Storm Overflow Assessment Framework

1. Overview of assessment framework

Discharges from storm overflows are a reputational issue for the water industry. Population growth, urban creep, infiltration and changing rainfall patterns will further increase the pressure on storm overflows.

The Urban Waste Water Treatment Regulations (UWWTR) require sewer networks for agglomerations with a population equivalent of 2,000 or more to be designed, constructed and maintained according to best technical knowledge not entailing excessive costs (BTKNEEC). This includes the volume and characteristics of the wastewater, the prevention of leaks, and the limitation of pollution of receiving waters due to storm water overflows. The regulations supplement the duty imposed on sewerage undertakers by the Water Industry Act 1991 to provide, improve, and extend a system of public sewers. In accordance with long-standing guidance (DETR, 1997) where such overflows have an adverse environmental impact, measures are required to address these problems.

More latterly, there have been concerns expressed regarding the frequency of discharge as well as the environmental impact. Population growth, urban creep, infiltration and changing rainfall patterns will further increase the likelihood of discharges from storm overflows.

The assessment framework set out in Figure 1 and described in stages 1 – 5 below, is intended to address the problems caused by discharges from storm overflows considered to operate at too high a frequency. The framework will ensure that the water industry is proactively monitoring and managing the performance of its overflows in light of the pressures of growth, urban creep and changing rainfall patterns. It is also intended to demonstrate that sewerage systems are compliant with relevant legislation such as the UWWTR.

The framework currently applies to discharges affecting rivers. Further work will be undertaken to extend the assessment to address storm overflows affecting lakes, estuaries and coastal waters. However, the framework will not be applied to storm overflows designed to meet bathing or shellfish water standards. The performance of these overflows will be considered under separate monitoring and investigation processes.

The need to monitor the performance of storm overflows was set out by Government in 2013, with the expectation that the majority of storm overflows be monitored by 2020 (Benyon, 2013). A risk based approach was developed to deliver this, with prioritisation according to environmental considerations, public visibility and spill frequency. Storm overflows were categorised according to discharge significance based on amenity, spill frequency and the provision of information (Environment Agency, 2013). Discharges identified as either high or medium significance under the criteria, which includes the vast majority of storm overflows, require event duration monitoring (EDM). Monitors record the frequency and duration of storm discharge events and will be installed on the following types of permitted asset discharging to Water Framework Directive (WFD) water bodies:

1. Combined sewer overflows (CSOs) on the sewer network including pumping stations

2. Storm overflows at the inlet to sewage treatment works (STWs)
3. Storm discharges from storm tanks at STWs

Storm overflows identified for EDM were included in the National Environment Programme and Water & Sewerage Company (WaSC) business plans for the Asset Management Programme 2015 – 2020 (AMP6).

Monitoring conditions and reporting requirements will be included within discharge permits for each storm overflow identified for EDM. Monitoring frequencies for high significance (EDM1) and medium significance (EDM2) discharges and the method used to count spills is summarised in Appendix A.

Once monitoring begins under a discharge permit, annual calendar year reports will be submitted to the Environment Agency (EA) by the end of February each year (unless otherwise agreed). They will summarise the number of spills recorded in the preceding calendar year and the total duration of discharge. Annual reports will be used by WaSCs to identify storm overflows for investigation that discharge too frequently and could potentially be improved through a 5-stage process illustrated in Figure 1 and summarised as follows:-

Stage 1: overflows will be identified for investigation using the following spill frequency triggers depending on the number of years for of EDM data collected (Table 1);

Table 1. Spill frequency investigation triggers.

No. of years EDM data	Investigation trigger (average no. spills/year)
1	>60
2	>50
3 or more	>40

Stage 2: where hydraulic capacity is identified as the cause of trigger exceedance during the first stage of the investigation, the level of environmental impact will be quantified;

Stage 3: improvement options are assessed including analysis of the costs and benefits;

Stage 4: a decision is made based on the cost benefit results;

Stage 5: delivery of the most cost beneficial solution (subject to appropriate funding and prioritisation) to reduce environmental impact and/or reduce the frequency of discharges.

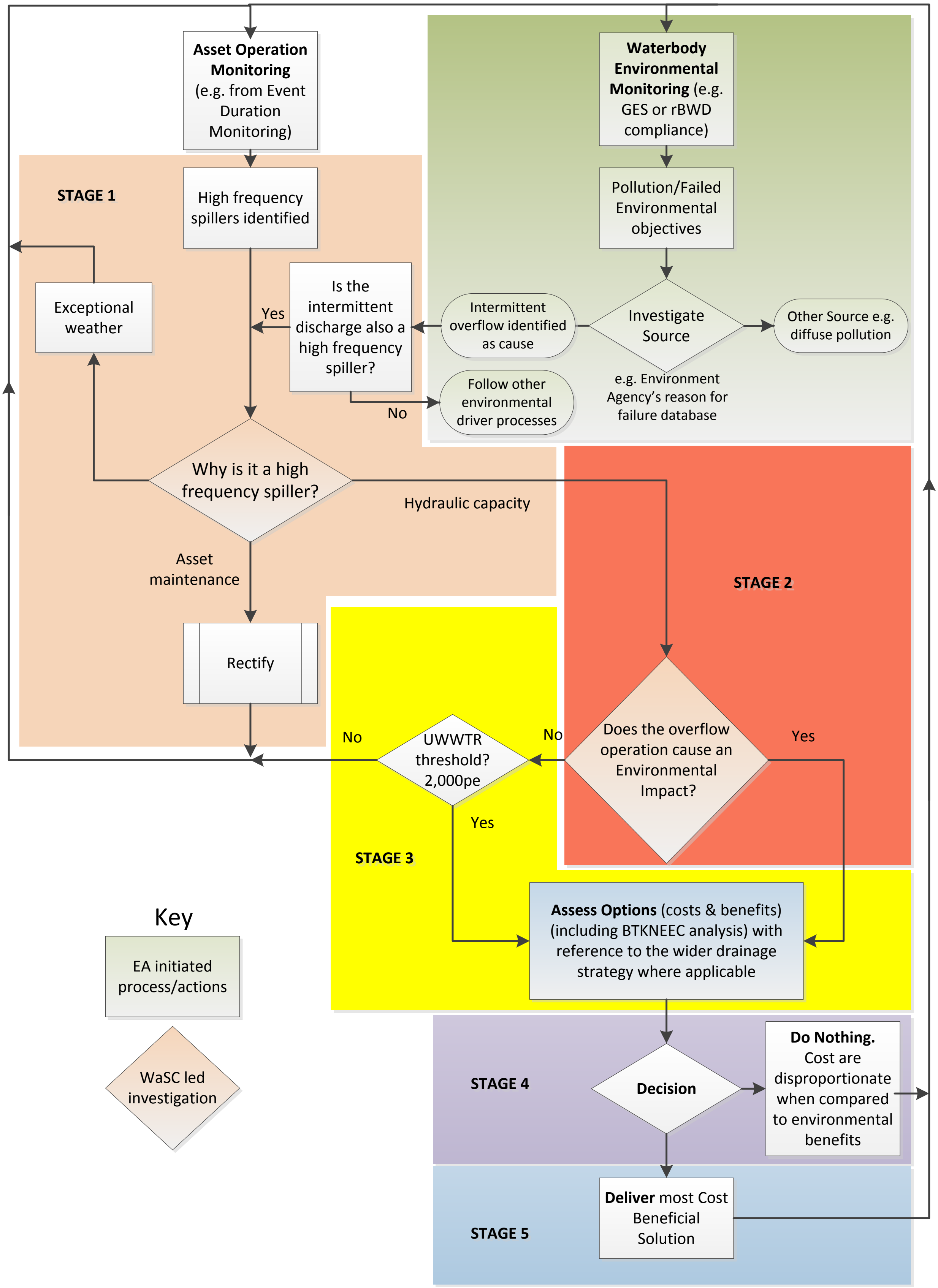

Figure 1. Assessment framework for addressing high frequency discharges from storm overflows under the UWWTR.

2. Stages of the assessment framework

2.1 Stage 1 – Why is the storm overflow a high frequency spiller?

Once a storm overflow has been identified as a high frequency spiller through EDM, the first stage in the assessment framework involves identifying the factors that are causing frequent spills in excess of the investigation triggers (Table 1). This involves the following three main sub-stages:

Stage 1a – Exceptional rainfall

Catchment rainfall should be reviewed to determine whether rainfall was exceptional during any of the EDM reporting years. If rainfall was exceptional, the relevant calendar year of EDM data should be marked accordingly and not used. The remaining years of data is assessed against the triggers (Table 1). This is intended to avoid carrying out investigations when frequent spills have been driven by exceptional wet weather, in order to prioritise investigations to assets which spill frequently in more typical years.

The following two options can be used to assess whether rainfall was exceptional:

a) EA water situation reports

Water situation reports are published each month at a hydrological area level and include rainfall statistics for the last 12 months. Rainfall is typically reported as a percentage of a long-term annual average figure and categorised according to 7 classes, from 'exceptionally low' through to 'exceptionally high'. The probability ranking used to define the categories for rainfall and other hydrological parameters is updated every five years as the period of long-term observed data increases. If rainfall during the year was classified as 'exceptionally high', then that year's EDM data is not used in assessing whether the high frequency trigger has been exceeded. The 'exceptionally high' category is defined as a value that is likely to fall within the band for 5% of the time.

Water situation reports for England are available on gov.uk. An example of a water situation report for Yorkshire is shown in Appendix B.

b) Local rainfall records

Water situation reports provide an indication of exceptional rainfall at a hydrological area level. They may not be representative of some local catchments within that area. Consequently, an alternative is to use local rainfall data for the catchment where available and use this to estimate if rainfall during the EDM calendar year was exceptional (5% probability). This may be carried out to varying levels of complexity, but at an overall annual resolution. For example, the total depth of rainfall recorded by the gauge in the year could be compared to the long-term record to decide whether it was exceptional. Alternatively, the number of rainfall events of the same critical duration of the overflow could be counted and compared to the long-term annual average for those events. However, individual spill events or time periods within the annual dataset should not be excluded.

Where rainfall has not been exceptional and the EDM trigger is exceeded, the following sub-stages are used to establish why the overflow is spilling frequently:

Stage 1b – Asset maintenance

This stage in the process is about investigating the asset and potentially parts of the upstream and downstream catchment to examine if the high spill frequency is the result of a maintenance issue. If available, existing verified hydraulic models, survey data and maintenance records will assist with this assessment. Asset inspection could include one or more of the following aspects depending on the asset type and potential issue:

a) Storm overflows on gravity sewers
Inspection of the overflow chamber and any relevant flow controls, for example orifice plates, penstocks and throttle pipes, to see if there are any obstructions responsible for the high spill frequency. CCTV inspection of downstream sewers from the overflow to check for any service or structural defects that will reduce the hydraulic capacity of the continuation sewer, such as obstructions, debris/silt and deformation or partial collapse.

b) Storm overflows at pumping stations
Where the pass forward flow of an overflow is controlled by one or more downstream pumps, they can be inspected for any service issues that might be responsible for the high spill frequency. For example, partial or soft blockages, worn impellors, failed reflux valves and leaking pipework. The condition of the rising main can also be inspected.

c) Storm overflows at sewage treatment works
For inlet and settled storm overflows at STWs, the downstream flow controls and treatment units can be reviewed to identify any issues that might be contributing to high spill frequencies. This might include inspection of pumps at inlet pumping stations, the condition of inlet screens, manual and automatic controls regulating flow to full treatment (FFT), such as actuated penstocks and variable speed pumps, and any service issues with downstream pipework or treatment units.

d) Infiltration assessments

Where existing long or short-term flow data is available, such as MCERTified data at STWs or flow data used to verify sewer models of the catchment, this data could be reviewed to see if the catchment has a strong seasonal flow response due to groundwater or rainfall induced infiltration. The EA’s water situation reports include an assessment of groundwater levels that may assist with investigations should infiltration be suspected. The reports categorise groundwater levels according to 7 classes from ‘exceptionally low’ through to ‘exceptionally high’, based on historic datasets from observation boreholes. An example of a groundwater assessment for Yorkshire is shown in Appendix C. In the case that infiltration is suspected or already known to be an issue in the catchment, infiltration studies should be carried out. Tools, such as the infiltration risk tool developed by the UKWIR Strategic Infiltration project, could be used to prioritise surveys to parts of the catchment at most risk based on groundwater availability and pipe integrity (UKWIR, 2012).

e) Crossed connections / misconnections investigation

Where there is the potential for the foul/combined system to interact with surface water drainage upstream of the overflow, investigations might assess whether misconnected surface water is the cause of high spill frequencies. For example, surface water sewers in poor service or structural condition on dual manhole systems may cause surface water to enter the foul/combined.

If maintenance issues are identified as the likely cause of frequent discharges, then these problems should be rectified. Timescales for resolving the issue will vary according to the problem, local constraints and the proposed resolution. However, with the exception of infiltration, it is expected that most issues will be resolved within the calendar year that the investigation is triggered. Where infiltration is the issue, it is expected that an infiltration reduction plan (IRP) will be developed to address the problem. It is recognised that investigation and resolution of infiltration issues can be difficult, that solutions may be iterative, and that IRPs may only succeed over the medium to long-term.

Once the issue has been rectified, the annual EDM dataset(s) that triggered the investigation should be archived and not included in future assessments against the triggers. Only the annual dataset(s) affected by the maintenance issue should be excluded from future assessments. For example, if it is known based on level trends that a partial blockage only caused an issue during one calendar year, then only this year's EDM data should be excluded. Evidence of the maintenance issue will be required to exclude datasets. This may include photographic evidence of poor service condition, such as from CCTV surveys or manual inspections, level trend data from EDM indicating transient silt, and records of maintenance carried out (e.g. sewer jetting and pump repairs).

In the case that asset inspection does not identify reasons that are likely to be responsible for the high spill frequency, the following investigation of the hydraulic performance of the overflow is required:

Stage 1c – Hydraulic assessment

If a verified hydraulic model of the overflow is already available, this should be used to assess whether the high spill frequency is a genuine reflection of the permitted hydraulic design of the asset, and the amount of connected area contributing rainfall runoff. Alongside asset inspections carried out under stage 1b (above), models may have already been used to determine that the high spill frequency is not due to maintenance issues.

Where a verified hydraulic model is not already available, a new model will be required to predict the performance of the overflow. A verified model is also likely to be required in order to quantify the environmental impact of the overflow under stage 2. In order to have confidence in model predictions, models should be verified in accordance with the CIWEM Urban Drainage Group Code of Practice for the Hydraulic Modelling of Urban Drainage Systems (CIWEM UDG, 2017). The EDM datasets will assist with verification.

3. Stage 2 – Does the storm overflow cause an environmental impact?

The following impact assessment will be used to quantify the environmental impact of the storm overflow. The assessment is divided into three main components:

- Aesthetic impact including amenity and public complaint
- Invertebrate (biological) impact
- Water quality impact

Each of these components is scored and classified separately depending on the information available, and will link to the cost and benefits analysis for overflow improvements under stage 3. The process is illustrated in Figure 2. It is hierarchical and gives preference to invertebrate impact data over modelled water quality assessments. The process is summarised as follows:

Stage 2a: the process begins with an aesthetics assessment. A score and classification ranging from no impact to severe impact is assigned to the overflow.

Stage 2b: where it is possible to collect representative invertebrate samples upstream and downstream of the overflow, an invertebrate impact classification will be assigned, ranging from no impact to extremely severe. Where the invertebrate assessment is possible, an assessment of water quality impact based on levels of dilution or modelling is not needed. The invertebrate samples provide evidence of the degree of impact.

Stage 2c: an assessment of water quality impact is required where it is not possible to collect representative invertebrate samples upstream and downstream of the outfall. The water quality impact assessment involves an initial assessment based on dilution. If the dilution criteria are not met, a modelled impact assessment is required. The overflow is then assigned a water quality impact classification ranging from no impact to severe impact.

More detail on the individual components is provided under stages 2a – 2c below.

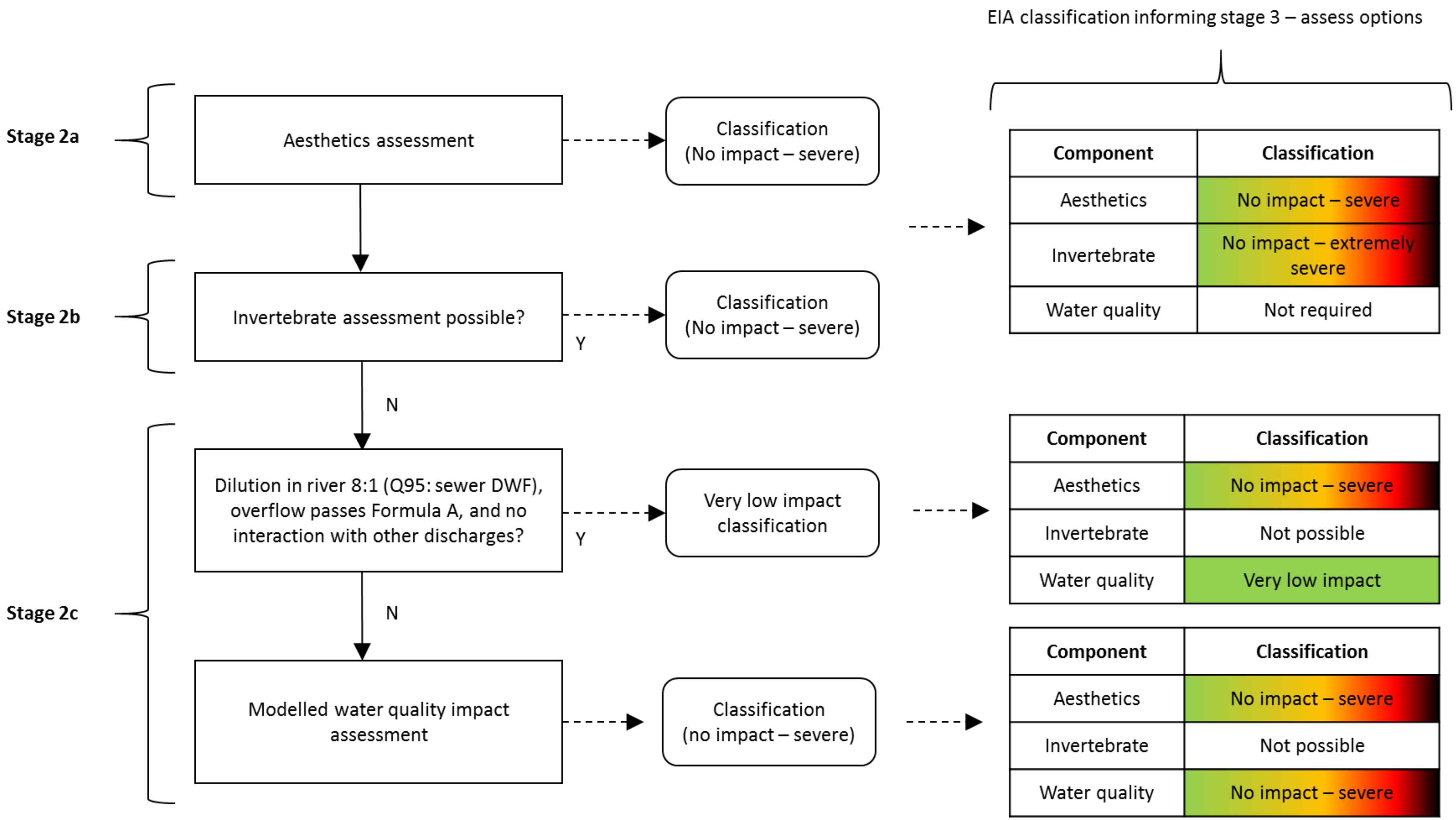

Figure 2. Summary of environmental impact assessment process.

Stage 2a – Aesthetics Assessment

The purpose of this component is to address issues surrounding the public acceptability of storm overflows in terms of visible impact, the amenity value of the receiving water, any history of substantiated public complaint, and any history of recorded pollution incidents due to storm sewage discharges. These four subcomponents are set out in Table 2 below. Each subcomponent is scored separately and the individual scores summed to give a total score. The impact classification according to this total score is shown in Table 3.

Aesthetics surveys will be based on the FR0466 methodology (FWR, 1994), but will use the scoring system in Table 2. Where it is foreseeable that litter may be stranded and visible in areas downstream of the notional 50m survey area defined in FR0466, the survey should be extended to include this area. This will be important where the amenity class increases downstream of the immediate 50m reach. For example, where there is a park alongside the watercourse 300m downstream of the outfall, then this would be included in the aesthetics assessment.

Due to the potential effects of bankside vegetation on access, visibility and the potential for litter to collect, two surveys will be required to judge aesthetic impact. One survey should take place in late autumn, winter or early spring (November – April) when any bankside vegetation is minimal, and one survey should take place between late spring and early autumn (May – October). The worst score returned by the two surveys will be used.

Where more than one overflow impacts the outfall (e.g. where discharges are made to a common surface water sewer), judgement will be required in order to assign a score taking into account whether the overflows are screened and their comparative spill volumes.

Amenity is explicitly included in the impact scoring (see Table 2). As a result, moderate and high amenity sites will always trigger, as a minimum, a 'very low impact' classification even where there is no evidence of debris, public complaint or pollution incidents. It is included because two seasonal aesthetics surveys may not be sufficient to identify a problem. The overflow will always pose a risk of aesthetic impact and complaint in areas of moderate to high amenity.

Amenity will be selected according to the highest amenity class within 1km downstream of the overflow, or by using judgement as appropriate. For aesthetics purposes amenity categories are defined in Appendix D.

Pollution incidents recorded on the Environment Agency's National Incident Recording System (NIRS) will be used in the assessment (Table 2). Only incidents attributed to legitimate wet weather discharges from the overflow should be included. These incidents will be recorded in NIRS with a pollutant type of 'storm sewage'. Pollution incidents in dry weather, for example due to problems such as blockages, should be excluded from the assessment.

Table 2. Aesthetics impact assessment

Aesthetics		**Score**
Sewage derived litter (no. of items) downstream	0	0
	1 – 10	5
	11 – 25	10
	26 – 50	15
	>50	20
Sewage fungus on outfall (present / absent)	N	0
	Y	5
Sewage fungus in downstream mixing zone (% cover)	0	0
	<2	5
	2 – 10	10
	11 – 25	15
	26 – 50	20
	>50	25
Amenity		**Score**
Low or none amenity		0
Moderate amenity		5
High amenity		10
Public complaints		**Score**
No. of validated public complaints related to wet weather discharges from the overflow	0	0
	1 – 4	10
	5 – 9	20
	10 – 14	30
	15 or more	40
Pollution incidents due to storm sewage	**Incident category**	**Score (per incident)**
NIRS incidents due to storm sewage attributed to the overflow	Cat 3	20
	Cat 2	60
	Cat 1	100
Total score		?

Table 3. Aesthetic impact classification

Total Aesthetic Score	Aesthetic impact classification
0	No impact
1 – 10	Very low
11 – 25	Low
26 – 50	Moderate
51 – 75	High
>75	Severe

Stage 2b – Invertebrate impact

Where it is possible to collect representative benthic invertebrate samples immediately upstream and downstream of the overflow, impact will be assessed using abundance weighted Whalley Hawkes Paisley Trigg (WHPT) indices with the River Invertebrate Classification Tool (RICT). This is the method used for WFD assessments (UKTAG, 2014). The method is designed to detect impacts due to organic pollution and is also sensitive to toxic pollutants. The RICT was developed by the three UK environmental agencies to classify the ecological quality of rivers. It is hosted by the Scottish Environmental Protection Agency (SEPA) and is available online.

Invertebrate sampling is only appropriate in simple scenarios where there is a single storm overflow discharging to that reach of the river. Where there are multiple outfalls in close proximity, or other sources of pollution which could account for differences in invertebrate quality between sampling sites upstream and downstream of the outfall, then this method should not be used. In degraded urban watercourses where background / upstream invertebrate quality is already poor status then this method should also not be used.

Invertebrate sampling and analysis should be carried out according to Environment Agency operational instructions 024_08 and 018_08 (Environment Agency 2014, 2017). A minimum of two separate seasonal samples are required – one taken in the spring (March – May), and one taken in the autumn (September – November). The number of abundance weighted WHPT scoring families found during sampling (WHPT NTAXA), and their individual abundance weighted scores for sensitivity to organic pollution are recorded. An average score per taxon (ASPT) for the sample is then calculated. The observed abundance weighted WHPT NTAXA and ASPT values are compared to the values that might be expected under undisturbed or reference conditions for that site. These undisturbed or reference scores are predicted by statistical models in the RICT software. The observed values of WHPT ASPT and WHPT NTAXA are compared to the predicted values to generate an Environmental Quality Ratio (EQR). EQRs close to 1.0 indicate that invertebrate communities are close to their natural state. The EQR ratios for different WFD invertebrate status classes are shown in Table 4 below.

Table 4. Environmental quality ratios for invertebrate status

EQR Values		Invertebrate Status Class
WHPT NTAXA	**WHPT ASPT**	
>=0.8	>=0.97	High
>=0.68	>=0.86	Good
>=0.56	>=0.72	Moderate
>=0.47	>=0.53	Poor
<0.47	<0.53	Bad

During WFD assessments prediction and classification of invertebrate quality is carried out for each of the individual spring and autumn samples. A mean EQR is then calculated for the two seasons. Overall classification is based on the worst status class assigned for the multi – season mean WHPT NTAXA and WHPT ASPT. The RICT uses Monte Carlo processes to simulate uncertainty in observed and expected EQRs due to factors such as sampling variation, error in measuring environmental variables, and laboratory processing errors (bias). The software typically uses 10,000 'shots' to build up a distribution of potential EQRs in order to estimate confidence of status class. To assess the impact of high frequency spillers, the RICT Compare Module will be used to compare the quality of the upstream and downstream sampling sites. The 'Compare – At a Glance' report will be used. This shows the percentage number of simulations where the downstream sample is in a different status class to the upstream sample for both WHPT NTAXA and ASPT. The scoring system in Tables 5a and 5b below will be used for both indices (WHPT NTAXA & ASPT):

Table 5a. Invertebrate impact scoring for WHPT NTAXA & ASPT.

% of simulations the downstream sample is one or more classes worse than upstream	Score	Class Multiplier
1 – 4	1	× No. of classes the downstream sample is worse than upstream
5 – 9	2	
10 – 29	4	
30 – 49	6	
50 – 70	8	
71 – 90	10	
>90	12	

Table 5b. Invertebrate impact classification for WHPT NTAXA & ASPT.

Total score	Overall classification
1	No impact
2 – 3	Very low
4 – 5	Low
6 – 7	Moderate
8 – 9	High
10 – 11	Very high
12 – 15	Severe
16 – 19	Very severe
20 or more	Extremely severe

The worst score for WHPT NTAXA and ASPT should be used to assign impact. The scoring process will be repeated for each of the individual spring and autumn samples, and the overall mean of the seasons in order to produce a short – term and long – term impact assessment (Table 5c). A worked example is shown in Appendix F.

Table 5c. Overall short and long – term invertebrate impact classification

Type	Description	Value
Short – term	Worst single season classification result for WHPT NTAXA and ASPT	No impact – extremely severe
Long – term	Worst of WHPT NTAXA and ASPT for the overall multi season (spring & autumn) classification	No impact – extremely severe

Where available, existing biological monitoring data for fish and invertebrates used for WFD classification may be used to provide additional evidence that the overflow is not causing an environmental impact. For example, where representative sampling points are present downstream of the overflow, in close proximity, or in locations likely to be sensitive to discharges from the overflow, and these consistently record good or high status, then this may be used as evidence to support no impact classifications.

Stage 2c – Water quality impact

For many storm overflows it will not be possible or appropriate to collect invertebrate samples immediately upstream and downstream of the outfall. For example, where the overflow discharges into a surface water sewer, which also receives spills from other overflows, directly attributing any impact on invertebrate communities to the high frequency spiller will be difficult. Similarly, where there are multiple discharges in close proximity, or upstream invertebrate quality is already poor in degraded urban watercourses, the invertebrate assessment will be inappropriate. Consequently, in these circumstances a modelled assessment of water quality impact is required to inform the environmental impact assessment.

In order to reduce the need for water quality modelling, an initial screening assessment based on dilution will be used to identify those overflows that are unlikely to be causing water quality issues and jeopardising water quality standards. If the overflow passes forward a retained flow of Formula A over the full duration of spills, the dilution in the receiving water is >8:1 (Q95 river flow: sewer DWF), and there is no potential for interaction with other discharges, then a water quality classification of 'very low' should be assigned. Formula A is defined in Technical Guidance Note 7.01 available on gov.uk.

If the dilution criteria above are not met, then the impact of the overflow on river water quality will be assessed using water quality modelling. The assessment should quantify the impact of the storm overflow on the duration of 99 percentile exceedance, or 99 percentile quality for total ammonia and BOD, and the number of exceedances of the fundamental intermittent standards (FIS) for dissolved oxygen and un-ionised ammonia. This should be undertaken as a relative assessment by comparing the impact of the urban drainage system on downstream river quality with and without the discharge from the storm overflow.

Although a verified sewer model is required to assess impact (as developed under Stage 1), it is not expected that complex sewer quality and dynamic river quality modelling is carried out in all cases. The third edition of the Urban Pollution Management (UPM) manual provides guidance on modelling the impact of storm discharges (FWR, 2012). The level of complexity involved depends on the complexity of the problem and the potential cost of any solutions. A complex problem, for example where a large number of storm overflows discharge into a river channel which contains structures such as weirs or sluices likely to affect quality, will need more detailed models and data collection. In contrast, simplified impact approaches will be sufficient for simple scenarios, for example where a single or very small number of overflows discharge into a simple river reach and dilution levels are relatively high. For the purposes of the SOAF, guidance on potential modelling approaches is provided in Appendix G. This is intended to assist with scoping investigations. There are four levels of complexity:

Level 1

This is the simplest form of impact assessment. Time series outputs from the verified sewer model are mixed with random picks of upstream river flow and quality selected from statistical distributions. Default or sampled values for storm sewage BOD and total ammonia concentrations can be used and applied as an event mean concentration. The river reach is simplified to a trapezoidal channel. Hydraulic equations are used to estimate the depth and velocity of the mixed flow of river and storm sewage. A simplified water quality model usually representing the main oxygen demand processes (BOD decay and nitrification) and re-aeration is used to predict levels of dissolved oxygen and un-ionised ammonia at the end of the reach. Checks against 99 percentile standards and initial un-ionised ammonia can be made at the point of mixing.

Level 2

This is similar to level 1. However, instead of a stochastic approach to representing upstream river flow, a river flow time series is used. This allows the flow and therefore dilution available in the river at the time of a spill to be better represented. As in level 1, simplified river hydraulics and water quality are still used to predict the time of travel for pollutants along the reach, and the depth and velocity of flow used to predict re-aeration rates.

Level 3

In level 3 studies calibrated flow routing models are used to more accurately predict time of travel along longer and more complex water bodies. This allows better representation of advective pollutant transport. More complex water quality simulation can be used with the model calibrated for the key parameters – BOD, ammonia and dissolved oxygen – using observed event sampling and water quality sonde data. Storm sewage quality is represented using observed sampling data or calibrated sewer quality models.

Level 4

This is the most complex form of impact model. Calibrated hydrodynamic river models used to simulate the varying depth and velocity of flow within the watercourse. Advection and dispersion is calibrated against observed data (e.g. dye tracing). Various levels of water quality simulation are possible with calibration and verification against event sampling and water quality sonde data.

For all levels, a long (minimum 10 year) historic or synthetic rainfall time series representative of the catchment is required.

New models are not required in all cases. Where they are 'fit for purpose', existing sewer and river impact models from recent drainage planning or UPM studies should be used.

Impact scoring

The worst water quality score from the two types of assessment (99 percentiles and FIS) should be used as follows:

1) 99 percentile quality

Two approaches are available depending on the type of modelling tool used:

A) Estimate of 99 percentile

Select the relevant 99 percentile BOD and total ammonia standards for the receiving water according to WFD water body typology. These standards can be obtained from the third edition of the UPM manual (FWR, 2012). As an example, Table 6 below shows the 99 percentile classes for water body types 3, 5 and 7. Where there is a drop in 99 percentile status class between the modelled upstream and downstream assessment points assign a score of 45.

Table 6. 99 percentile standards for WFD water body types 3, 5 and 7.

WFD status for water body types 3, 5 and 7	99 percentile	
	BOD (mg/l)	Total ammonia (mg/l)
High	9.0	0.7
Good	11.0	1.5
Moderate	14.0	2.6
Poor	19.0	6.0

Where the overflow does not cause a drop in status class but causes a degree of within class deterioration, assign a score according to the percentage within class deterioration as shown in Table 7 below. Use the worst score returned for the BOD and total ammonia assessments.

Table 7. 99th percentile within class deterioration scores.

Percentage within class deterioration	Score
1 – 10	5
11 – 25	15
26 – 50	25
51 – 75	35
>75	45

B) Duration of exceedance

Where modelling tools are used which do not calculate a 99th percentile, but instead estimate the duration for which a 99th percentile standard is exceeded, then use the following scoring system in conjunction with the 99th percentile BOD and total ammonia standards for good status (Table 8). The impact duration with the worst score should be used.

Table 8. Scoring system for duration / number of 99th percentile exceedances.

Impact duration	Allowable exceedances (no./year)	Score
1 hour	87.6	+ 0.50 points for every 1.0/yr increase in exceedances
6 hours	14.6	+ 3.0 points for every 1.0/yr increase in exceedances
24 hours	3.65	+ 12.0 points for every 1.0/yr increase in exceedances

2) Fundamental intermittent standards

Select the relevant fundamental intermittent standards for the receiving water according to fishery type (sustainable cyprinid, sustainable salmonid and salmonid spawning). The FIS for dissolved oxygen and un-ionised ammonia are available in the third edition of the UPM manual (FWR, 2012). Compare the frequency of FIS exceedances in the receiving water with and without the storm discharge. For example, the FIS for dissolved oxygen in sustainable cyprinid waters (correction factors are also required) are shown in Table 9 below.

Table 9. Fundamental intermittent dissolved oxygen standards for sustainable cyprinid waters

Frequency (return period)	Dissolved oxygen concentrations (mg/l)		
	1 hour	6 hours	24 hours
1 month	4.0	5.0	5.5
3 months	3.5	4.5	5.0
1 year	3.0	4.0	4.5

Use the following scoring system where the discharge causes a deterioration (increase) in the frequency of allowable exceedances:

Table 10. Scoring system for increases in FIS exceedances for un-ionised ammonia and dissolved oxygen.

Frequency (return period)	Allowable exceedances (no. / year)	Score
1 month	12	+ 1.5 point for every 0.5/yr increase in exceedances
3 months	4	+ 4 points for every 0.5/yr increase in exceedances
1 year	1	+ 6 points for every 0.2/yr increase in exceedances

The worst score obtained from the FIS and 99 percentile assessments should be used for the water quality impact classification set out in Table 11 below.

Table 11. Water quality impact classification.

Water quality Score	Water quality impact classification
0 – 5	No impact
6 – 9	Very low
10 – 19	Low
20 – 29	Moderate
30 – 39	High
40 or more	Severe

It is expected that environmental impact assessments will take up to 24 months to complete. This will allow sufficient time to carry out seasonal invertebrate sampling and aesthetic surveys, and allow sufficient time to complete sewer and river impact modelling. Once the impact assessments are complete and the scores calculated, options for improving the overflow, including assessment of the costs and benefits of improvement options, will be assessed under stage 3.

4. Stage 3 – Assess options

An economic assessment of improvement options for storm overflows will be made under two circumstances:

i) The overflow causes an environmental impact as assessed under SOAF Stage 2. An overflow has an environmental impact if its aesthetic, invertebrate, or water quality impact classification is 'very low' or greater.

ii) The overflow does not cause an environmental impact as assessed under SOAF Stage 2, but the overflow is located within an agglomeration which has a PE of 2000 or more. The UWWTR require sewer networks for agglomerations with a PE of 2000 or more to be designed, constructed and maintained according to BTKNEEC. Consequently, where frequently spilling overflows in these drainage areas do not cause environmental impacts, BTKNEEC still needs to be considered through an assessment of the costs and benefits of reducing spill frequency. The interpretation and definition of 'agglomeration' and 'population equivalent' is described in Appendix H.

The economic assessment of overflow improvement options involves an ecosystem services approach, which identifies both the direct and indirect benefits of overflow improvement. The ecosystem services considered include a range of environmental, social and economic services, which have the potential to be impacted by storm discharges. A detailed methodology and framework for carrying out the assessment is available in a separate report and accompanying practitioner's guide (Water UK, 2017). The aim of the process is to assess the costs and benefits of improvement options to allow investment decisions to be made under Stage 4 of the SOAF. The assessment framework involves six key steps. These are summarised below and shown in Figure 3:

Step 1 – Set decision making context

This step explicitly sets out the overall objective of the options to reduce the frequency of storm discharges. The overall objective is to identify the most cost – beneficial option, which provides the best value for customers, the environment and society. In this context, the degree to which spill frequencies are reduced is set where the value of the benefits is greatest compared to the costs incurred. However, this overall objective may be limited by certain criteria, for example where it is important that a solution meets minimum water quality standards. Alternatively, the desired or target outcome may include other objectives, such as reducing flood risk. This initial step also sets out other key parameters which will affect CBA.

These include the timeframe for assessment and implementation of solutions, discount rates, geographical scale, beneficiary groups to be considered, and approaches to uncertainty.

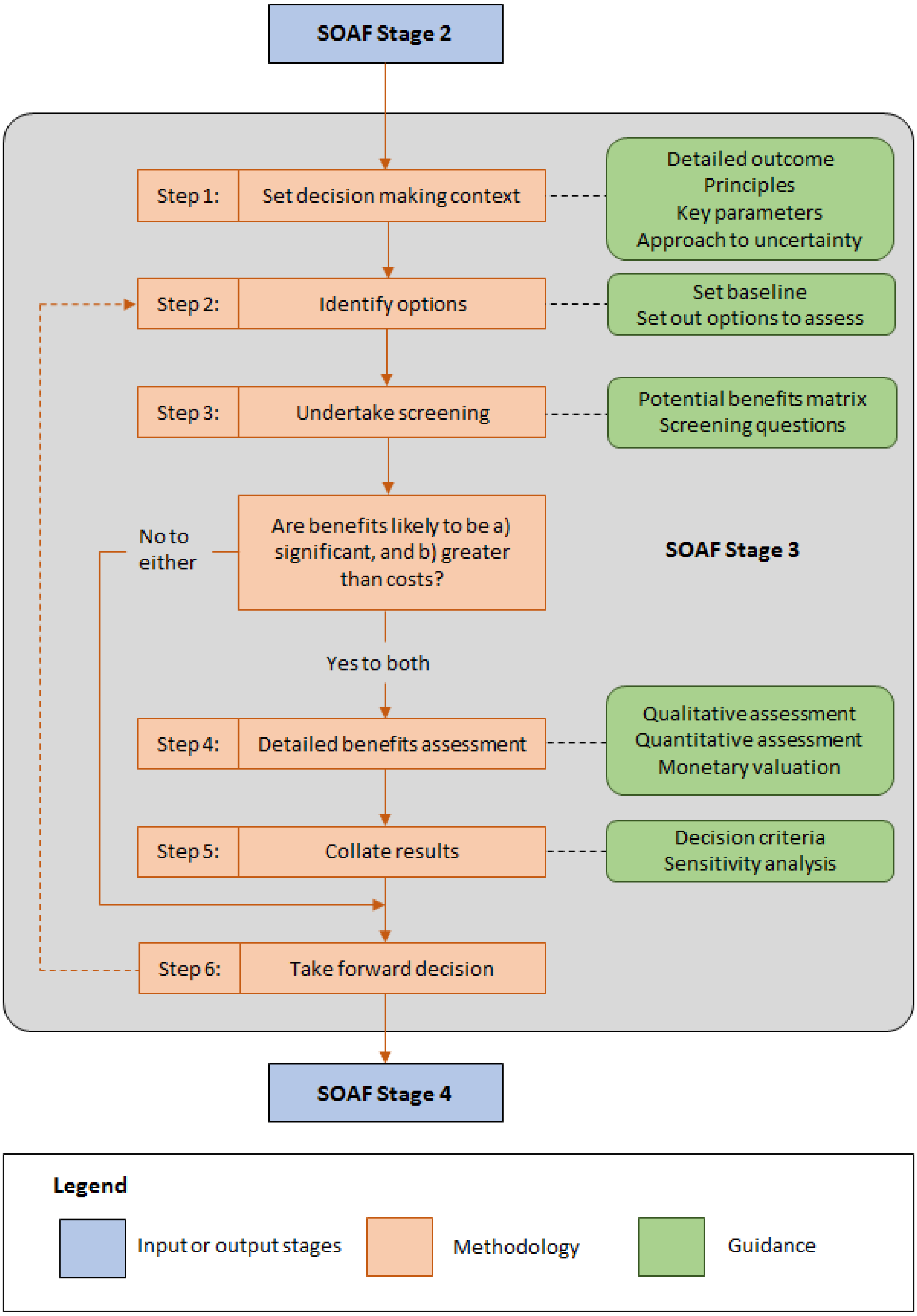

Figure 3. Summary of the overall framework for the assessment of costs and benefits (after Water UK, 2017).

Step 2 – Identify options

Under step 2 WaSCs will identify options for reducing spill frequencies to meet the overall objective or desired outcome set under step 1. Due to the range of costs and benefits potentially associated with different options, at least two different options must be considered. These options should be different in nature – for example a traditional storage tank solution and a green infrastructure approach. In general, options involving green infrastructure in conjunction with more limited traditional (grey infrastructure) solutions provide the greatest benefits. Consequently, it is important that these types of solution are assessed as they are more likely to identify cost – beneficial solutions.

Step 3 – Screening

The options identified under step 2 are screened during step 3 to remove any options that are unlikely to be cost – beneficial, and to ensure detailed CBA is focussed on the options where the net benefits are greatest. A series of basic questions are used to establish whether the benefits are a) likely to be significant (net present value >£100,000), and b) greater than the likely costs. If the benefits are significant and potentially greater than the costs then these options are considered for detailed assessment under step 4. Due to the inevitable uncertainty associated with estimates of costs and benefits, options with a benefit cost ratio (BCR) of 0.5 will also be taken forward for more detailed assessment under step 4.

Step 4 – Detailed benefits assessment

Under step 4, the direct and indirect benefits of the options identified at the screening stage are assessed in detail. The Practitioner's Guide provides guidance on how to carry out a more detailed benefits assessment. A basic or advanced assessment is possible, with guidance on potential ways to quantify and value benefits in monetary terms.

Step 5 – Collate results

The results of the detailed assessments for each option are collated under step 5. This involves aggregating the estimates of the benefits over the chosen timeframe, and incorporating the costs involved in delivering the options. A choice is then made on the decision rules used in the economic assessment. An option is deemed cost – beneficial if the discounted benefits of the option are greater than the discounted costs over the timeframe considered (typically 40 years). Each WaSC will have their own approach to determining economic efficiency. However, it is recommended that both net present value (NPV) and benefit – cost ratio (BCR) are calculated for each option. This will ensure that both the absolute and relative costs and benefits of an option are considered.

It may not be possible for some benefits to be monetized. This is likely to be the case for potential impacts on human welfare such as employment and productivity, or mental health benefits. Key non – monetized benefits are taken into account through a qualitative ranking score (from 1 – low, to 5 – significant). Where the score is 4 (high), or 5 (significant), these benefits are explicitly incorporated within the analysis. Finally, due to the uncertainty associated with CBA, sensitivity analysis is carried out on the results. This analysis will be relatively simple, and involve looking at the effect of changes to key parameters such as discount rates, assessment periods and cost estimates.

Step 6 – Take forward decision

Under this step options are refined to enhance their cost – benefit justification, and to ensure that the most economically efficient options proceed to Stage 4 of the SOAF – the investment decision. The process of carrying out the benefits assessment and collating results may influence the options considered. For example, additional benefits may be realised by identifying further information requirements or adjusting options. As a result, the process is expected to be iterative and option refinement under this step may feedback to the original process of identifying options under step 2.

5. Stage 4 – Decision

Following the assessment of options and the cost – benefit analysis carried out during Stage 3, a final decision is made on whether to deliver an option to reduce the frequency of storm discharges, or do nothing if no cost – beneficial solution can be found.

6. Stage 5 – Deliver cost beneficial solution

Delivery of the most cost beneficial solution is carried out under Stage 5 in order to reduce environmental impact and / or the frequency of storm discharges. This will be subject to appropriate funding and prioritisation.

7. Other Environment Agency initiated processes/actions

Storm overflow investigations initiated by the EA may also prompt assessment under the assessment framework where spill frequencies do not exceed the triggers for investigation (summarised in Table 1 above).

Under the WFD, the EA has a statutory duty to prevent deterioration of waterbodies and to improve or maintain them with the aim of achieving Good status. River basin management plans (RBMPs) are published on six year cycles providing an overview of the river basin district, the condition of its waterbodies, and the measures that are needed to meet Good status.

The EA's Catchment Planning System (CPS) is used to manage data and report on the status of waterbodies under WFD. Classification results are produced nationally every three years. Where waterbodies are failing to achieve Good status or show deterioration in classification, investigations are needed to confirm the existence and source of the problem, and to identify improvement measures.

Storm sewage discharges may be implicated where the failing element(s) involve physico-chemical parameters, such as dissolved oxygen and ammonia; or biological elements, such as fish and invertebrates. Where it is suspected or probable that storm overflows are a significant reason for failure of the WFD element, investigations may be triggered to confirm the impact (or otherwise) of intermittent contributions. This allows improvement measures to be identified, which are subject to socio-economic and affordability appraisal. EDM reports will provide useful information to improve confidence in the weight of evidence available.

Similar monitoring, classification and investigation processes are carried out for designated bathing waters under the Bathing Waters Regulations (BWR) and designated shellfish waters under WFD and the Food Hygiene Regulations. Where minimum environmental quality standards (EQSs) are not achieved, the performance of storm overflows may be investigated by the EA if they are suspected of making a significant contribution to the failures. Storm overflows may also be investigated and identified as unsatisfactory through pollution incidents, complaints or other environmental monitoring.

Should these investigations identify high frequency spillers, the overflows will assessed under this framework. In addition to the improvement measures needed to achieve the EQS under the relevant legislation (e.g. WFD or BWR), the cost and benefits of options to further reduce spill frequencies will also be assessed under stage 3. For storm overflows not exceeding the high frequency spill triggers, measures will only be required to meet the relevant EQS.

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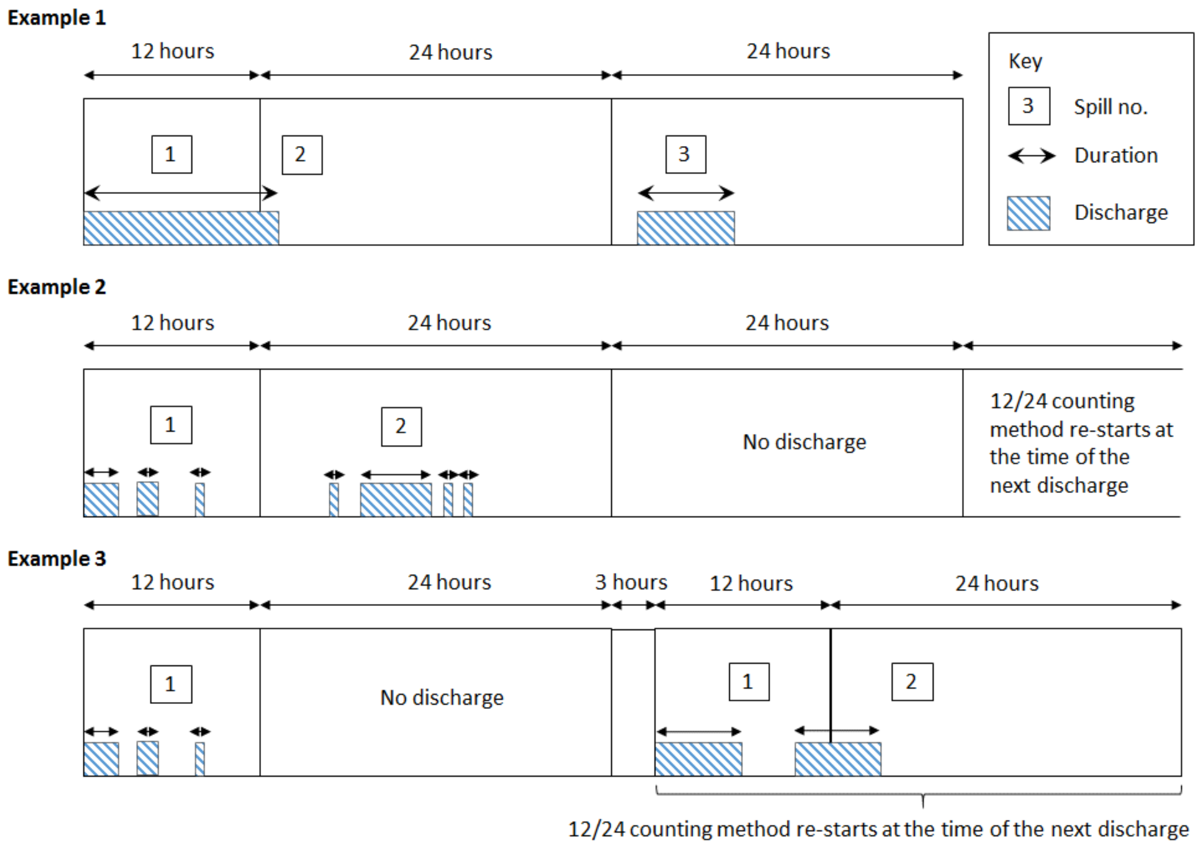
Appendices

Appendix A – Monitoring frequencies and spill counting method

Monitoring frequency will be set at 2 minute intervals for high significance discharges (EDM1), and 15 minute intervals for medium significance discharges (EDM2). Spills will be counted using the 12/24 counting method, which is defined as follows: one or more overflow events within a period of 12 hours or less will be considered to be one spill, one or more overflow events extending over a period of greater than 12 hours up to 36 hours will be considered to be 2 spills. Each subsequent 24 hour duration counts as one additional spill and the whole of the 24 hour block is included. Three examples are provided below to illustrate this method:



Example 1:

Counting starts when the first discharge occurs. Any discharge(s) within the first 12 hour block are counted as one spill. In this example there is a single continuous discharge over the whole of this 12 hour block. This is counted as one spill. After the first 12 hour period, any further discharge(s) in the next 24 hours are counted as one additional spill. In this example the first discharge lasts for 13 hours and so there is an hour of discharge within the 24 hour block between 12 and 36 hours after the start of the first discharge. This is again counted as one spill. Thereafter, any further discharge(s) in the next and subsequent 24 hour blocks are each counted as one additional spill per block. In this example, there is one additional spill.

Counting continues until there is a 24 hour block with no discharge, after which the 12 and 24 hour block spill counting sequence starts again. In this example the total spill count is 3.

Example 2:

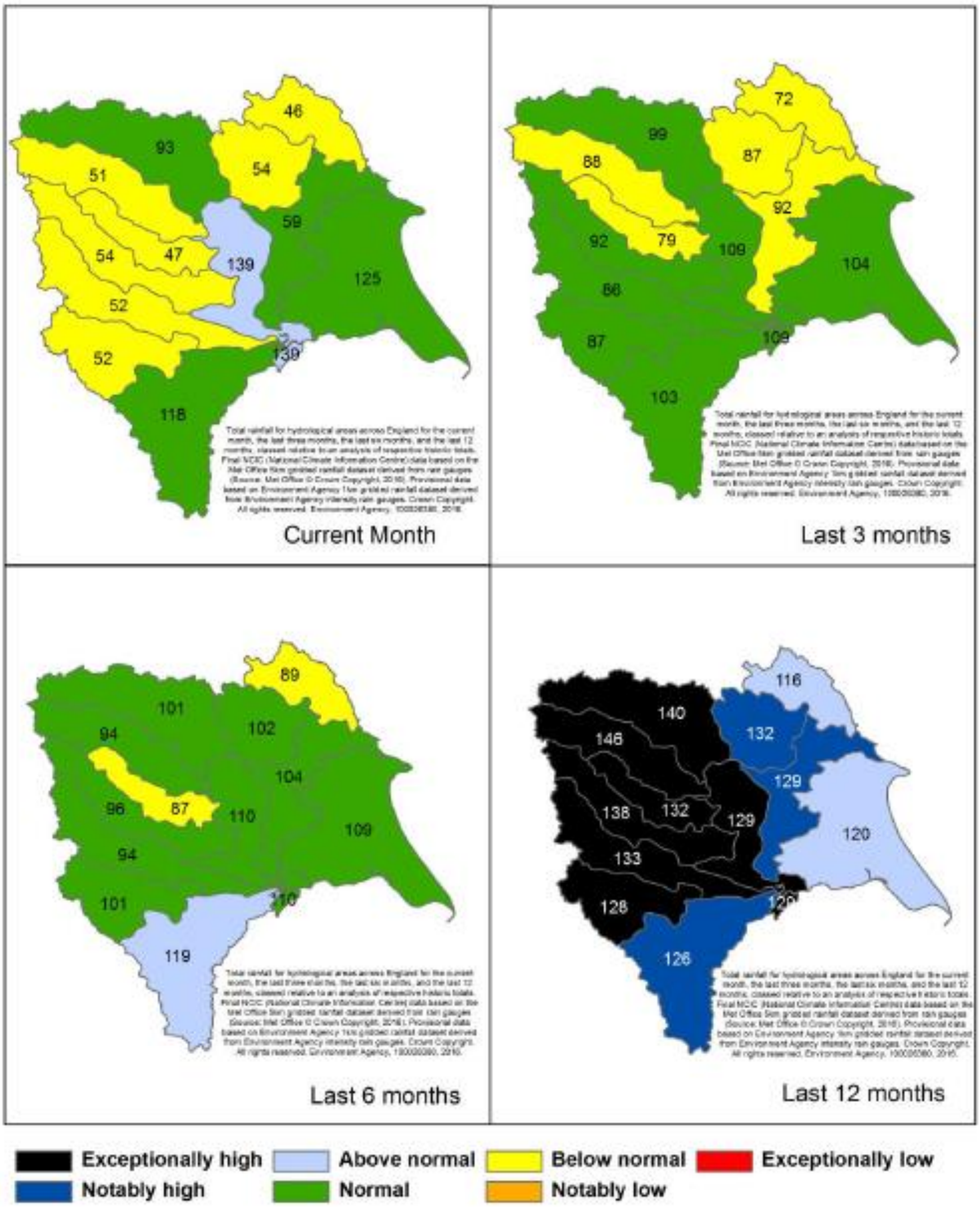
In this example, there are 3 separate periods of discharge within the first 12 hour block, each lasting a few hours or so. These are counted as one spill. There are further intermittent spills in the next 24 hour period between 12 and 36 hours after the start of the first discharge. These discharges are again counted as one spill as they all fall within the same 24 hour block. This 24 hour block is then followed by a 24 hour period during which no discharges occur. At this point the 12/24 hour counting sequence starts again when the next discharge occurs. In this example the total spill count is 2.

Example 3:

In example 3, there are intermittent periods of discharge within the 12 hour period following the start of the first spill. These are all counted as a single spill. The 12 hour block is then followed by a period of 24 hours during which no discharges occur. Consequently, the 12/24 counting process starts again at the time of the next discharge. In this example, the next discharge involves two periods of spill which cross the 12 hour block and continue into the next 24 hour block. Consequently, these are counted as 2 spills.

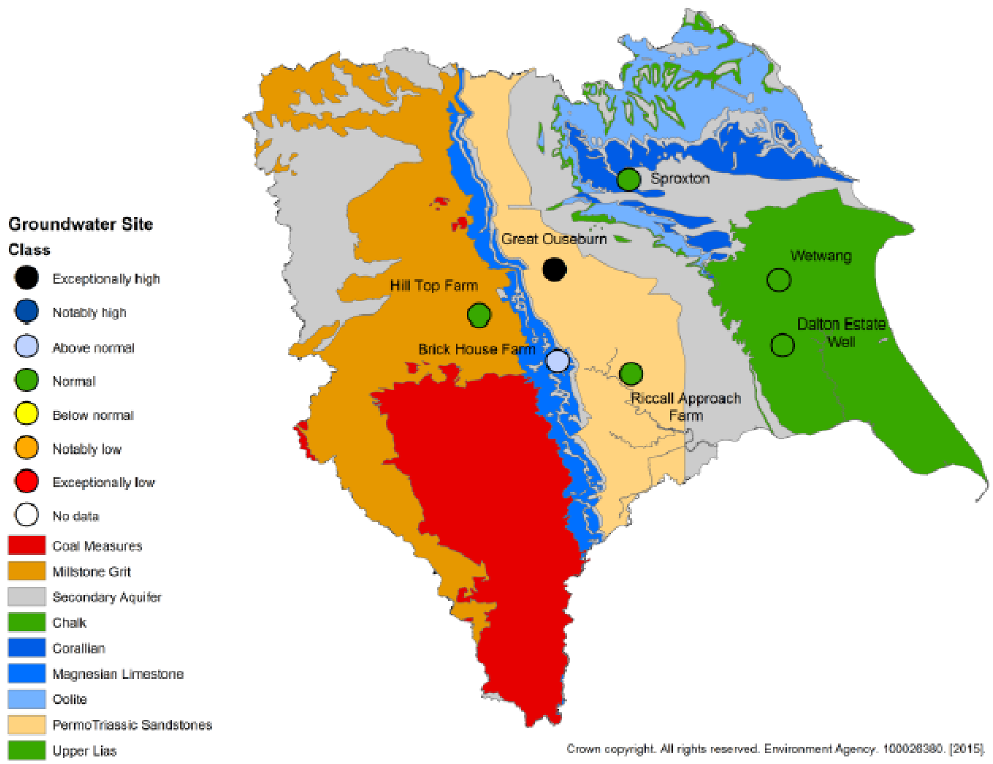
Appendix B – Example water situation report for rainfall (Yorkshire, September 2016)

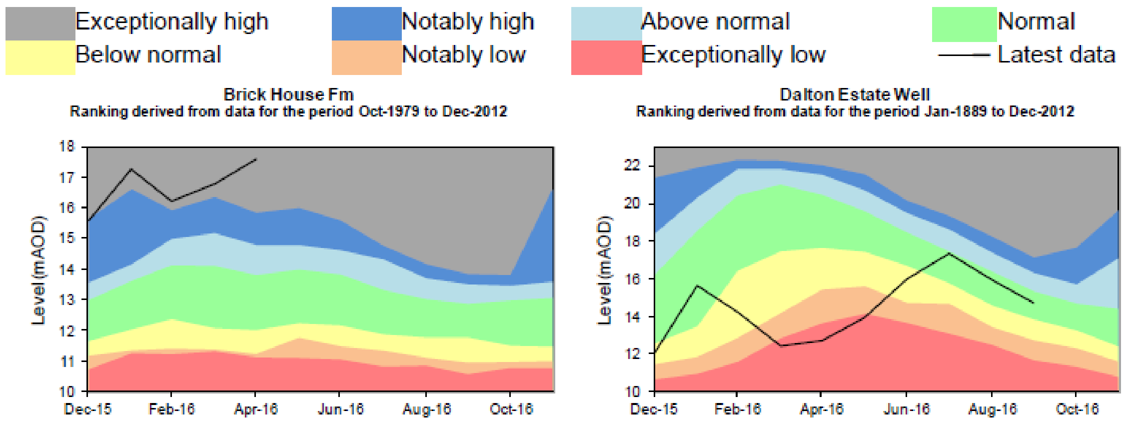
Rainfall



Appendix C – Example water situation report for groundwater (Yorkshire, September 2016)

Groundwater Levels





Appendix D – Amenity definitions

Amenity class	Example criteria
High	• Influences area where bathing and water contact sport (immersion) is regularly practised (for example wind surfing, sports canoeing). • Receiving watercourse passes through formal Public Park. • Formal picnic site. • Designated shellfish waters. • Designated bathing waters. • Waters designated under the Wild Birds and Habitats Directive that are Sensitive Areas.
Moderate	• Boating on the receiving water. • Popular footpath adjacent to watercourse. • Recreation and contact sport (non immersion) areas. • A watercourse that passes through a housing development or frequently used town centre area (for example bridge, pedestrian area, shopping area). • It is linked through substantiated reasons for failure work to an element of the Water Framework Directive classification being less than Good.
Low	• Basic amenity use only. • Casual riverside access on a limited or infrequent basis, such as a road bridge in a rural area, footpath adjacent to watercourse.
None	• Seldom or never used for amenity purposes. • Remote or inaccessible area.

Appendix E – Example impact assessment at Manthorpe Mill CSO, Grantham

Introduction

Manthorpe Mill high level sewer overflow (permit ref. AWNNNF 851/13024) was chosen to test the methodology and scoring system used to assess the environmental impact of a high frequency spiller under the overflows assessment framework. This overflow was chosen due to the availability of an existing verified sewer model and targeted invertebrate sampling data upstream and downstream of the outfall. The annual spill frequency of the overflow is thought to be 22 spills per year based on 10 years of modelled rainfall events. Although 22 spills per year is below the thresholds currently envisaged for investigation (60, 50 and 40 spills per year for 1, 2 and 3 years' worth of EDM data respectively), it was the only site with readily available data to test the process.

The overflow is located on the northern outskirts of Grantham, close to Manthorpe village. It discharges to a short section of the Running Furrows Dyke (approximately 60m) before entering the River Witham. The location of the overflow is shown in Figures 1 and 10. Photos of the outfall, Running Furrows Dyke, and sections of the River Witham upstream and downstream of the outfall are shown in Figures 2 – 9 below.

The overflow discharges to the Upper Witham water body, which is currently classified as moderate status. The classification of the individual biological and physico – chemical elements potentially affected by intermittent discharges are summarised in Table 1.

Table 1. Upper Witham WFD classification.

Water body name:	Upper Witham	
Water body ID:	GB105030056780	
Overall classification:	Moderate	
Classification elements		**Status (2015 Cycle 2)**
Biological quality elements:		
	Fish	Good
	Invertebrates	High
Physico – chemical quality elements:		
	Ammonia	High
	Biochemical oxygen demand	High
	Dissolved oxygen	High
	Phosphorus	Moderate

The monitoring points currently used to classify the water body for the second cycle river basin management plans are a long distance from Manthorpe Mill CSO. The exception is the physico – chemical monitoring point at Barkston Bridge (site ref. WITH5) which is approximately 4.4km downstream of the overflow. Historically, an invertebrate sampling point at Barkston Bridge was also used in first cycle classifications (site ref. 55422). Fish monitoring has also been carried out in the past at the A607 Road Bridge (site ref. 5897), and upstream of Syston Weir (site ref. 5867). These monitoring locations are shown in Figure 10.

The amenity value of the reach of the River Witham immediately downstream of the overflow is high. The first 1.5km runs through the grounds and parkland of Belton House (National Trust). There are footpaths along the river, fishing, and a children’s adventure playground.

The separate components of the investigation are set out below, including the modelled hydraulic performance of the overflow, and the environmental components of the impact assessment (aesthetics, biology and water quality). The impact scores are summarised at the end.

Figure 2. Photo 1 – Manthorpe Mill high level CSO outfall

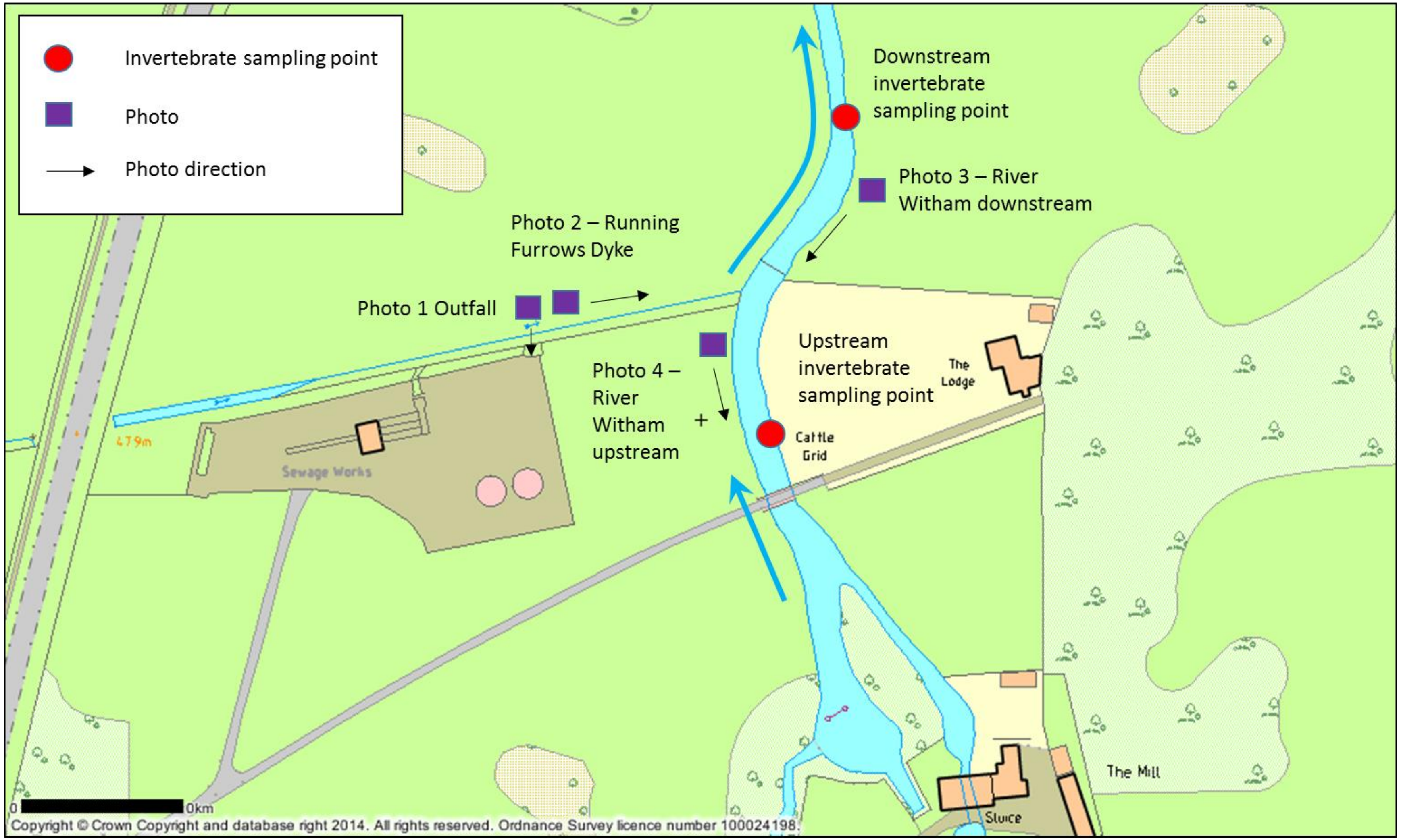


Figure 1. Invertebrate sampling and photo points.

1. Hydraulic performance

The verified hydraulic model compiled for the 2010 Grantham Drainage Area Plan (DAP) was used to assess the hydraulic performance. The long – term performance of the high level overflow was simulated using 10 years of synthetic rainfall events derived using StormPac. Predicted spill frequencies and volumes for each year in the series are shown in Table 2 below, along with the annual average predicted spill frequency and volume.

Table 2. Simulated spill frequency and volume.

Year	Spill frequency (no/year)	Spill volume (m^3/year)
2020	20	47631
2021	19	71431
2022	23	37374
2023	20	42100
2024	23	72435
2025	17	30544
2026	27	80348
2027	19	47802
2028	26	57640
2029	24	86281
Average	**22**	**57359**

At the time of the invertebrate surveys (February 2014), the high level overflow had a pass forward flow of 442l/s, and a bar screen with 6mm apertures. The overflow and its permit have since been modified (September 2015) to include 900m^3 of storage and screening to 6mm in two dimensions. This example, including the modelled performance and biology surveys, relates to the performance of the old overflow prior to the improvement works of 2015.

2a

2b

Figure 3. Photo 2a – the Running Furrows Dyke downstream of Manthorpe Mill CSO. Photo 2b – sewage litter is visible stranded on overhanging branches.

Figure 4. Photo 3 – River Witham immediately downstream of the Running Furrows Dyke and Manthorpe Mill CSO.

Figure 5. Photo 4 – River Witham immediately upstream of the Running Furrows Dyke and Manthorpe Mill CSO. The garden of The Lodge (residential property) is on the left bank.

Figure 6. Photo 5 – River Witham downstream of Manthorpe Mill CSO in Belton Park.

Figure 7. Photo 6 – River Witham downstream of Manthorpe Mill CSO in Belton Park closer to Belton House.

Figure 8. Photo 7 – River Witham upstream of the sluices at Belton House.

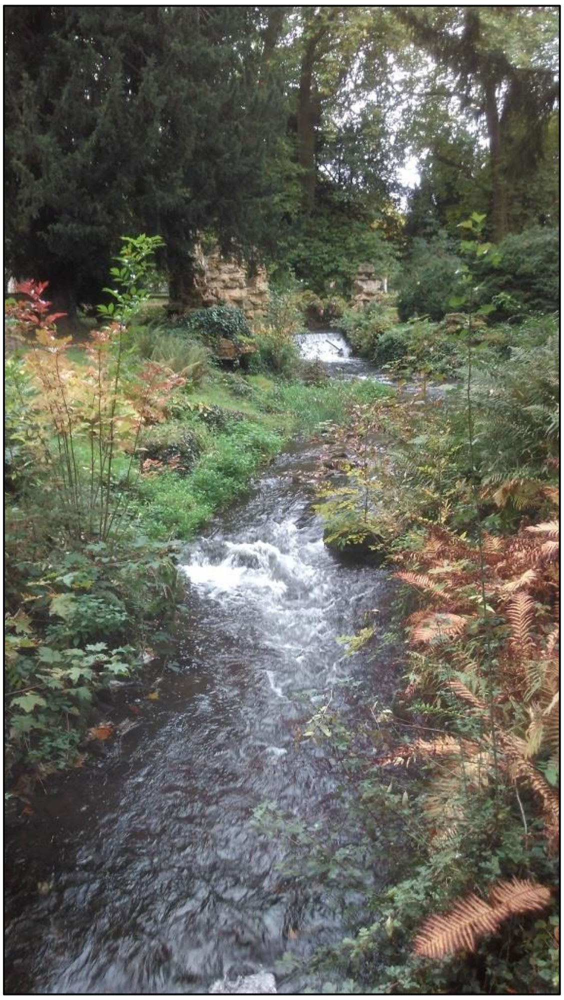


Figure 9. Photo 8 – River Witham downstream of Belton House sluices.

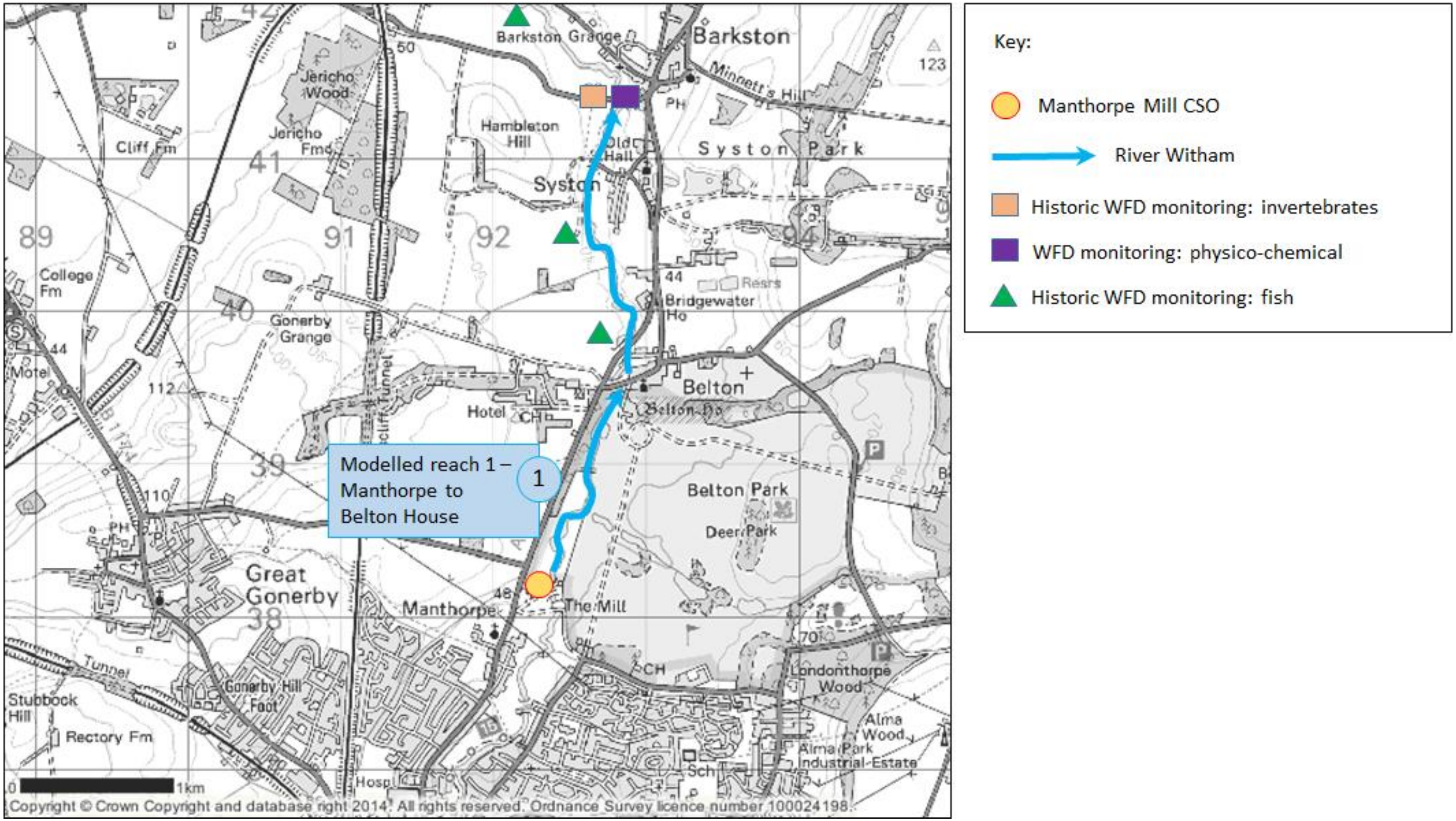


Figure 10. River Witham between Manthorpe Mill CSO and Barkston Bridge showing WFD monitoring points.

2. Aesthetics assessment

The results of the aesthetics assessment are summarised in Tables 3 and 4 below. Overall, the overflow scored 50 giving a classification of moderate impact. Significant amounts of sewage litter were present in the Running Furrows Dyke immediately downstream of the outfall (see photos in Figure 3). Small amounts (3 pieces) of sewage litter were also found caught on nettles along the banks of the River Witham within Belton Park. However, there was no evidence of sewage fungus, either within the Running Furrows Dyke or the main river. There are no recorded pollution incidents due to storm sewage on the National Incident Reporting System (NIRS), but Anglian Water indicate there have been twelve customer complaints recorded over the last 10 years (2006 – 2016).

Table 3. Aesthetics impact assessment.

Aesthetics		**Score**
Sewage derived litter (no. of items) downstream	0	0
	1 – 10	5
	11 – 25	10
	26 – 50	15
	>50	20
Sewage fungus on outfall (present / absent)	N	0
	Y	5
Sewage fungus in downstream mixing zone (% cover)	0	0
	<2	5
	2 – 10	10
	11 – 25	15
	26 – 50	20
	>50	25
Amenity		**Score**
Low or none amenity		0
Moderate amenity		5
High amenity		10
Public complaints		**Score**
No. of validated public complaints related to wet weather discharges from the overflow	0	0
	1 – 4	10
	5 – 9	20
	10 – 14	30
	15 or more	40
Pollution incidents due to storm sewage	**Incident category**	**Score**
No. of NIRS incidents due to storm sewage attributed to the overflow	Cat 3	20
	Cat 2	60
	Cat 1	100
Total score		50

Table 4. Aesthetic impact classification

Total Aesthetic Score	Aesthetic impact classification
0	No impact
1 – 10	Very low
11 – 25	Low
26 – 50	Moderate
51 – 75	High
>75	Severe

3. Invertebrate assessment

Invertebrate samples were collected from the River Witham immediately upstream and downstream of the confluence with the Running Furrows Dyke, and the discharge from Manthorpe Mill CSO. The sampling point locations are shown in Figure 1. The samples were collected 24 February 2014 and the results of the surveys are summarised in Table 5. Although the invertebrate data available does not allow for the full WFD assessment set out in the methodology (SOAF Section 2b), it does provide an indication of impact.

Table 5. Whalley Hawkes Paisley Trigg (WHPT) scores for the number of invertebrate taxa (NTAXA) and the average score per taxon (ASPT).

Site	WHPT NTAXA	WHPT ASPT
Upstream	19	4.34
Downstream	19	4.62

The number of WHPT taxa recorded upstream and downstream of the overflow were the same (19), while the average sensitivity score for the taxa found downstream of the overflow was slightly higher than at the upstream site. Consequently, it is not thought that the overflow is impacting the invertebrate community and the overflow receives a score of zero (Table 6). It was not possible to predict environmental quality ratios for the sites as environmental variable data was not available for use with the river invertebrate classification tool (RICT). Historic invertebrate sampling approximately 4.4km downstream of the overflow at Barkston Bridge (site ID 55422), has tended to show either good or high status for macroinvertebrates. White clawed crayfish are also known to be present in the Witham through Belton Park to Barkston Bridge. Populations tend to occur in good quality waters high in dissolved oxygen and low in organic pollution, and their presence suggests the overflow is not having a serious impact on water quality.

Table 6. Macroinvertebrate impact classification.

Type	Description	Value
Short – term	Worst single season classification result for WHPT NTAXA and ASPT	No impact
Long – term	Worst of WHPT NTAXA and ASPT for the overall multi season (spring & autumn) classification	Assessment not possible

4. Water quality assessment

Although the invertebrate sampling indicated the overflow was not causing an environmental impact, the water quality assessment was completed in order to test and demonstrate the process that will be applied in those situations where invertebrate sampling is not possible.

I. Dilution assessment

The dilution afforded by the River Witham was estimated using data for the gauging station at Saltersford immediately upstream of Grantham with a 10% uplift factor. The flow duration curve is shown in Figure 11. The Q95 (5 percentile flow) is approximately 190l/s. The modelled dry weather flow in the sewer immediately upstream of the overflow is 100l/s. Consequently, the level of dilution afforded by the river is low (only 2:1 Q95 river flow: sewer DWF), and a modelled water quality impact assessment is required.

II. Water quality modelling

A level 1 simplified modelling assessment was used to assess the impact of the overflow on water quality. Ten years of rainfall events were generated using StormPac software and simulated in the Grantham DAP model. Predicted spills were used as inputs to a simplified water quality impact model in order to assess any increase in the number of exceedances of the 99 percentile and fundamental intermittent standards. Upstream flow boundaries for the River Witham are shown in Table 7, and as described above were based on the gauging station at Saltersford with a 10% uplift factor. Upstream river quality statistics (Table 7) were derived from water quality spot samples collected at Saltersford Footbridge (WITHN) between 2000 and 2015.

Table 7. Upstream river flow and quality parameters.

Parameter	Statistic	
	Mean	Standard deviation
Flow (l/s)	930	728
BOD (mg/l)	1.266	0.326
Total ammonia (mg/l)	0.037	0.022

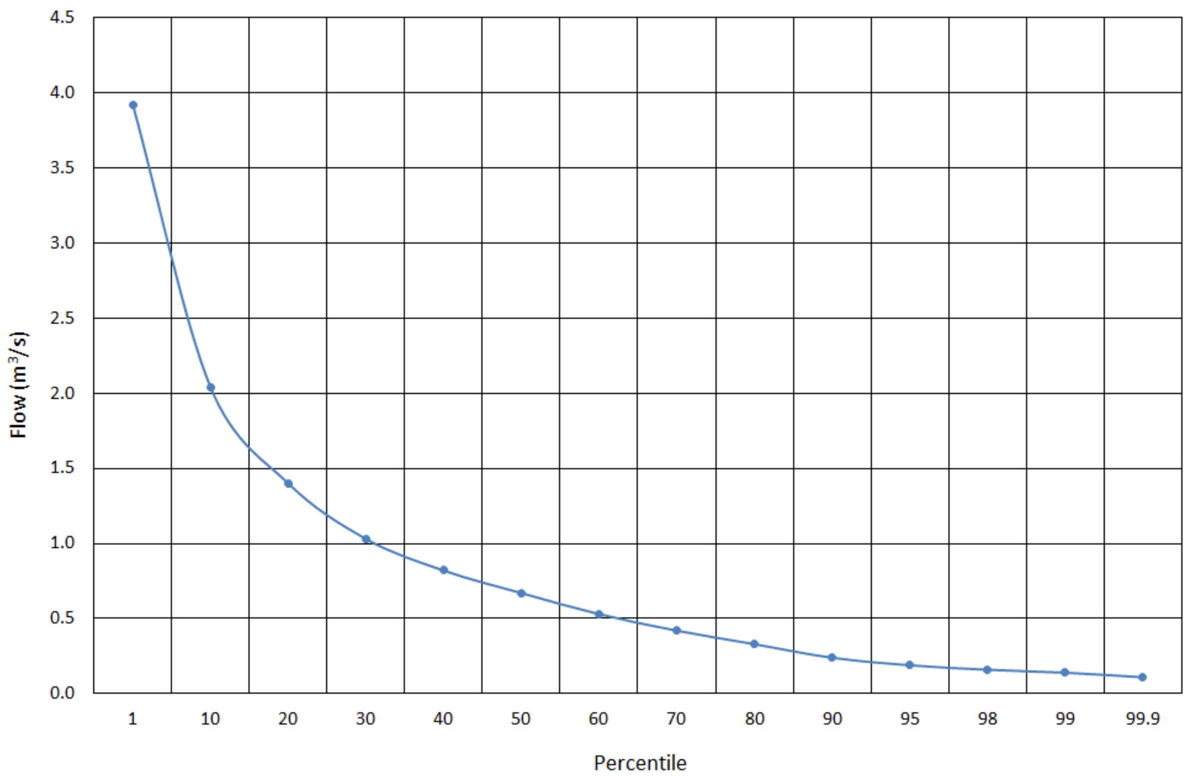


Figure 11. Flow duration curve for the River Witham upstream of Manthorpe Mill.

Water quality statistics for the mixed river and spill are shown in Table 8. Dissolved oxygen for the mixed water was set high at 8mg/l based on high upstream oxygen readings at Saltersford Footbridge (range 8 – 14.7mg/l, average 11mg/l) and the presence of weirs and sluices upstream of Manthorpe Mill likely to increase aeration. Spill pollutant concentrations were assumed to be 125mg/l for BOD, and 8mg/l for ammonia based on default guidance values (Dempsey, 2005).

Table 8. River characteristics following mixing with the discharge.

Parameter	Statistic	
	Mean	Standard deviation
Dissolved oxygen	8.0	1.25
pH	8.11	0.21
Temperature (degrees C)	10.84	3.33

A single reach analysis was carried out for the Witham between Manthorpe Mill CSO and the sluices at Belton House (see Figure 10). The reach characteristics are summarised in Table 9 below, and are based on the Environment Agency's ISIS model of the River Witham.

Table 9. Reach characteristics for simplified channel between Manthorpe Mill and Belton House.

Reach parameter	**Value**
Length (m)	1511
Slope (m/m)	0.00091
Width (m)	6.84
Side slope (m/m)	0.7
Manning's N	0.070

Table 10. Water quality parameters.

Water quality parameter	**Value**
BOD decay rate (day^{-1})	0.35
Ammonia decay rate (day^{-1})	2.0
Ammonia yield factor (gO_2/gN)	4.46
Ammonia release from BOD decay (gNH_4-N/gBOD)	0.3
Re-aeration constant	3.9
Velocity exponent	0.5
Depth exponent	1.5

The parameters used in the simplified water quality impact model are shown in Table 10 above. Default values were used for the re-aeration coefficients (Dempsey, 2005). A BOD decay rate of 0.35/day and an ammonia decay rate of 2.0/day was selected as there are sewage treatment works upstream (e.g. Little Ponton), and the river has lots of macrophytes. The rate of ammonia generation through BOD decay was set at 0.3.

Additional reaches of the River Witham downstream of Belton House to Marston sewage works were not considered for FIS impact analysis due to the presence of various weirs and sluices.

The results of the impact assessment are summarised below for A) 99 percentiles and B) FIS.

A) 99 percentiles – duration of exceedance

The scoring system for increases in the duration of 99 percentile exceedance is shown below in Table 11. Water quality impact classes depending on the score are summarised in Table 15. The predicted increase in the duration of 99 percentile exceedance for BOD and total ammonia caused by the overflow is shown in Table 12 along with the score. Based on the increase in the number of exceedances for BOD, the overflow scores a severe impact on water quality, and is predicted to narrowly fail the 99 percentile standard for the 24 hour impact scenario. For total ammonia the impact is low.

Table 11. Scoring system for duration / number of 99 percentile exceedances.

Impact duration	Allowable exceedances (no./year)	Score
1 hour	87.6	+ 0.5 points for every 1.0/yr increase in exceedances
6 hours	14.6	+ 3.0 points for every 1.0/yr increase in exceedances
24 hours	3.65	+ 12.0 points for every 1.0/yr increase in exceedances

Table 12. 99 percentile impact assessment for Manthorpe Mill CSO.

i. BOD

Impact duration	BOD exceedances (no./year)			Score
	Without CSO	With CSO	Difference	
1 hour	0	49.36	49.36	25
6 hours	0	9.48	9.48	28
24 hours	0	3.79	3.79	45

ii. Total ammonia

Impact duration	Total ammonia exceedances (no./year)			Score
	Without CSO	With CSO	Difference	
1 hour	0	30.06	30.06	15
6 hours	0	4.76	4.76	14
24 hours	0	0.97	0.97	12

B) Fundamental intermittent standards

The scoring system for increases in the number of FIS exceedances is shown below in Table 13. The predicted increase in the number of FIS exceedances for dissolved oxygen and un-ionised ammonia caused by the overflow for the different durations and allowable return periods is shown in Table 14 along with the relevant scores. The overflow scores a severe impact on water quality for both dissolved oxygen and un-ionised ammonia. The severe impact is created by a predicted failure of the 1 hour 1 year standards for dissolved oxygen and un-ionised ammonia.

Table 13. Scoring system for increases in FIS exceedances for un-ionised ammonia and dissolved oxygen.

Frequency (return period)	Allowable exceedances (no. / year)	Score
1 month	12	+ 1.5 point for every 0.5/yr increase in exceedances
3 months	4	+ 4 points for every 0.5/yr increase in exceedances
1 year	1	+ 6 points for every 0.2/yr increase in exceedances

Table 14. FIS impact assessment for Manthorpe Mill.

i. Dissolved oxygen

Impact duration	Frequency	Dissolved oxygen exceedances (no./year)			Score
		Without CSO	With CSO	Difference	
1 hour	1 month	1.01	6.26	5.25	16
	1 year	0.05	3.15	3.1	93
6 hours	1 month	0.35	2.5	2.15	6
	1 year	0	1.14	1.14	34
24 hours	1 month	0.93	1.87	0.94	3
	1 year	0.08	0.39	0.31	9

ii. Un-ionised ammonia

Impact duration	Frequency	Un-ionised ammonia exceedances (no./year)			Score
		Without CSO	With CSO	Difference	
1 hour	1 month	0	2.46	2.46	7
	1 year	0	1.34	1.34	40
6 hours	1 month	0	1.18	1.18	4
	1 year	0	0.35	0.35	11
24 hours	1 month	0	0.99	0.99	3
	1 year	0	0.17	0.17	5

The reach is also predicted to narrowly fail the 6 hour 1 year standard for dissolved oxygen, and the impact of the overflow is mainly predicted to be on BOD/dissolved oxygen levels.

Performance against the 3 month return period scenarios was not reported due to a problem with the software.

The predicted impact on water quality conflicts with the invertebrate assessment, which suggested there was no impact. The FIS and 99 percentile standards are intended for design purposes, and are considered to allow for a margin of error. Consequently, although, the standards are predicted to be failed, the standards are not heavily breached, especially for ammonia, and the impact assessment may be pessimistic. Further sensitivity testing may eliminate the predicted failure of standards given the simplification used. For example, sampling of the overflow might justify using reduced BOD & total ammonia concentrations for spill quality.

Table 15. Water quality impact classification.

Water quality Score	Water quality impact classification
0 – 5	No impact
6 – 9	Very low
10 – 19	Low
20 – 29	Moderate
30 – 39	High
40 or more	Severe

Summary

The classification for the aesthetic, biology, and invertebrate components of the assessment are summarised in Table 16 below. Aesthetic impact was moderate, with the score driven by public complaint, and the presence of sewage litter within the Running Furrows Dyke. For biology, invertebrate sampling upstream and downstream of the discharge revealed no impact. This was supported by good or high status being recorded at biological monitoring points up to 4.4km way for both fish and invertebrates. The presence of white clawed crayfish along the reach to Belton Park and downstream toward Barkston Bridge also suggests the overflow is not having a significant impact. Due to the availability of good biology data which indicates no impact, a water quality assessment would not normally be carried out. However, in order to test the process a modelled water quality assessment was undertaken. In contrast to the invertebrate assessment, water quality modelling predicted a severe impact due to increases in the number of exceedances of the FIS to the extent that the annual 1 hour standards for dissolved oxygen and un-ionised ammonia were failed.

Table 16. Summary impact classification.

Component	Impact classification
Aesthetics	Moderate
Invertebrates	No impact
Water quality	Not required

References

Dempsey, P. 2005. Default and sensitivity values for use in simplified UPM modelling studies. Water Research Centre, Report Ref. UC6835.

Appendix F – Example Invertebrate Impact Assessment

The following hypothetical example is based on data for sites on the River Blithe. It shows how WHPT invertebrate indices are classified using the RICT, how the upstream results are compared with the downstream site using the RICT Compare Module, and how impact is scored and classified under the SOAF.

Table 1 shows the results for WHPT NTAXA and ASPT for invertebrate samples collected in spring and autumn at the upstream site. Table 2 summarises the environmental characteristics of the upstream sampling site. Average environmental quality ratios (EQRs) simulated by the RICT, along with their quality class and confidence of class for the spring, autumn and combined season samples are shown in Table 3.

Table 1. WHPT NTAXA & ASPT results for upstream spring and autumn samples.

Season	WHPT NTAXA	WHPT ASPT
Spring	16	5.125
Autumn	16	5.125

Table 2. Environmental variables for the upstream sample site.

Environmental variable	Value
Grid reference	SK 04800 25900
Altitude (mAOD)	97
Slope (m/km)	1.8
Discharge category (1 – 10)	3
Distance from source (km)	27
Mean width (m)	10
Mean depth (cm)	8.7
Mean alkalinity (mg $CaCO_3$/l)	164
Substrate composition (% cover):	
Boulder / cobbles	25
Pebbles / gravel	53
Sand	15
Silt/clay	7

Table 3. Upstream sample classification results.

Season	Index	Average Face Value EQR	Class	Probability (%)
Spring	WHPT NTAXA	0.673	Moderate	39.54
	WHPT ASPT	0.842	Moderate	57.98
Autumn	WHPT NTAXA	0.651	Moderate	42.82
	WHPT ASPT	0.875	Good	51.94
Spring & autumn	WHPT NTAXA	0.669	Moderate	53.22
	WHPT ASPT	0.871	Good	61.23

Tables 4 and 5 show the results of the WHPT indices and environmental variables respectively for the downstream sample site. The downstream sample point is approximately 100m downstream of the upstream site, is narrower, deeper, and has a higher proportion of sand, silt & clay. Lower values of WHPT NTAXA and ASPT were recorded for both the spring and autumn samples compared to upstream. The average environmental quality ratios (EQRs) simulated by the RICT for the downstream samples, along with their quality class and confidence of class for the spring, autumn and combined seasons are shown in Table 6.

Table 4. WHPT NTAXA & ASPT results for downstream spring and autumn samples.

Season	WHPT NTAXA	WHPT ASPT
Spring	14	4.82
Autumn	13	4.77

Table 5. Environmental variables for the downstream sample site.

Environmental variable		Value
Grid reference		SK 04745 25728
Altitude (mAOD)		96
Slope (m/km)		1.8
Discharge category (1 – 10)		3
Distance from source (km)		27.1
Mean width (m)		5
Mean depth (cm)		17
Mean alkalinity (mg $CaCO_3$/l)		162
Substrate composition (% cover):		
	Boulder / cobbles	22
	Pebbles / gravel	48
	Sand	20
	Silt/clay	10

Table 6. Downstream sample classification results.

Season	Index	Average Face Value EQR	Class	Probability (%)
Spring	WHPT NTAXA	0.597	Moderate	41.6
	WHPT ASPT	0.793	Moderate	71.81
Autumn	WHPT NTAXA	0.545	Poor	35.32
	WHPT ASPT	0.816	Moderate	67.97
Spring & autumn	WHPT NTAXA	0.577	Moderate	50.95
	WHPT ASPT	0.818	Moderate	82.62

Tables 7, 8 and 9 show the results of the comparison between the upstream and downstream samples for the individual spring and autumn seasons, and for the overall combined spring &

autumn classification. The tables show the percentage number of the 10,000 simulations where the downstream sample was in the same or a different class to the upstream sample. For example, in Table 9 which shows the comparison for the overall classification, 47.55% of the simulations for downstream WHPT ASPT were one status class worse (-1) than the upstream site.

Table 7. RICT compare module – at a glance results for comparison of upstream and downstream samples collected in spring.

WHPT Index	% of simulations where the downstream sample is in the same or a different WFD status class compared to upstream										
	-5	-4	-3	-2	-1	Even	+1	+2	+3	+4	+5
NTAXA	0	0	0	0	64.7	35	0	0	0	0	0
ASPT	0	0	0	0	35.73	64	0	0	0	0	0

Table 8. RICT compare module – at a glance results for comparison of upstream and downstream samples collected in autumn.

WHPT Index	% of simulations where the downstream sample is in the same or a different WFD status class compared to upstream										
	-5	-4	-3	-2	-1	Even	+1	+2	+3	+4	+5
NTAXA	0	0	0	3.41	87.13	9	0	0	0	0	0
ASPT	0	0	0	0	46.49	54	0	0	0	0	0

Table 9. RICT compare module – at a glance results for comparison of upstream and downstream following multi – season classification (spring & autumn).

WHPT Index	% of simulations where the downstream sample is in the same or a different WFD status class compared to upstream										
	-5	-4	-3	-2	-1	Even	+1	+2	+3	+4	+5
NTAXA	0	0	0	0	79.51	20	0	0	0	0	0
ASPT	0	0	0	0	47.55	52	0	0	0	0	0

The scoring method for estimating impact is summarised in Tables 10a – 10c. The method involves a 'worst of' approach for WHPT NTAXA and WHPT ASPT, and is repeated for the individual spring and autumn season samples, as well as the overall multi – season classification in order to estimate both short – term (single season) as well as longer – term (overall) impacts.

Table 10a. Invertebrate impact scoring for WHPT NTAXA & ASPT.

% of simulations the downstream sample is one or more classes worse than upstream	Score	Class Multiplier
1 – 4	1	× No. of classes the downstream sample is worse than upstream
5 – 9	2	
10 – 29	4	
30 – 49	6	
50 – 70	8	
71 – 90	10	
>90	12	

Table 10b. Invertebrate impact classification for WHPT NTAXA & ASPT.

Total score	Overall classification
1	No impact
2 – 3	Very low
4 – 5	Low
6 – 7	Moderate
8 – 9	High
10 – 11	Very high
12 – 15	Severe
16 – 19	Very severe
20 or more	Extremely severe

Table 10c. Overall short and long – term invertebrate impact classification.

Type	Description	Value
Short – term	Worst single season classification result for WHPT NTAXA and ASPT	No impact – extremely severe
Long – term	Worst of WHPT NTAXA and ASPT for the overall multi season (spring & autumn) classification	No impact – extremely severe

Tables 11a – 11d summarise the results of the SOAF scoring assessment for this hypothetical example. For the spring scoring assessment the worst result was for NTAXA – 64.7% of the simulations gave downstream NTAXA values one WFD status class worse than upstream. From table 10a this gives a score of 8 which is classified as 'High' impact (Table 10b). For the autumn assessment, the worst result was seen again for NTAXA. In this case the percentage of simulations where the downstream sample was one class worse than upstream was slightly higher (87.13%). From Tables 10a and 10b this gives a score of 10 and an impact classification of 'Very high'. The overall multi – season (spring & autumn) WFD assessment also gave a 'Very high' impact classification based on NTAXA, which was again worse than ASPT. Since the worst single season result was 'Very high' impact for NTAXA in autumn, this gives a SOAF short – term impact classification of 'Very high'. Impact was also 'Very high' for the SOAF long – term classification due to 'Very high' impact for NTAXA for the overall spring & autumn comparison.

Table 11a. Spring scoring assessment.

WHPT Index	One class worse than upstream				Two classes worse than upstream				Overall score	Impact
	% sims	Score	× no. of classes	Total score	% sims	Score	× no. of classes	Total score		
NTAXA	64.7	8	1	8	0	0	2	0	8	High
ASPT	35.73	6	1	6	0	0	2	0	6	Moderate

Table 11b. Autumn scoring assessment.

WHPT Index	One class worse than upstream				Two classes worse than upstream				Overall score	Impact
	% sims	Score	× no. of classes	Total score	% sims	Score	× no. of classes	Total score		
NTAXA	87.13	10	1	10	0	0	2	0	10	Very high
ASPT	46.49	6	1	6	0	0	2	0	6	Moderate

Table 11c. Spring & autumn scoring assessment.

WHPT Index	One class worse than upstream				Two classes worse than upstream				Overall score	Impact
	% sims	Score	× no. of classes	Total score	% sims	Score	× no. of classes	Total score		
NTAXA	79.51	10	1	10	0	0	2	0	10	Very high
ASPT	47.55	6	1	6	0	0	2	0	6	Moderate

Table 11d. Short (single season) and long – term (spring & autumn) impact classification.

Assessment type	Impact
Short – term	Very high
Long – term	Very high

Appendix G – Guidance on modelling approaches and levels of complexity

Level	Urban drainage inputs				Boundary river conditions		River model		Rainfall series
	Storm overflow flow	**Storm sewage quality**	**WWTW flow**	**WWTW quality**	**Upstream river flow**	**Upstream river quality**	**Hydraulic**	**Water quality**	
1	Verified sewer model	Event mean concentrations using default values (e.g. Dempsey, 2005) or sampled values	Statistical distribution from MCertified data	Statistical distribution from sampled effluent quality	Statistical distribution from gauged data or ungauged estimate	Statistical distribution from EA routine samples	Simplified channel, steady & uniform	Simplified WQ processes & re-aeration using default values for rate coefficients	10 year representative historic or synthetic time series
2	Verified sewer model	Event mean concentrations using default values (e.g. Dempsey, 2005) or sampled values	Predicted flow time series from verified sewer model	Statistical distribution from sampled effluent quality	10 year historic flow time series from EA gauging station or calibrated rainfall runoff model	Statistical distribution from EA routine samples	Simplified channel, steady & uniform	Simplified WQ processes & re-aeration using default values for rate coefficients	10 year representative historic or synthetic time series
3	Verified sewer model	Sampled values or calibrated sewer quality model	Predicted flow time series from verified sewer model	Statistical distribution from sampled effluent quality	10 year historic flow time series from EA gauging station or calibrated rainfall runoff model	Statistical distribution from EA routine samples	Calibrated flow routing model	Advective pollutant transport, WQ simulation calibrated from event sampling & sonde data	10 year representative historic or synthetic time series
4	Verified sewer model	Sampled values or calibrated sewer quality model	Predicted flow time series from verified model	Statistical distribution from sampled effluent quality	10 year historic flow time series from EA gauging station or calibrated rainfall runoff model	Statistical distribution from EA routine samples	Calibrated hydrodynamic model	Calibrated advection – dispersion model, WQ simulation calibrated from event sampling & sonde data	10 year representative historic or synthetic time series

Appendix H

The interpretation and definition of 'agglomeration' and 'population equivalent' is set out in the UWWT Regulations and supporting Guidance Note (DETR, 1997). Agglomeration is used to describe an area where the combined population's sewage is collected and treated. An agglomeration population is the total population connected to the sewerage network upstream of the STW. The sewerage catchment is not subdivided further into smaller agglomeration populations upstream of individual storm overflows. The population equivalent is a measurement of organic biodegradable load. A population equivalent of 1 (1 PE) is the organic biodegradable load having a five-day biochemical oxygen demand (BOD5) of 60g of oxygen per day (the load shall be calculated on the basis of the maximum average weekly load entering the treatment plant during the year, excluding unusual situations such as those due to heavy rain).