Simplified UPM Approaches – The Complex Scunthorpe Study

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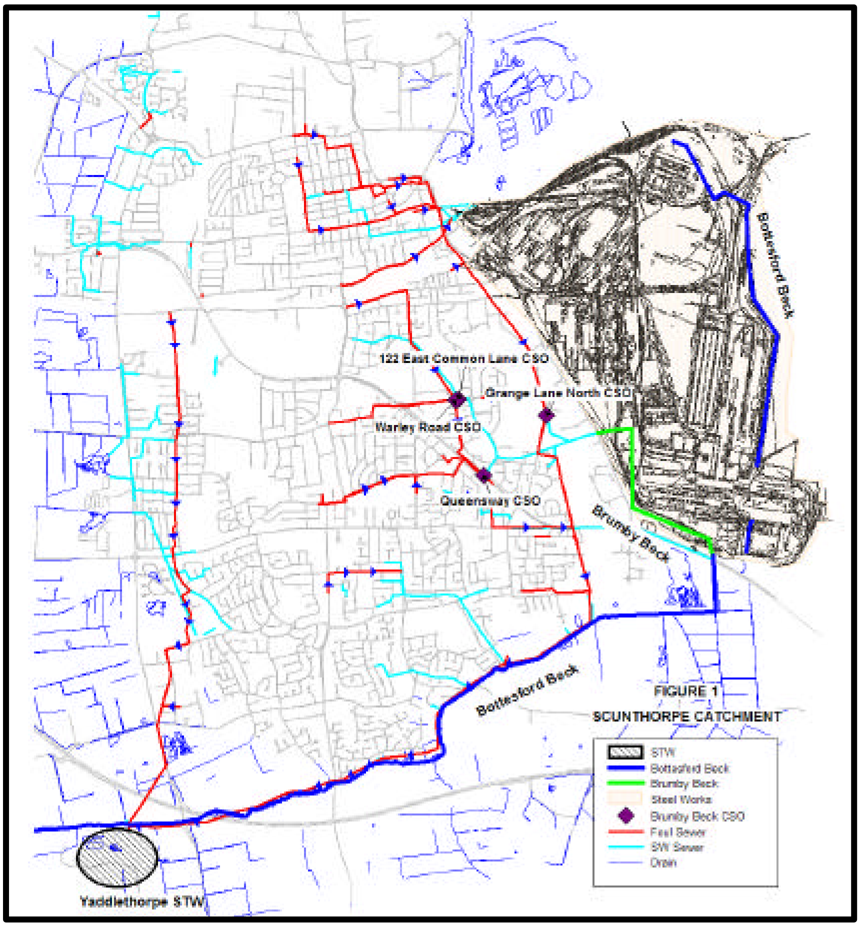
1 Introduction

Much of the focus of AMP3 has been the resolution of unsatisfactory intermittent discharges (UIDs), with a total of over 350 requiring assessment within the Severn Trent region. A large proportion of these were UIDs with water quality rather than aesthetic drivers and subsequently the EA required that UPM Procedures be followed to demonstrate that any proposed UID solutions meet the appropriate environmental quality standards.

Many of the UIDs fell into the category whereby simplified quality modelling, generally based on the 'default' approach, was appropriate to demonstrate environmental quality compliance. Due to the number of UIDs requiring this approach, a set of procedures was agreed with the EA to allow a standardised approach to simplified UPM studies to be undertaken throughout the region.

The procedures outline the broad methodology for completing simplified UPM studies on a step-by-step basis, whereby data collection is generally limited to currently available data (held by either Severn Trent Water or the EA), and the agreed modelling tools are outlined. However, fundamental to the procedures is a flexibility to allow further targeted data collection, and higher level modelling work, where this would have a significant cost benefit on any proposed solution through refining the conservative assumptions inherent in simplified studies. EA buy-in is sought in any cases where deviation from the procedures is required.



This paper highlights the issues with the Scunthorpe UPM study, where initially a simplified approach was considered adequate. However, as the study progressed, it became apparent that an extensive solution may be required and that there would be benefits in deviating from the standard approach to refine some of the conservatism and address unknowns contained within the simplified approach. Likewise, a number of issues and limitations were identified with the relatively 'black box' stochastic simplified modelling software that complicate the conclusions drawn from modelling results.

2 The Scunthorpe Catchment and Study Drivers

The Scunthorpe catchment, which covers a total area of 2,600ha and contains a total population of 75,000, is located approximately 16 miles to the south west of Hull. The River Trent runs in a south – north direction 5km to the west of Scunthorpe. The catchment is surrounded by land drains, due to the flat topography. The Bottesford Beck skirts the eastern and southern boundary of the catchment before discharging into the Trent. There is a significant amount of industry, based predominantly on the steel industry.

This study is concerned with the impact of 4 CSOs discharging to the Brumby Beck (Figure 1). Of these, the Grange Lane North CSO is the dominant spiller comprising over 85% of the total spill volume. The Brumby Beck is almost entirely culverted and drains for 1Km through a Steel Works, before discharging to the Bottesford Beck on the southern boundary of the Steel Works. This is an important point in relation to complicating issues encountered during the study. Initially, the study driver was to achieve compliance within the Brumby Beck. Given that the Brumby Beck has little natural catchment with a baseflow of only 1-5l/s and is almost entirely closed along its length through the steel works, it was agreed with the EA that it would be more appropriate to develop solutions based on achieving water quality compliance within the publicly more accessible Bottesford Beck.

3 The Simplified UPM Procedure

The basic approach involves an initial scoping study to identify and agree with the EA the impact of the UIDs, the basic modelling methodology and the water quality criteria to be adhered to (FIS or %ile, or both). Available hydraulic sewer models are identified at this stage, along with any requirements for new model build or update in the critical areas. Ancillary, flow or impermeable area surveys and verification exercises are then undertaken to ensure the hydraulic models meet the usual requirements of the WaPUG Code of Practice. In this case a verified InfoWorks DAP model was available, and this was further upgraded in the CSO areas with additional flow survey and verification. The Bottesford Beck target river class was identified by the EA as RE4 and Sustainable Cyprinid.

The procedure then identifies the starting point for the simplified river impact (RI) modelling; detailing data sources and default parameters to be used (Table 1). Recognition is given to the fact that it is often uneconomic to collect significant amounts of site-specific data, though obviously does not discount its use if it is already available.

Parameter	Source
Sewer Quality Data	➢ QSIM Defaults ➢ Estimate of storm flow concentration based on DWF concentration x ratio of storm flow to DWF at first spill ➢ Defaults identified in Tables 4.1 and 4.2 of UPM
Upstream River Quality Data (BOD and NH_3)	➢ EA routine river quality sample data ➢ Mid-Class Approach (i.e. mid point of target RE class)
After Mixing River Quality Data (DO, Temp and pH)	➢ EA routine river quality sample data ➢ DO estimate of 7.0 ± 0.5
River Mixing Parameters	Set values specified by ST based on published literature (EA guidance on SIMPOL default values)
River Flow	➢ Available EA measured data ➢ Flow estimates provided by EA
Rainfall	Historic hourly data from EA network of rain gauges disaggregated in StormPAC

Table 1 Data Sources for Simplified UPM Approach

It was agreed with the EA that the InfoWorks UPM Tool would be used to undertake the RI analysis, due to the complex nature of the sewer system and the likely need to consider long duration, successive storms. A 5-year series of historic hourly data from a nearby EA rain gauge was disaggregated in StormPAC, and generated to form 585 individual storm events with an 8-hour inter event dry period.

4 Extension of the Simplified Approach to the Scunthorpe Study

Initial RI analysis based on the basic methodology and default parameters approach indicated that due to predicted exceedences within the Bottesford Beck, a major capital scheme was likely to be required. It was subsequently considered to be a potential cost benefit to deviate from the standard procedures and enhance the confidence that could be placed in the available data or modelling approaches. The following sections detail instances where deviations from the standardised procedure were required to either refine some of the assumptions within the simplified approach, or to overcome the 'black box' river impact modelling issues and allow an improved, more relevant interpretation of the model predictions.

4.1 Effect of the Steel Works

The Bottesford Beck flows through the Steel Works (Figure 1 and 2a, 2b), as does the contributing Brumby Beck. EA BOD and NH_3 river quality sample data was only available for the Bottesford Beck downstream of the Steel Works. There was concern that a proportion of any deterioration in water quality within the Bottesford Beck may be attributed to wash off from the Steel Works, though this could obviously not be quantified. The EA are currently undertaking separate studies to identify and, if required, reduce inputs from the site. As a result, it was considered inappropriate to use the downstream river sample data due to the potential impact of the Steel Works, as this may lead to an overly conservative scheme design.

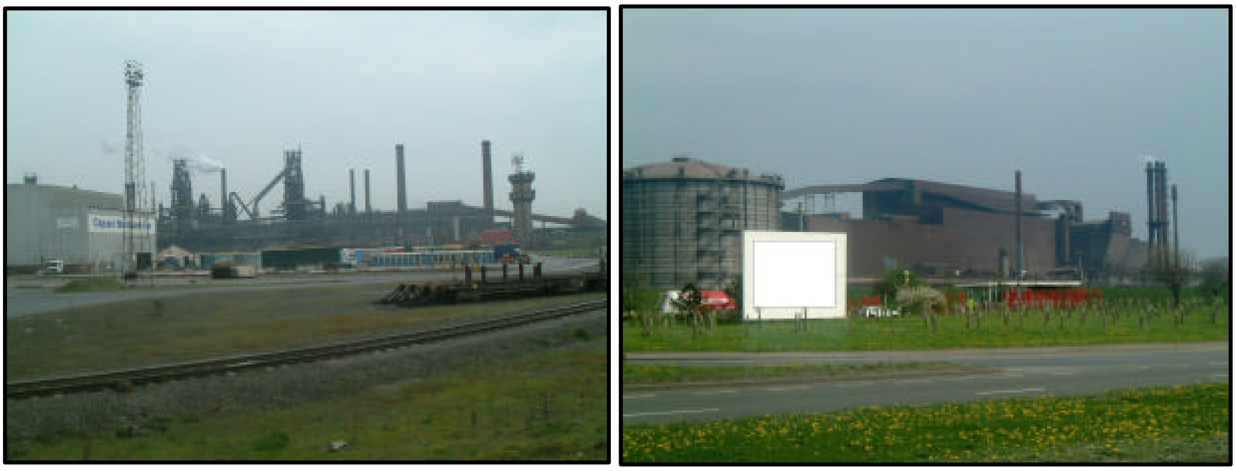


Figure 2a and 2b – Steel Works

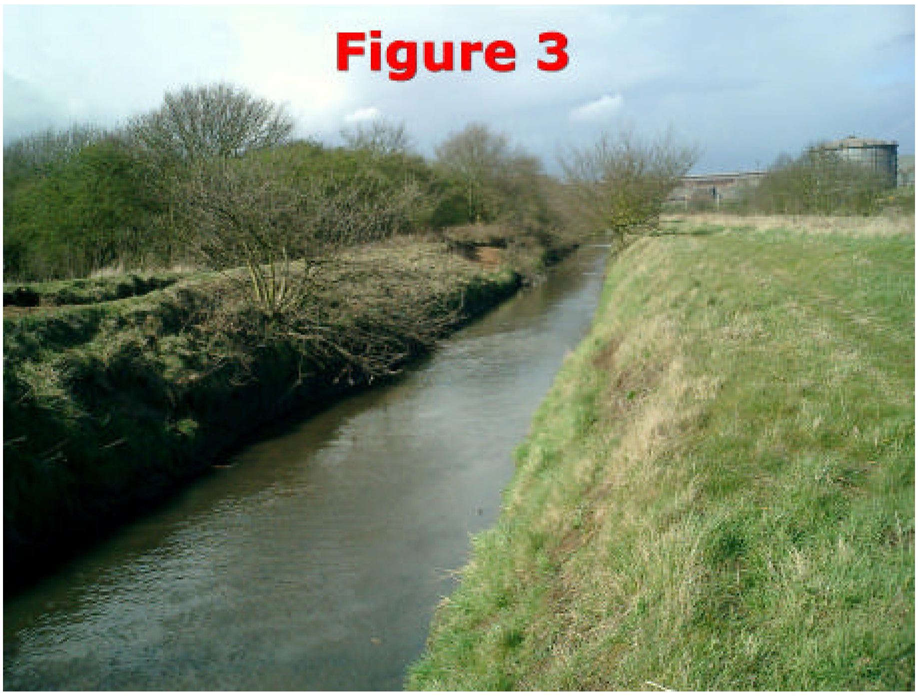
The EA asked that the mid class approach be used as a way of assessing compliance for the UID portion of any quality impact, and removing the potential influence of the Steel Works.

EA Measured Data	BOD 3.053 mg/l ± 3.718, NH_3 1.275 mg/l ± 0.649
Mid Class Data (RE4)	BOD 3.7 mg/l ± 1.8, NH_3 1.03 mg/l ± 0.72

Whilst the mid class approach results in a higher mean BOD, the higher standard deviation of the measured data may result in an unrealistic high number of extreme BOD values being utilised in any stochastic river impact modelling. The ammonia data is relatively similar.

4.2 Availability of Bottesford Beck River Flow Data

The EA do not have a flow gauge on this river and supplied calculated flow data was based on assumptions relative to 'similar' catchments. This data indicated a DWF of 18.5l/s, and a mean flow of 120.4l/s. The DWF river figure (rather than the mean) was to be used in the RI analysis, in addition to modelled surface water storm flow inputs, due to the fast response of the sewer system and dominance of the urban surface water contributions in the river flow during storm events. Figure 3 shows the Bottesford Beck during DWF conditions, and it is clear to see that the calculated DWF is a significant under estimate. This low DWF figure was queried, and following agreement with the EA, a brief flow measurement exercise in the Beck over a single dry day indicated a river DWF of 358l/s. The implications of this more representative flow data on modelled dilution and ensuing solution design are obvious. The river flow software calculates flows based on data for similar catchments in the region, yet fails to take into account site specific factors such as the large amount of artificial flow from the Steel Works and local mine drainage that provide a constant source of flow in the Bottesford Beck.



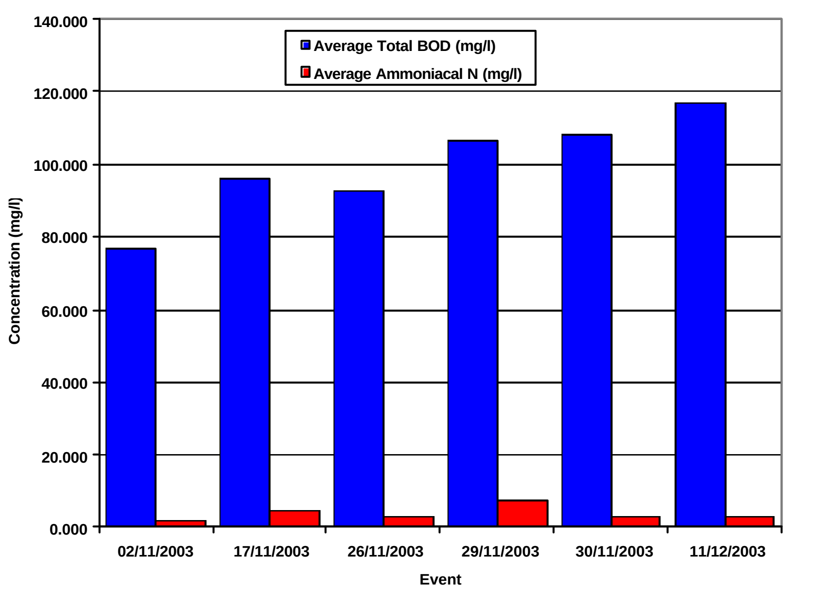
4.3 Sewage Effluent Quality

The InfoWorks QSIM module was initially used to estimate storm sewage concentrations based on default DWF load and washoff parameters. This approach predicted high pollutant loads with BOD and NH_3 concentrations of up to 1,000mg/l and 60mg/l respectively. As a result, it was deemed beneficial for a small amount of sewer quality sampling to be undertaken at the key CSO, and the constant load (or event mean spill concentration) approach being used in the RI analysis. Initially, DWF samples were obtained, indicating storm sewage BOD and NH_3 estimates of 273mg/l and 16mg/l respectively based on Table 4.1 of the UPM. Table 4.1 identifies DWF/storm flow multiplying factors of 0.5BOD and $0.3NH_3$.

This multiplying factor approach was refined further, based on the modelled storm flow at time of first spill, resulting in estimates of 55-113mg/l BOD and 5-6mg/l NH_3 at the biggest spilling CSOs. Due to the potentially significant capital works required to achieve compliance, it was considered important that more accurate data be obtained relating to the sewage effluent quality, given the potential variation in estimated concentrations following the different simplistic approaches. Subsequently, the sewer water quality sampling programme was extended to obtain sample data for a small number of storm events at the key Grange Lane North CSO.

Samples were obtained at the Grange Lane North CSO for 6 storms throughout Nov and Dec 2003, covering a range of durations, intensities and antecedent dry periods (1 day to 7 days). The individual events did show a significant difference in peak concentrations associated with the first flush (ranging from 110-376mg/l BOD and 3.5-9mg/l NH_3). However, it is clear from Figure 4 that despite the different types of storm, the observed event mean concentrations appear relatively constant, resulting in an 'all event' average concentration of 99.653mg/l BOD and 3.660mg/l NH_3 for modelling purposes.

Figure 4 Sample Sewage Effluent Concentrations



4.4 Background Failures

The RI analysis was complicated further by the issue of background unionised NH_3 (Un-NH_3) FIS exceedences. These background exceedences have the effect of artificially raising the total number of predicted exceedences attributable to the CSO inputs, and were attributable to two different potential mechanisms, which are explained in detail below. It is important that background exceedences are identified, and accounted for, as attempting to eliminate these through improving the sewer system may lead to a significantly over designed solution. However, due to the 'black box' nature of the RI modelling software, differentiating between background failures and true CSO discharge related failures is difficult, and requires a significant amount of further post processing.

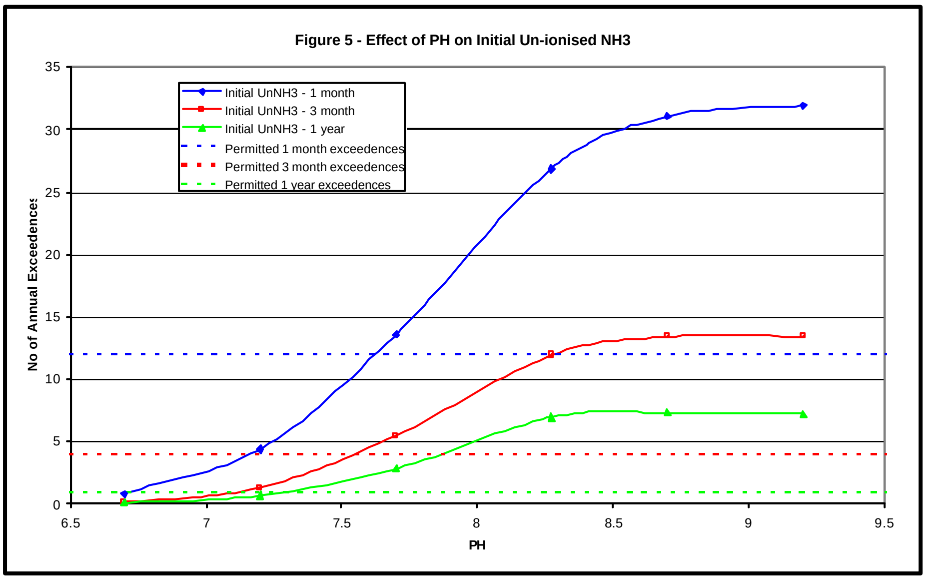
24-Hour Un-NH_3 FIS Background Exceedences

A disproportionate number of initial unionised NH_3 FIS exceedences were predicted for the 24-hour impact duration, with the pattern of these exceedences not specifically related to the larger CSO spill events. In the RI analysis, storm sewer inputs were modelled and included to provide an estimate of peak river flows during the CSO spill events. A number of the modelled events contained only the SW inputs, as the CSOs were not predicted to spill; yet Un-NH_3 exceedences were still predicted by the model. This indicates that the initial Un-NH_3 failures are a result of the stochastically generated initial river pollutant concentrations used for each event analysis, rather than the effect of mixing higher NH_3 CSO spills with the river flow.

Further filtering of the data confirmed that where initial Un-NH_3 exceedences were predicted to occur, the 10%ile stochastically generated river NH_3 concentration was 1.1mg/l. In contrast, where Un-NH_3 exceedences were predicted to not occur, the 90%ile stochastically generated river NH_3 concentration was similar at 1.2mg/l. The input mean river NH_3 concentration from which these stochastically generated values are chosen is 1.03mg/l $\pm$ 0.72. Given the pH of 8.27 and temperature of 14°C, hand calculations indicate the resulting Un-NH_3 from an NH_3 of 1.2mg/l is approximately the same as the 1 month 24 hour impact duration threshold of 0.03mg/l.

This indicates that due to the combination of input river NH_3, pH and temperature, many of the exceedences are predicted by virtue of the stochastic nature in which the upstream boundaries are generated in the RI analysis. These predicted background exceedences are independent of any CSO discharges.

The upstream NH_3 boundary condition of 1.03mg/l is not likely to be the cause of these background exceedences, as it is not a particularly high estimate. In contrast, the pH estimate of 8.27 could be considered high, and may show the influence of the upstream mine drainage or Steel Works. As a test, the analysis was repeated with decreasing values of pH, and this showed that a more realistic pH of between 7 and 7.5 acted to remove the majority of these predicted Un-NH_3 exceedences for the 24-hour impact duration (figure 5).

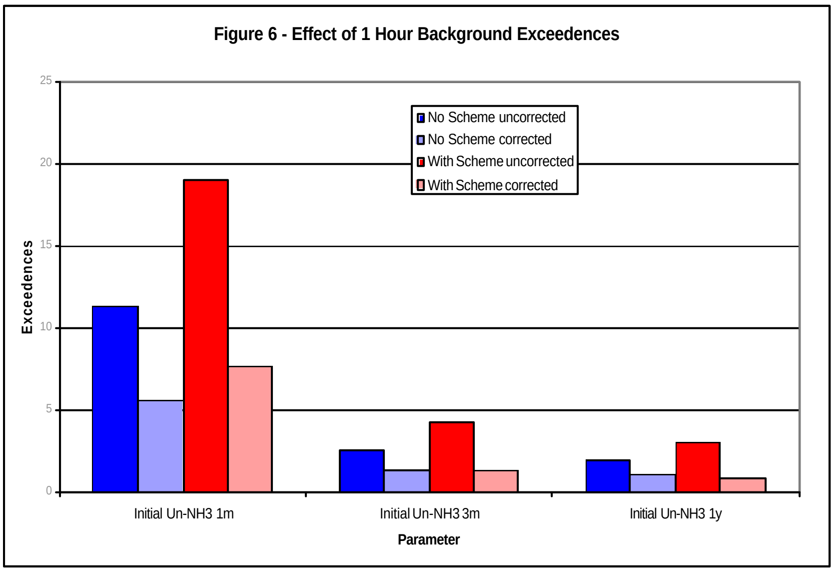


<u>1-Hour Un-NH_3 FIS Background Exceedences</u>

A number of proposed solutions were investigated to improve the existing system water quality, including offline storage at the Grange Lane North CSO. Due to the need to not worsen the hydraulic performance of the downstream sewer system, initial modelling indicated that any proposed storage solution would continue emptying for a number of hours after a rainfall event, and thus increasing the estimated sewer drain down period from 6-8 hours to 15-18 hours. In order to adequately test the performance of this proposed solution, the 5-year time series of rainfall was regenerated with an 18 hour inter event dry period, and simulated with the option model in InfoWorks. This is in contrast to the original 5 year time series that was generated with an 8 hour inter event dry period to assess the effect of successive storms during the existing system drain down period.

When the river impact analysis was repeated for the proposed solution, the predicted number of 1-hour initial Un-NH3 exceedences increased by nearly a factor of 2, despite the CSO spill frequencies and volumes being substantially reduced by the incorporation of the storage solution. This is obviously counterintuitive, and further post processing of the results was required to identify why. For the existing system '8 hour' rainfall, the 1 hour RI analysis would split the 585 events (representing 5 years) into a total of 9,673 hourly blocks, which is the total event time and any intervening dry periods simulated. Due to a baseflow in one of the surface water sewers included within the analysis, the inter event dry periods are subsequently included within the RI analysis. For each of these 1-hour blocks, the analysis would stochastically generate initial river NH_3 concentrations, of which a proportion would result in initial Un-NH_3 background failures (as in the 24 hour case discussed above). By regenerating the rainfall to include an 18-hour inter event dry period, the total simulation, and thus RI analysis time increases to 16,807 hours. By increasing the analysis frequency by increasing the period to be analysed, the number of background exceedences increases accordingly.

To account for this, post processing in MS Access was undertaken to discount all initial Un-NH_3 exceedences predicted during the 'dry periods' where only the surface water baseflow is being input to the river. Figure 6 highlights the effect of correcting the model predictions for background exceedences. Whilst this is a relatively simple process, the 'black box' nature of the RI software makes it very difficult and time consuming to identify and unravel inconsistencies such as this.



5 Conclusions

The Scunthorpe UID study was initially intended to follow the simplified approach, yet the examples discussed highlight that in order to develop the best solution, it may be necessary to deviate from the standardised approach to refine assumptions and modelling interpretations. The following conclusions can be drawn from this study:

- Standardised approaches, such as the simplified UPM procedure, are essential in providing control and direction to allow large programmes of work to be completed.
- However, these approaches must provide a degree of flexibility to allow the refinement of conservative assumptions if there is an obvious and substantial cost benefit to any proposed solution in doing so.
- Each study should be assessed on its own merits, as the data availability and confidence issues will vary on a catchment specific basis. Much of the data provided is simply used as it is the best available, however, many benefits (particularly in terms of scheme cost) can be obtained from sensibility checking this data and possibly collecting more accurate data.
- As with all modelling tools, it is necessary to question and check the model output to ensure that it is sensible and within expected bounds.
- There are issues with the simplified RI tools, particularly with the assessment of background exceedences. Improved transparency within the tools to allow these to be assessed, incorporated or removed from design would be beneficial.

Some of the issues identified in this study will help refine the procedure for use during AMP4, and hopefully be of use to similar studies.