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BALANCING WATER QUALITY AND INFRASTRUCTURE

A Case Study for the Bottesford Beck

INTRODUCTION

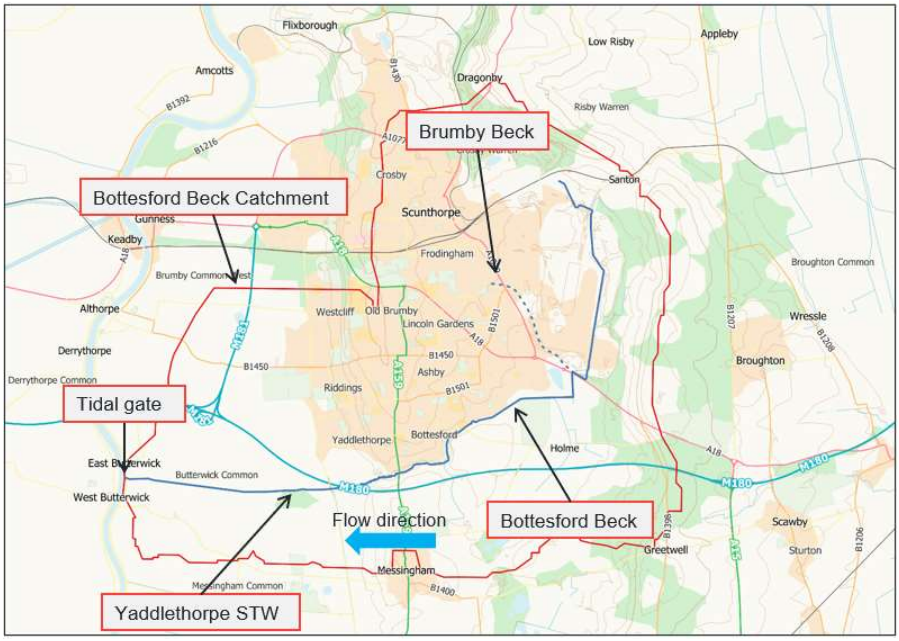

Figure 1 - Study area

WSP was commissioned in 2023 by Severn Trent to undertake an optioneering study for a Water Framework Directive (WFD) driver on the Bottesford Beck (GB104028064290), Scunthorpe. This is a 15 km waterbody with a hydromorphological designation of 'heavily modified'. The Bottesford Beck starts to the east of Scunthorpe town and flows to a confluence with the River Trent. The headwaters are predominantly urban, with 6 Combined Sewer Overflows (CSOs) and 6 Surface Water (SW) sewers discharging directly, or indirectly into it. The Beck joins the River Trent at a tidal gate, which operates using gravity alone, enabling it to let the water flow out when the Beck is higher than the River Trent.

This project was the continuation of a study which focused on the historical water quality of Bottesford Beck, this study assessed the water quality standards of the Beck against the WFD standards and Urban Pollution Management (UPM) manual criteria. The original study, undertaken in 2017, involved the review of historical data in three Environmental Agency (EA) monitoring stations, and the installation of another 4 water quality monitors within the catchment, which monitored effluents from the Yaddlethorpe Sewage Treatment Works (STW), the intermittent discharges from Combined Sewers Overflows (CSOs), the Surface Water sewers from the urban catchment, and the Beck itself. Calibration of a water quality model using observed data revealed satisfactory agreement in flow predictions, with some variations in water quality parameters during storm events. The final water quality assessment, spanning a 10-year period, indicated varying water quality classifications in the Beck, influenced by CSO spills, Final Effluent (FE) discharges and tidal gate operation. Results highlighted challenges in meeting Good WFD classification, particularly for Soluble Reactive Phosphorus (SRP) and BOD99, emphasizing the need for broader catchment improvements.

As a result of the 2017 study, and as part of the commitment to the Environment Agency (EA) under the Thriving Environment outcome, Severn Trent agreed to undertake its 'fair share' of investment to improve the BOD99 concentration in the Bottesford Beck to 'Good' status. The current EA classification of the Bottesford Beck does not meet the Good standard for BOD99 (11 mg/l).

This investment is in line with the AMP7 CSO Investigation and Improvement Protocol and is a product of the AMP6 WFD (Water Framework Directive) investigations as outlined in the AMP7 Water Industry National Environment Programme (WINEP) list.

PREVIOUS STUDIES: SETTING THE SCHEME'S LINE

Once the water quality model was calibrated, the previous study aimed to test options that, as a minimum, would improve the SRP annual average and the BOD99 to 'Good' status. It was concluded that the main source of SRP in the Beck was caused by the FE from the Yaddlethorpe STW. As a result, a FE transfer to the River Trent was tested.

YADDLETHORPE FLOW EFFLUENT TRANSFER

The transfer of FE from Bottesford Beck to the River Trent exhibited a variable impact on water quality. Marginal improvements were observed in BOD and ammonia 90%ile concentrations, failing to enhance overall standards in the watercourse. Transferring FE improved SRP concentration but downgraded Urban Pollution Management (UPM) standards with the most notable downgrade in the BOD 99%ile standard. Un-ionised ammonia FIS exceedances increased post-transfer.

However, as shown in Figure 2, this is a beneficial option for SRP concentrations. For this reason, the option was taken forward and the UPM standards affected by the FE transfer have been balanced by other interventions in the upper catchment.

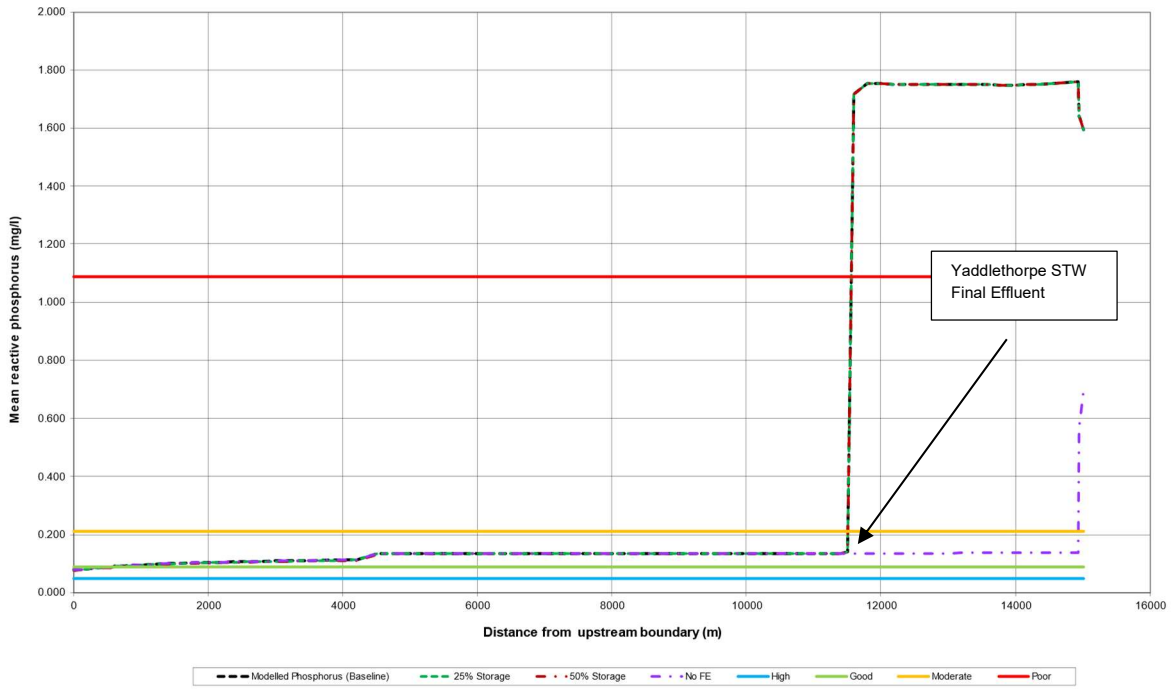

Figure 2 - SRP annual average concentration long section

CSO IMPROVEMENTS

A variety of different tests were initially undertaken to reduce the spills from the CSOs contributing to the Beck, to improve the BOD to Good levels, indicating the scale of the intervention required. The impact of decreasing spills from groups of CSOs discharging to the same point of the Beck (e.g. only Brumby Beck CSOs or only South Grange CSO) was tested in a series of scenarios (1 to 5). They proved to improve the BOD99 levels locally, but not along the whole of the Reach.

The most relevant findings, observed in Scenarios 6 to 10, are highlighted in Figure 3. Scenarios 6 to 10 are tests where, as a minimum, one CSO upstream of a combined outfall discharging to the Beck had spill volumes decreased.

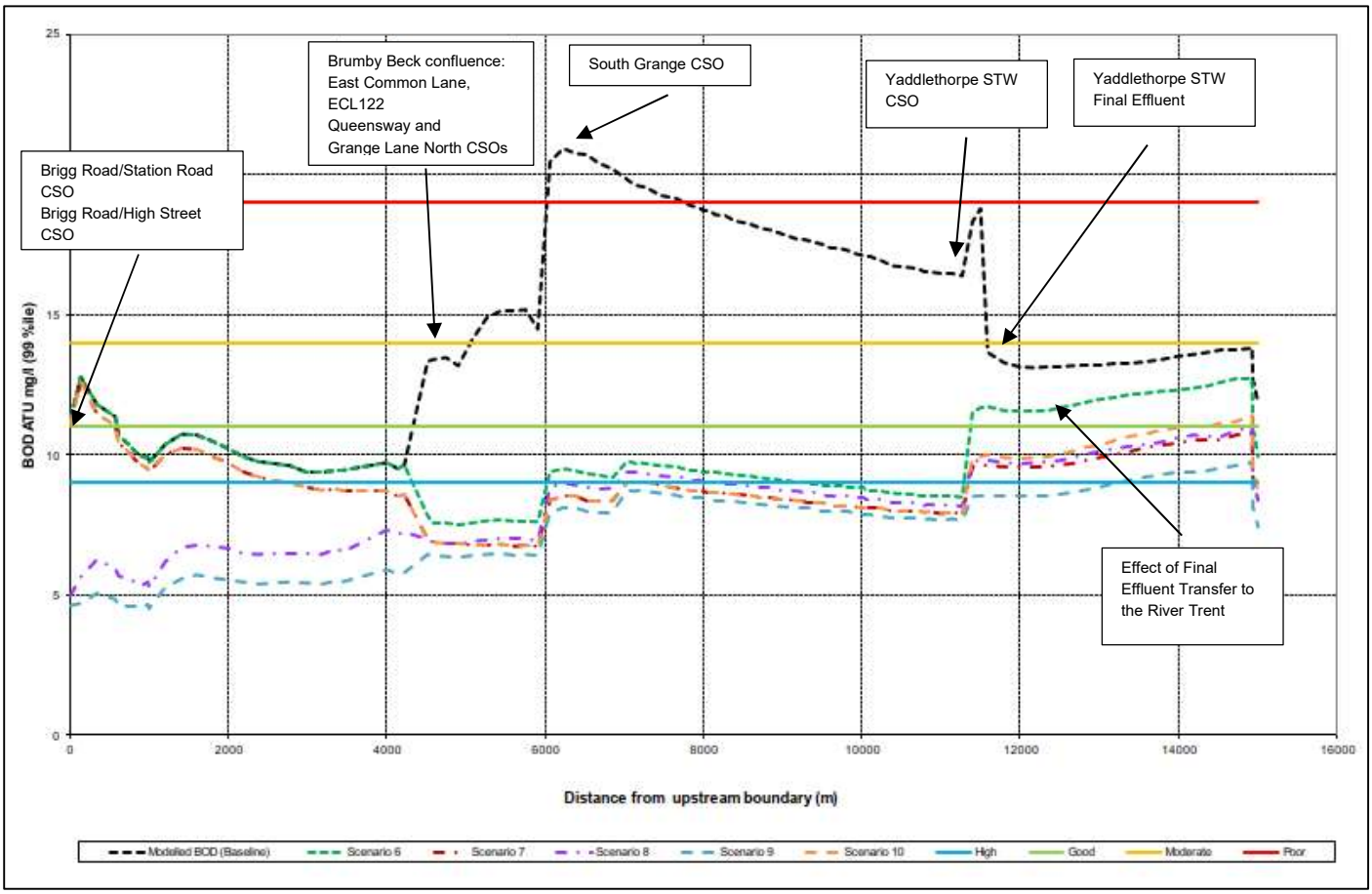

Figure 3 BOD99%ile concentration long section

Figure 3 shows the results for the following scenarios:

- Scenario 6 – 50% reduction of spills at South Grange CSO and 50% reduction of spills at CSOs discharging to Brumby Beck, with the Yaddlethorpe FE transfer scheme. All other modelled inputs were unchanged . The results from this text indicated that the decrease of spills in the mid-reach CSOs improved the BOD levels to Good status, although the hydrograph shows the Beck is back to Moderate status after the Yaddlethorpe STW CSO discharge.
- Scenario 7 – As Scenario 6 and 25% spill volume reduction at Brigg Rd/Station Road CSO. The BOD concentration of the Yaddlethorpe STW CSO discharge was decreased from 90 mg/l to 50 mg/l to test the difference. This scenario added two additional features. The 25% spill volume reduction at Brigg Rd/Station Road CSO did not seem to significantly affect the BOD results at the headwaters. Decreasing the BOD concentration in the Yaddlethorpe STW CSO discharge improved the results compared to Scenario 6.
- Scenario 8 – As Scenario 6 and 25% spill volume reduction at Brigg Rd/High Street CSO. The BOD concentration of the Yaddlethorpe STW CSO discharge was decreased from 90 mg/l to 50 mg/l to test the difference. The scenario 8 results shed some light on the difference between decreasing the spills at Brigg Road/High Street CSO and Brigg Road/Station Road CSO. The Scenario 8 showed when 25% of the spill

volume is reduced at Brigg Road/High Street, the BOD is reduced by 7mg/l more than with Brigg Road/Station Road CSO.

- Scenario 9 – As Scenario 6 and 25% spill volume reduction at Brigg Rd/Station Road CSO and Brigg Rd/High Street CSO. The BOD concentration of the Yaddlethorpe STW CSO discharge was decreased from 90 mg/l to 50 mg/l to test the difference. These results provided the most beneficial solution.
- Scenario 10 – As Scenario 6 and with 25% spill volume reduction at Yaddlethorpe CSO and 25% spill volume reduction at Brigg Rd/High Street CSO. This scenario proved that adding storage at Yaddlethorpe STW CSO would provide approximately the same benefit as reducing the BOD load to 50 mg/l, which is a more realistic approach.

After these scenario testing, it was concluded that a hybrid solution between Scenario 9, which contains an intervention at the headwaters CSOs and Scenario 10, which contains an intervention at Yaddlethorpe STW CSO, could be a potential solution to maintain the "Good" status along the whole of the Bottesford Beck.

CASE STUDY: OPTIONEERING WITH INFOWORKS ICM

A hydraulic modelling software provides a practical advantage, enhancing our understanding of how storm tanks interact with the sewerage network and the implications of flow returns. In the previous study's approach, the assumption was that a specific storage amount would remain in the tanks following an intermittent discharge, gradually draining over the subsequent 12 hours. However, the pump-returned flows, particularly in high-capacity storage tanks, introduce risks to the sewerage catchment, including potential flooding or pollution risks in downstream CSOs if flows are returned when network capacities are still insufficient.

The conclusion from the previous study was that the spills would need to be reduced in 4 strategic areas within the Bottesford Beck:

- Headwaters: either Brigg Road/Station Road CSO or Brigg Road/High Street CSO. These CSOs are located at the top end of the catchment and play a key role in the BOD99 levels at the Beck.
- Brumby Beck Confluence: East Common Lane CSO, East Common Lane 122 CSO, Queensway CSO and Grange Lane North CSO.
- South Grange CSO. This CSO serves 45,000 population.
- Yaddlethorpe STW CSO. After the FE transfer to the river Trent, it was advised to decrease the spills here to provide further BOD99 reduction.

SCENARIO COMBINATION

In line with the previous tests, a set of 7 different options was implemented in an InfoWorks ICM model to assess the results. Although the initial scenario indicated better BOD removal could be achieved with a scheme upstream of Brigg Road/High Street CSO, it was decided to implement a scheme on Brigg Road/Station Rd CSO due to construction constraints with the location of the CSO.

In the Severn Trent strategic framework, innovation is a key objective aimed at achieving operational excellence, and their strategic ambitions focus on creating a carbon neutral business. For this reason, some of the 'hard-engineering' solutions were replaced by "Active Network Management Control" (ANMC) solutions which aim to maximise the capacity of the network before spill with the use of smart sluices that can open or close based on sensor levels to store water upstream.

Table 1 shows the most relevant tests undertaken.

Table 1 – Storage needed in m^3 for each model scenario

ASSET	OPTION 1	OPTION 2	OPTION 3	OPTION 4	OPTION 5	OPTION 6	OPTION 7
Brigg Rd / Station Rd CSO	1,040	850	1,040	1,040	1,040	1,040	1,040
E. C. Lane & E. C Lane 122 CSO	1,495	600	NS	NS	ANMC	NS	ANMC + SWS
Queensway CSO	1,040	850	1,040	NS	ANMC	1,040	ANMC + SWS
Grange Lane North CSO	3,250	2,600	3,250	3,250	3,250	3,250	3,250
South Grange CSO	3,510	2,750	3,510	3,510	3,510	3,510	3,510
Yaddlethorpe STW	3,120	3,120	3,120	3,120	3,120	5,000	3,120

NS – No Solution

SWS – Surface Water Separation

ANMC – Active Network Management Control

The proposed solutions were tested in an InfoWorks catchment model for Scunthorpe, and 10-year series simulations were run in InfoWorks ICM and the hydrographs were subsequently exported to MIKE11. While the individual tanks reduced spill volumes and improved BOD99 in localized discharge areas, the Bottesford Beck BOD99 status still fell short of achieving a "Good" classification downstream of the Yaddlethorpe STW CSO. This was attributed to occasional flow returns when the Yaddlethorpe STW storm tanks were at maximum capacity. Consequently, the schemes required an additional level of control to allow the CSO storage to return flows to the network only when the Yaddlethorpe STW storm tank capacity permitted it.

RESULTS

The outcomes portrayed in Figure 4 reveal that for Options 1, 2, and 3, the BOD99 maintained a status of High or Good until the Yaddlethorpe Sewage Treatment Works (STW). However, the results indicated a deviation from the anticipated water quality status in the Beck, as initially predicted in Figure 3. In Figure 3, it can be observed that the BOD99 peak was approximately 2mg/l after the Yaddlethorpe STW CSO discharge, whereas the results in Figure 4 showed an increase ranging between 5 to 7 mg/l This discrepancy arose from the shaft tanks returning flows to the network when the storm tanks at Yaddlethorpe STW were operating at maximum capacity, resulting in additional spill from the storm tanks to the Bottesford Beck. Although these situations were not predicted to happen regularly, the BOD99 is indicative of the 1% exceedances. As a result, in those instances where the shaft tanks in the upstream network activated, the BOD99 issue worsened.

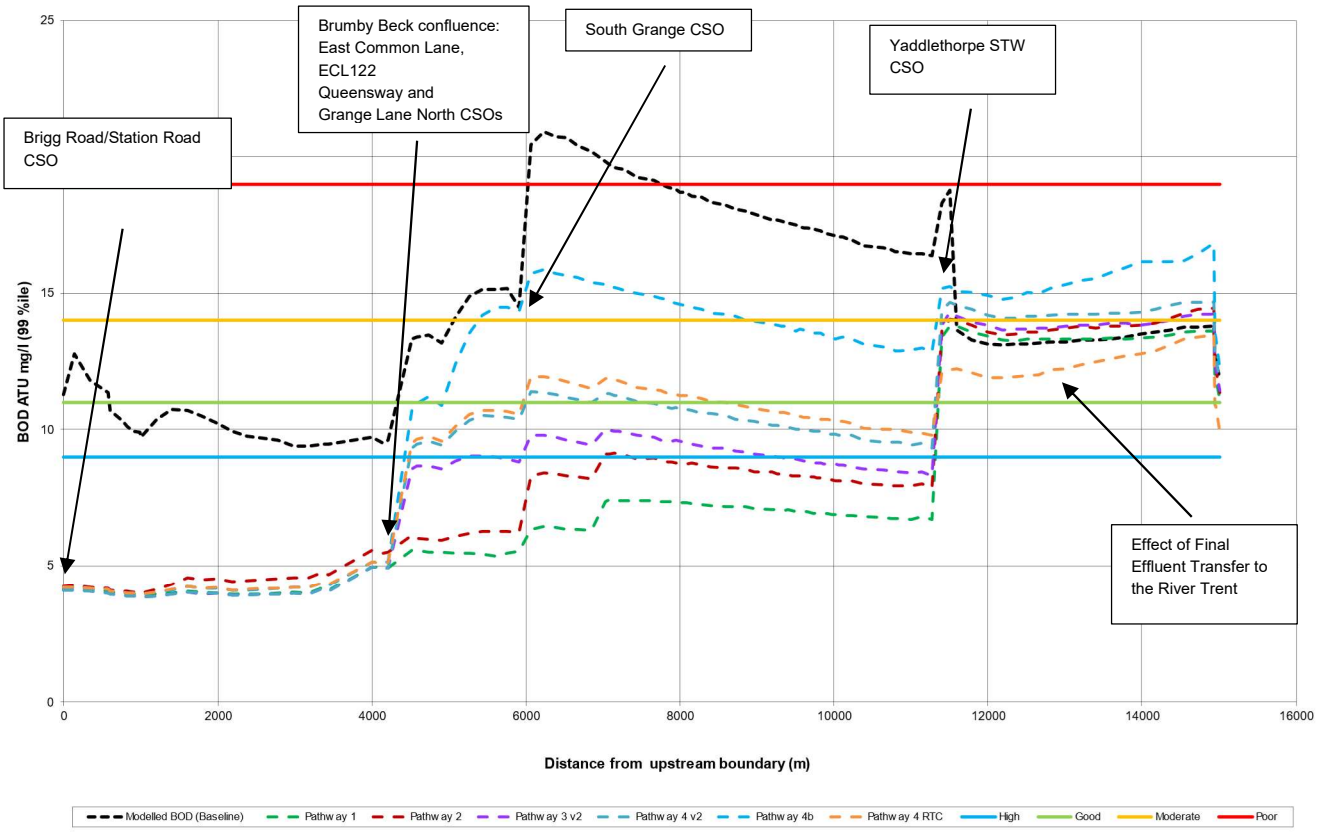

Figure 4 - BOD99%ile long section after running results with InfoWorks ICM

Volumetrically, the solution was deemed to be sufficient. However, a further level of inhibition in the tanks was required to activate them only when there was capacity at the works after storm completion, which was no later than 24hrs. A Real Time Control (RTC) scenario was developed and optimised within InfoWorks ICM to provide a return level sufficient to reduce the new BOD99 peak at Yaddlethorpe STW, but not too low to avoid increasing the retention times and create septicity.

The results for this new test, keeping the same network storage options, are shown in Figure 5. Overall, it was proved that after adding a further level of control, Options 1, 2 (not shown in Figure 5), 3, 5 and 6 could be sufficient to provide a 'Good' status along the whole of the river reach.

The effect on BOD99 of different solutions can be well observed in the Brumby Beck confluence point. As Option 1 provided the highest spill reduction for the Brumby Beck CSOs (East Common Lane CSO, East Common Lane 122 CSO, Queensway CSO and Grange Lane North CSO), BOD99 remained as "High" status along most of the Bottesford Beck.

Option 3 did not include a scheme for East Common Lane CSO and East Common Lane 122 CSOs, and Option 4, in addition, did not include a scheme for Queensway CSO either. As a result, the BOD99 was predicted to increase almost to 9 mg/l and 10 mg/l, whereas for Option 1 it remained below 6 mg/l.

The difference between Option 3 and Option 6 was that for Option 6, the new tank storage was increased from 3,120 m^3 to 5,000 m^3. However, the difference in BOD99 was less than 0.5 mg/l, with a % volumetric spill reduction increased from 33% to 45%.

Option 5 provided better results than Option 3 because of the addition of ANMC and SWS options, which provided additional BOD99 removal.

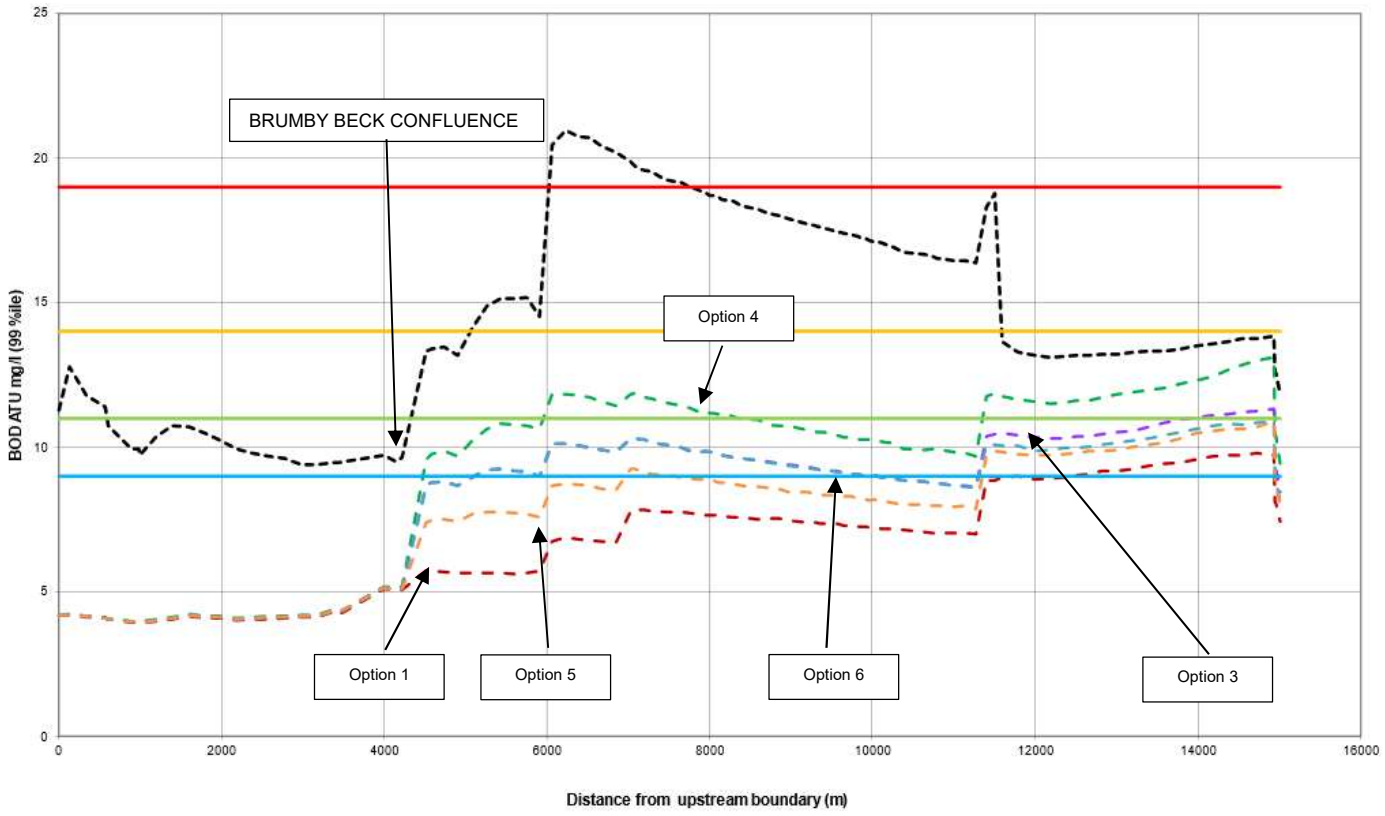

Figure 5 - BOD99 long section after adding the RTC inhibition.

FINAL OPTION

After running a few iterations and assessing the buildability of the schemes, the final option selected combined sustainable options such as separating SW sewers which have been confirmed to connect to the combined system with ANMC solutions. The shaft tanks are also going to be integrated with a telemetry system that will ensure an optimum return mechanism to hold the storm flows when the Yaddlethorpe STW storm tanks are still at maximum capacity. These solutions are predicted to improve the BOD99 levels of the Bottesford Beck to Good status. A new 3km gravity main to transfer flows to the River Trent will improve the SRP levels at the Yaddlethorpe STW discharge point, improving significantly the quality of the Beck. Achieving WFD good status for SRP at the current final effluent discharge location requires a permit limit below the current technically achievable limit, and the transfer allows for a relaxation in the ammonia permit limit, which in turn will enable the works to cater for population growth without the need to provide additional treatment capacity.

The final solution includes:

- 1,040 m3 shaft tank at Brigg Road/Station Road CSO
- 3,250 m3 shaft tank at Grange Lane North CSO
- 3,510 m3 shaft tank at South Grange CSO
- 3,120 m3 shaft tank at Yaddlethorpe STW.
- Active Network Management Control options at East Common Lane CSO, East Common Lane 122 CSO and Queensway CSO to mobilise up to 16,000 m3 of storage per year.
- SW separation provided an equivalent of 1,000 m3 of volume in a 1:1 year event or a peak flow of 150 l/s.
- A new pumping station and 3km gravity main to transfer the FE to the River Trent; and a new telemetry system to integrate the three shaft tanks with the Yaddlethorpe STW

Figure 6 provides the final BOD99 long section with a few different iterations to understand the effect of ANMC and separation.

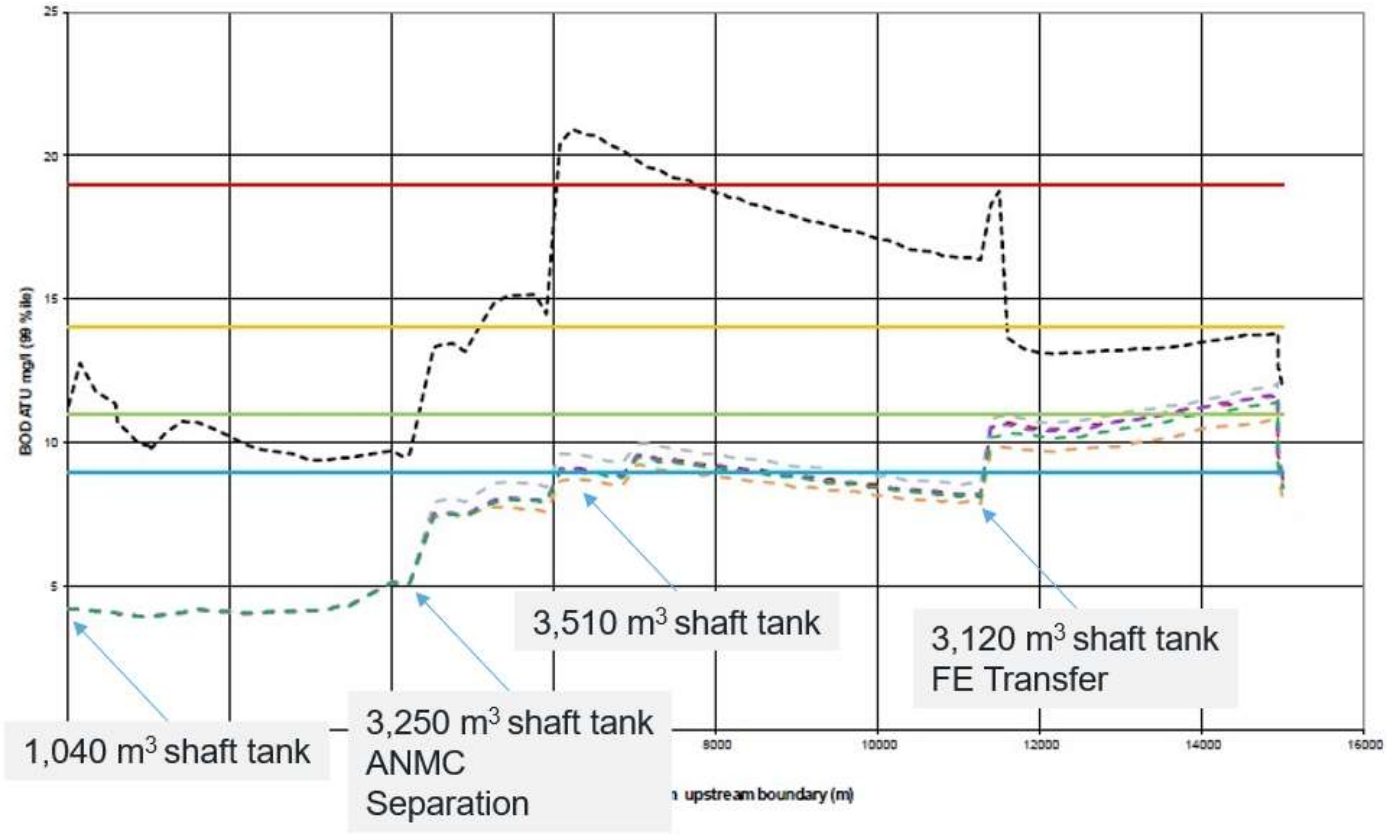

Figure 6 - Final BOD99 long section