a plastic concrete wall, which was found to be defective. Numerous alternatives were considered before opting for a 3.4m deep cement bentonite slurry trench to provide a replacement watertight barrier, keyed into the clay core.

At the same time, the crest of the dam was reduced in height by 0.5m to create an adequate construction working platform. The bentonite was sufficiently flexible to meet the design requirements and could be installed without significantly increasing the dam's susceptibility to raised reservoir levels in the temporary case. It was important to ensure that the interface between the bentonite and the new spillway would remain watertight. This was achieved by sloping the outer face of the spillway structure and incorporating a waterbar in the outer spillway face.

The existing wave protection on the upstream face of the embankment was limited in extent and was completely replaced. This comprised of an outer 440mm thick rip rap layer on top of two filter layers (110mm and 130mm thick) and extended from the top of the embankment to 1.75m below top water level. The sandstone was a locally sourced dense Pennine sandstone (from Appleton Quarry near Huddersfield).

The design of the new drawdown facility was the most innovative new element. The original drawdown was a 15" gravity pipe routed around the dam and laid through a masonry lined tunnel. Design options included a new gravity pipe through the dam (rejected because of waterproofing and environmental impact in construction), a total syphon over the top of the dam (high maintenance and not failsafe in an emergency) and a part gravity/part syphon arrangement (the final solution).

This option enabled re-use of the original shaft and tunnel, thus avoiding dam-core waterproofing problems. The 500mm DI pipe was sized to lower the reservoir by 1m per day under Q10 conditions (inflow into the reservoir that is exceeded 10% of the time). The shaft and tunnel were sealed with foamed concrete once the pipe had been fully commissioned. A priming pump facility was also included to start the syphon under low head conditions.

Construction

Construction started in September 2009 and was completed by June 2010. The principle contractor was Ringway Ltd with Vinci Construction UK Ltd as the main sub-contractor. Arup provided technical support, CDM coordination and contract administration services.

Initial ecological surveys identified grass snakes (a protected species) on the site. Site clearance was therefore undertaken by hand and


Ulley crest and riprap Courtesy of Arup


Ulley wildlife pond Courtesy of Arup

Aerial photograph of the completed Ulley Reservoir *Courtesy of Arup and Peter Smith Photography*

supervised by an ecologist. Subsequently, a reptile fence and boom was erected around the entire site to keep the construction area snake-free. Hibernacula areas were also established behind the fence for winter hibernation.

A wildlife pond located in an old filter bed had to be relocated prior to undertaking the main works to mitigate the lost habitat. This was populated with rescued flora and fauna from the old pond and also included access platforms for educational visits by local children. Demolition of redundant water treatment works structures ensued followed by construction of the stilling basin. Stream training works constructed from gabion baskets then returned the flow to the natural stream channel width.

Works were carefully sequenced to maintain reservoir safety throughout. Sheet piles were installed on the crest, anchored to the upstream approach slab to provide flood protection to the main spillway works. The spillway was then fully constructed upstream and downstream to minimise the infill works on pile removal. Reservoir levels were also controlled during construction (by overpumping) to allow for a 1 in 50 year return period construction flood event to occur, without overtopping the existing 1943 spillway (still in service during construction).

Casting the benched concrete spillway on a 19 degree slope presented a novel practical challenge. Permanent steel mesh formwork (exponet) was installed vertically at regular intervals between the top and bottom layers of reinforcement, held in position with z-bars. This helped control the slump of the concrete and enabled a good power float finish to be achieved. Reinforcing mesh was also installed on top of the main reinforcement on thickened benched areas of the spillway. This again helped to prevent concrete flowing downhill and also provided a more secure walkway for the concrete installation gang.

All excavated material from the spillway and stilling basin was re-used on site. Spoil was temporarily stockpiled during construction before being used to infill redundant spillways and re-landscape downstream embankment profiles. No additional topsoil was imported to preserve site ecology and prevent any potential cross contamination. Recovered Rotherham Red faced sandstone from demolished structures and channels was also used on new structures, with a surplus being stored by RMBC for re-use elsewhere. This helped the rehabilitation works blend into the country park setting, minimising its impact.

Stakeholder involvement was key to successful project delivery and onward management and use of Ulley as a country park amenity. Evening presentations were given at parish council meetings and to a local environmental group as well as organised site visits to keep members of the public appraised of progress.

To facilitate future use and enjoyment of the park, new timber clad footbridges were installed over the new spillway and across the stream by the wildlife pond. Footpaths were also modified to suit the new works to ensure continuity of public access.

Conclusion

Despite the extreme winter weather conditions, the project was finished on time and below budget with excellent site management and risk control.

The scheme has recently been awarded a Centenary Award Certificate of Excellence 2011 by the Institution of Civil Engineers Yorkshire and Humber and will continue to protect Rotherham residents for many years to come.

The editor & publishers thank Matthew Jenkins, Senior Engineer, with Arup, for preparing the above article for publication.

Ulley stilling basin and upstream *Courtesy of Arup*