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AMP7 Coastal Investigations SN021/0226-2.1.1

Bathing Water Quality Investigation

Seaham BW

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CONTENTS

ABBREVIATIONS

AD	Advection Dispersion
AMP	Asset Management Plan
BODC	British Oceanographic Data Centre
BW	Bathing Water
BWD	Bathing Water Directive
Cfu	Coliform forming units
CSO	Combined Sewage Overflow
EC	E.coli
EA	Environmental Agency
FIO	Faecal Indicator Organism
IE	Intestinal Enterococci
LSO	Long Sea Outfall
MSF	Measure Specification Form
NCMS 21	Northumbrian Coastal Modelling System 2021
NWG	Northumbrian Water Group
PT	Particle Tracking
SPS	Sewage Pumping Station
SSO	Short Sea Outfall
STW	Sewage Treatment Works
SWIM	Storm Water Impact Model
UKMO	United Kingdom Meteorological Office
UV	Ultraviolet
WFD	Water Framework Directive
WINEP	Water Industry National Environment Programme

EXECUTIVE SUMMARY

Northumbrian Water Group (NWG) commissioned Esh-Stantec to update the existing Northumbrian Coastal Modelling System (NCMS), and to use the updated model to understand and model the impact of NWG assets on bathing water quality.

The existing individual Northumbrian coastal models were previously used and accepted for bathing water compliance assessments. These have been updated to create a single model domain which covers the entire Northumbrian coastline. The updated model (NCMS21) has been converted into MIKE21 Flexible Mesh in line with current industry standards. Where applicable the bathymetry has been updated with latest information and the representation of the main rivers extended up to the tidal boundaries. The hydrodynamic calibration has also been enhanced in the key areas associated with bathing water compliance.

The sewerage network models have been updated with the latest available data and model performance has also been cross checked against Event Duration Monitoring (EDM) data to ensure all the input data feeding into the NCMS21 is as accurate as possible.

The modelled water quality calibration achieved at Seaham Hall bathing water (BW) shows a good fit across the entire percentile curve including the 90^{th} and 95^{th} percentile values needed for classification.

The model shows that bathing water is currently predicted to achieve 'Good' status, and this will continue into the future without interventions. The key source impacting the classification is the presence of an unknown source (predominantly Intestinal Enterococci) which the modelling indicates is at, or just to the north of, the bathing water. The most likely source of this contamination is the unnamed drainage ditch discharging to the bathing water adjacent to the sample point.

The main impacting NWG assets are CSO 25 (Windermere Road CSO) and CSO 16 (Dalton-le-Dale CSO 1). Modelling has shown that removing these, and all NWG assets altogether, will not improve on the existing 'Good' classification.

A robust Excellent classification can most confidently be achieved by significantly reducing, or removing, the unknown local source.

1 INTRODUCTION

1.1 Report Purpose

This report has been prepared for Northumbrian Water Group (NWG) by Esh-Stantec. A compliance assessment is presented for the Bathing Water Directive 2006/7/EC together with bacterial source apportionment for Escherichia coli or E. coli (EC) and intestinal enterococci (IE) at designated bathing waters. These bacteria are also generically referred to as Faecal Indicator Organisms (FIOs). If appropriate, interventions to NWG wastewater assets required to meet the target bathing water classification are identified. Specifically, the report considers compliance at the following bathing waters:

- Seaham Hall Beach bathing water

The report does not consider bathing water quality at the adjacent Seaham Beach bathing water.

Figure 3 provides a geographical overview of the catchment.

1.2 Assessment Objectives

Undertake an assessment in accordance with the coastal modelling requirements of the Measures Specification Form (MSF), provided in Appendix A. The MSF provides the drivers, tasks and requirements for the assessment. In meeting this objective, the assessment will:

1. Determine the FIO source apportionment at each bathing water
2. Assess the reasons why the bathing water target compliance may be at risk.
3. Identify suitable interventions for NWG assets, if their discharge is outside the risk envelope for target compliance.

1.3 Asset Management Plan 7 Investigations

Asset Management Plan 7 (AMP7) includes obligations to investigate bathing waters under the Water Industry National Environment Programme (WINEP). These investigations include a review of current bathing water performance and assessment against a range of WINEP drivers. Details of the required assessments are included in the MSF. The MSF for the Seaham Hall bathing water (BW) ambition drivers (INV4) is included as Appendix A. This includes relevant WINEP information such as WINEP drivers, Scheme/Investigation name, Unique ID and the investigation scope.

The scope of the AMP7 investigation includes assessment of wastewater infrastructure – including wastewater modelling and coastal modelling of the discharges.

For AMP7, sewerage network models were upgraded and validated to reflect latest developments.

For AMP7, NWG's coastal model was upgraded. This used latest technology to provide a flexible mesh resolution of the coastal waters with high resolution at bathing waters and key coastal features, such as estuaries. The 2021 Northumbrian coastal modelling system (NCMS 21) extends the length of coastline with no breaks. This was to ensure that all discharged plumes are accounted for and avoids some of the risks associated with the use of local sub-grids (i.e., more remote discharges being excluded, or mass being lost at the sub-grid boundary).

1.4 Drivers and Guidelines

PR19 bathing water driver guidance[1] associated with Seaham Hall BW is summarised in Table 1. Further information is provided in the MSF (Appendix A), which provides guidance specific to this assessment.

Table 1 - PR19 Bathing Water Driver Guidance

Driver code	Description
BW_INV4	Investigation part 2. Catchment investigation to understand what water company action would be needed to achieve a robust classification of Excellent (less than 20% risk of failing planning class of Excellent).

1.5 Bathing Water Standards

The Environment Agency (EA) takes up to 20 water samples at each of England's designated bathing waters during the bathing water season (15th May to 30th September) in line with the requirements from Bathing Water Directive (76/160/EEC, revised by 2006/7/EC) which defines the conditions and standards associated with bathing water compliance. A classification for each bathing water is calculated annually based on samples from the previous four years. These classifications are provided in Table 2.

Each sample is tested for two FIOs; E. coli and IE, which quantify the faecal matter in the water and thus subsequent risk to a bathers' health. These bacteria can come from many sources including human sewage, agriculture, animal faeces and polluted storm runoff.

The bathing water classification is based on a statistical measure of all samples, known as a percentile. The classification uses either the 95% or 90% percentile depending on the classification. The Bathing Water Directive assumes that bathing water concentrations fit a log-normal distribution and percentiles are calculated on that basis. The percentile standards for coastal bathing water classifications are presented in Table 2.

Table 2 - Coastal Bathing Water Classification and Thresholds

Classification	Thresholds (percentile)
Excellent	EC: ≤250 cfu/100ml ; IE: ≤100 cfu/100ml (95th percentile)
Good	EC: ≤500 cfu/100ml ; IE: ≤200 cfu/100ml (95th percentile)
Sufficient	EC: ≤500 cfu/100ml ; IE: ≤185 cfu/100ml (90th percentile)
Poor	Means that the values are worse than the sufficient

1.6 Bathing Water Performance

The official bathing water classifications since 2015 are shown in Table 3.

[1] Environment Agency, PR19 Bathing Waters - Driver Guidance

Table 3 - Seaham Official Classifications

Bathing Water	2015	2016	2017	2018	2019	2020	2021
Seaham Hall Beach	Sufficient	Good	Excellent	Good	Good	-	Good

No classification was provided by the EA for 2020 due to the limitations on sample collection and testing caused by the Covid-19 pandemic.

Seaham Hall Beach is subject to short term pollution procedures. The EA pollution risk forecasting system was revised in 2020 and subsequently 6 pollution risk warnings were issued during the 2021 bathing season.

2 CATCHMENT OVERVIEW

2.1 Coastal Overview

The flood tide at Seaham travels in a northerly direction with high water slack occurring on average 1 hr and 35 minutes after high water. The ebb tide travels in a southerly direction at Seaham with low water slack occurring on average 5 hours before high water.

An assessment of the impact from the areas around Seaham was done using modelled continuous releases of particle tracers (see Figure 1). This work showed that the “impacting catchment” around Seaham Hall is limited to the area between #34 (Hollycarrside) and #38 (Featherbed Rocks).

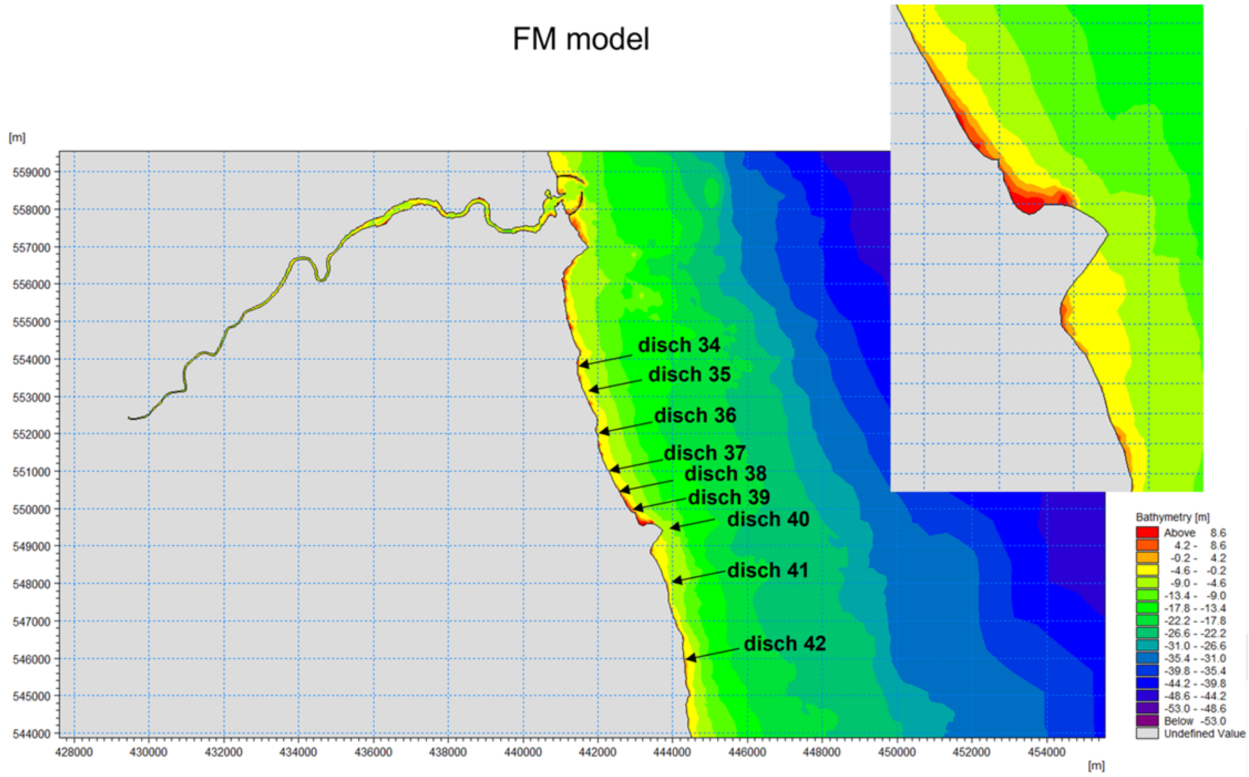

Figure 1 – Continuous Modelled Releases to Define the “Impacting Catchment”

The coastal model suggests there is a hydraulic ‘dead zone’ to the south of the bathing waters between #38 (Featherbed Rocks) and #39 (Seaham Marina). This can be seen in more detail in the velocity vector plot in Figure 2.

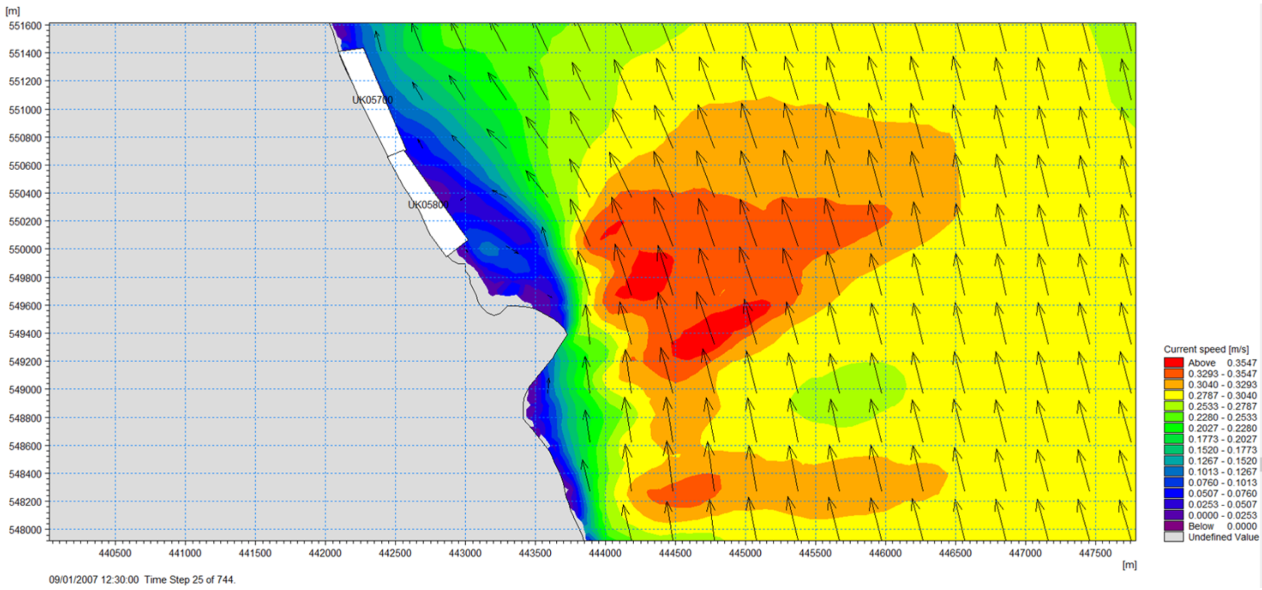

Figure 2 – Velocity Vector Plot showing the 'Dead Zone' south of the Bathing Water

2.2 Natural Catchment and General Description

Seaham Hall Beach is a gently sloping resort beach with the designated area measuring approximately 800 metres in length. The beach is mainly sand above the high water mark and a mixture of sand and rock in the inter tidal area. The designated area is in the centre of a two kilometres long bay and the main access to the beach is via stairs. The beach is backed with low cliffs with a promenade at its southern end.

The natural drainage catchment surrounding the bathing water is approximately 6.7 square kilometres, which is a mixture of arable and grassland in the upper catchment and urban in the lower.[2]

Figure 3 provides a geographical overview of the catchment, which shows the geospatial relationship between the bathing waters and other features.

2.3 Sewerage Catchment

Figure 3 also shows the key NWG sewerage infrastructure and wastewater discharge locations.

The Seaham and Seaham Hall bathing waters are influenced by NWG assets located within drainage area 08-D01 Seaham.

The residential areas of Northlea, Deneside and Seaham are served by a predominantly combined sewerage network, with some small infill developments served by separate foul and surface water networks. Flows typically follow the topography towards the coast before turning south and gravitating to Seaham STW.

There are a number of combined sewer overflows on the network, largely located inland away from the bathing waters.

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[2] Bathing water profile (data.gov.uk)

2.4 Private Sewerage Assets

There are a number of small private sewerage assets which are shown in Figure 3. Perhaps of most interest to this study are the three private discharges around Sharpley Burn to the north of the bathing water.

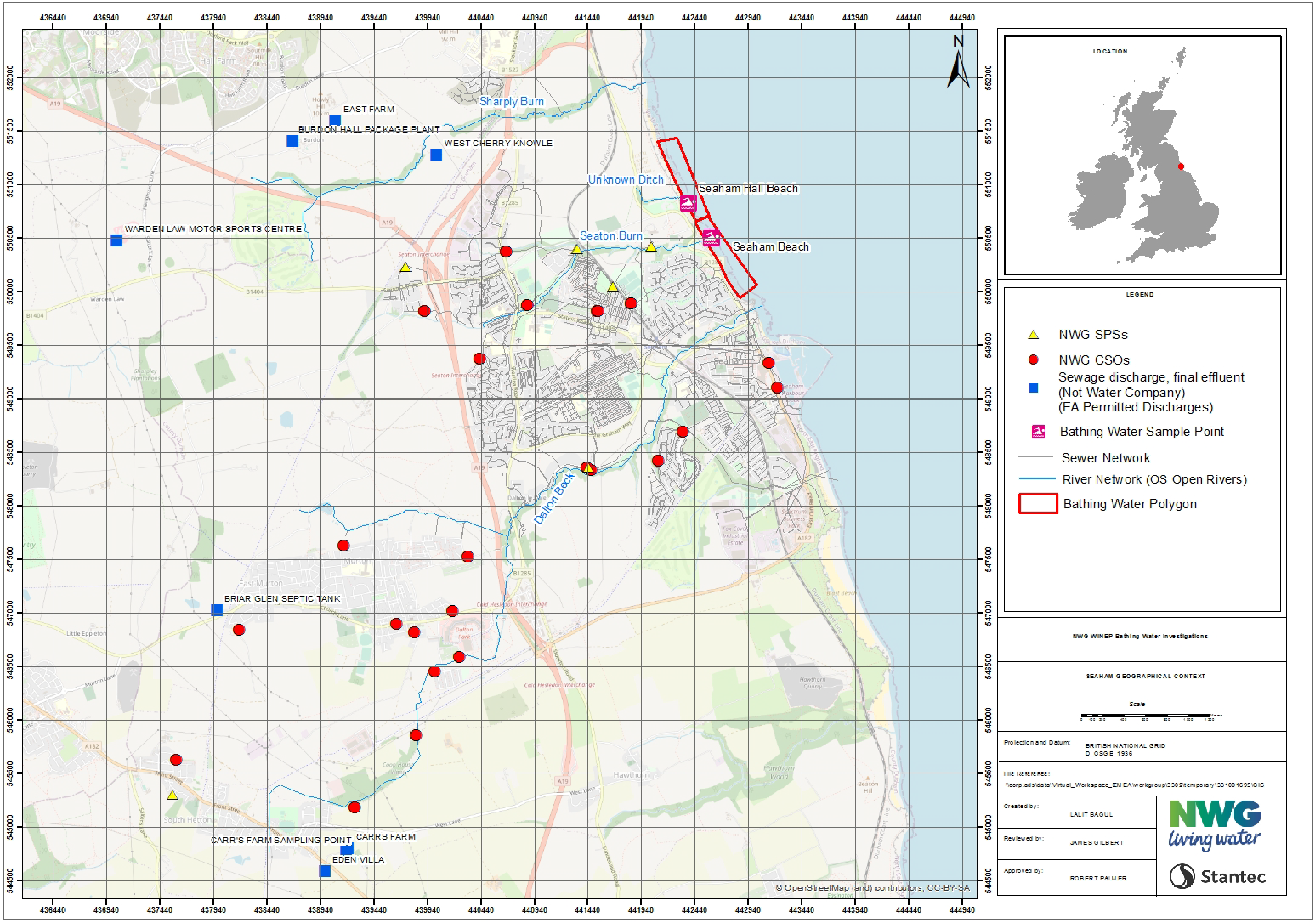

Figure 3 - Geographical Overview

3 INITIAL ASSESSMENTS

3.1 Previous Bathing Water Investigations

Several previous studies have been undertaken at Seaham Hall and Seaham Beach bathing waters. The most relevant to this study is the report addendum (RN3590) for NWG by Intertek issued October 2014. This document is an addendum to report RN2843, issued March 2012.

The document details the findings of an assessment of further solution development and its impacts on Seaham Hall Beach and Seaham Beach bathing waters. The investigation used a combination of tools to determine the impacts of NWG assets on bathing water compliance under both the current Bathing Water Directive (cBWD) and the revised Bathing Water Directive (rBWD).

This study comprised two elements:

- verification of the Intertek STORM-IMPACT model to reflect recent bathing water data and the upgraded and re-verified sewer network model; and
- Investigation of the impact of two proposed network upgrades on water quality at Seaham Beach and Seaham Hall Beach.

The verification of the coastal model demonstrated good agreement with the measured data at both bathing waters for both Faecal Indicator Organisms (FIOs). The measured and modelled results indicate that Seaham Beach and Seaham Hall Beach bathing waters were achieving the Sufficient classification (rBWD) at the 95% confidence level. Whilst this result suggested that a further option for the bathing waters was not required to ensure the Sufficient classification, system upgrades were required to comply with the Urban Wastewater Treatment Directive (UWWTD) and provide further certainty of meeting the Sufficient classification.

The predicted impact of the two scenarios (Option 1 and Option 2) on bathing water quality was assessed. The intended purpose of these two solutions was to ensure that the network was compliant with the UWWTD and minimise the impact on the Dalton Burn by restricting the pass forward flow from the Dalton Park flow control to below 175 l/s and 125 l/s for Option 1 and 2, respectively. Both Option 1 and Option 2 were predicted to achieve the Sufficient classification at the 95% confidence level for both EC and IE at both bathing waters.

3.2 Specific MSF Requirements

Following the drop in classification from Excellent to Good in 2018 it was agreed that the marine impact model should be updated with the capital improvements at Dalton-le-Dale during 2015. The updates to the marine impact model should revisit source apportionment at Seaham Hall.

3.3 Data Analytics

A high-level data analytics exercise was undertaken to identify patterns and trends in the EA sampling dataset (2015-2021) which may aid understanding of non-NWG source impacts and support the coastal modelling.

3.3.1 Performance Trends

Considering performance on an annual, rather than a four year basis, the variations in performance trends can be seen more clearly. These are shown in Table 4.

Table 4 – Seaham Hall Annual Performance Trends

	2015	2016	2017	2018	2019	2020	2021
Annual Classification	Good	Excellent	Good	Good	Sufficient	-	Good
95%ile IE	112	75	111	177	269	-	161
95%ile EC	108	113	61	55	731	-	92
Samples Discounted due to PRF	1	0	0	0	0	-	0

This data would suggest that there has been a general deterioration of performance at Seaham Hall Beach since 2016 with particular issues during 2019. Issues in 2019 are common at many bathing waters in the region due to a particularly wet summer.

3.3.2 Percentiles

IE and E. coli measured data exceed threshold standards for 'Excellent' during the 89th and 95th percentile respectively which is in-line with performance trend figures which show IE performance is driving the bathing water quality classification. Percentile concentrations appear to grow almost exponentially between the 64th and 98th percentile. There is no obvious step change in concentrations associated with impacts from critical intermittent discharges.

3.3.3 Seasonality

There is no obvious correlation between the time or date the sample was taken and percentile concentration or exceedance events.

3.3.4 Tidal Analysis

Tidal analytics was carried out on data between 2015 and 2020. Verified tidal gauge data from the BODC for 2021 was not available at the time of writing. Tidal analysis showed that the highest concentrations, likelihood of exceedance and number of exceedances at the bathing water all increase with proximity to high water.

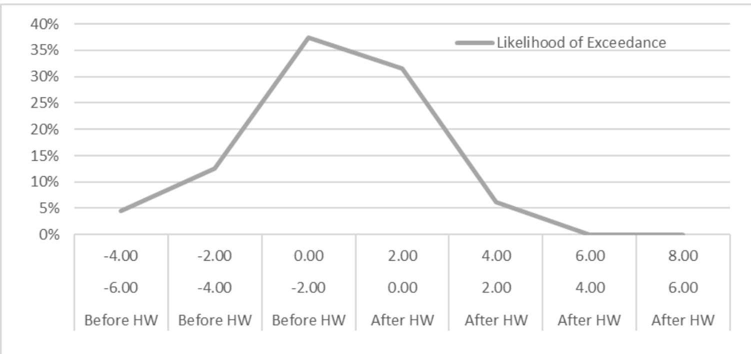

Figure 4 – Likelihood of Exceeding the Threshold Standards for Excellent Against Tidal Phase

3.3.5 Precedent Weather Conditions

Analysis of the precedent weather conditions was carried out on data between 2015 and 2020. Verified rain gauge data from the EA for 2021 for the local gauge was not available at the time of writing. Analysis showed that of the 13 exceedances of the threshold standards of 'Excellent' status, 31% of these occurred after >10mm of rainfall in the previous 48 hours. This shows that whilst wet weather sources can impact the bathing water there are other sources, there are just as many which can impact during dry weather conditions.

3.3.6 Correlations with CSO spills

Table 5 shows the occasions when CSO have spilt within 48 hours of exceedances of the threshold standards for Excellent bathing waters. This does not mean these CSOs are responsible for these exceedances but is suggestive of a possible link.

Table 5 – Comparing Exceedance Events with CSO spills (2017-2019)

Date	IE (cfu/100ml)	E. Coli (cfu/100ml)	CSO spills within previous 48 hours	Rainfall within previous 48 hours (mm)
19/06/2017	600	10	No	0
09/07/2018	460	45	No	0.4
09/08/2018	350	127	No	0
13/06/2019	2200	2700	Windermere Road CSO, Dalton-le-Dale CSO 1, Burnip Road CSO	43
26/06/2019	10	290	No	4.9
13/08/2019	190	760	Windermere Road CSO, Dalton-le-Dale CSO 1, Burnip Road CSO	26
28/08/2019	340	540	Windermere Road CSO, Dalton-le-Dale CSO 1, Burnip Road CSO	16

"Windermere Road CSO" is also referred to as "Seaham CSO 25" and "Warkworth Crescent". "Dalton-le-Dale CSO 1" is referred to as "Seaham CSO 16".

3.4 Input Data Quality Checks

In order to check the quality of the input data being used, multiple quality checks have been undertaken.

3.4.1 Sewerage Network Model Performance versus EDM

The spill frequency from the key intermittent discharges in the network models were cross checked against Event Duration Monitor (EDM) data.

Table 6 – Model Spill Frequency versus EDM Comparison for Key CSOs

		2016	2017	2018	2019	2020	Average
Dalton le Dale CSO / Seaham CSO 16	EDM	13	17	16	29	16	19
	Modelled	12	17	13	29	12	17

Burnip Road (No21) EA004	EDM	6	1	6	11	7	6
	Modelled	6	8	8	17	10	10

The network model shows a good correlation with EDM results leading to high confidence in the modelled impact of the critical assets.

Well established default bacterial concentrations for stormwater were used in the model. These are based on measured concentrations from a large number of assets over time.

4 ASSESSMENT APPROACH AND INPUTS

The assessment approach is summarised in the following sections. Further information can be found in the Appendices referenced below.

4.1 NWG CMS21 Coastal Model Calibration and Validation

The existing individual Northumbrian Coastal models previously used and accepted for bathing water compliance assessments have been superseded to create a single model domain which covers the entire Northumbrian coastline. This ensures all modelled discharges have the opportunity to impact any bathing water. The updated model (NCMS21, representing the 2021 upgrade) has been converted into MIKE21 Flexible Mesh in line with current industry standards. Where applicable the bathymetry has been updated with latest information and the representation of the main rivers extended up to the tidal boundaries. The hydrodynamic calibration has also been enhanced in the key areas associated with bathing water compliance.

The NCMS21 calibration and validation report details the updates and improvements made to the existing NCMS and the subsequent recalibration. This report can be found in Appendix B.

4.2 Storm Water Impact Model (SWIM)

Compliance assessments have been undertaken using Stantec's Storm Water Impact Model (SWIM). A detailed explanation of SWIM can be found in Appendix C.

All modelled discharges are shown in Figure 8.

The sewer model and river inputs to SWIM take into account the effects of rainfall and averages other environmental factors such as wind direction and tide.

4.3 Modelling Approaches

The full report detailing the modelling approaches used for this assessment can be found in Appendix D.

4.4 SWIM Performance

SWIM is calibrated against the last four years of observed data and the quality of the calibration is assessed by comparing 90th and 95th percentile values derived from the observed data and the modelled data. To ensure reliable model outputs there is a target of R^2 correlation value of 0.8 between the observed and modelled data across the entire percentile range.

Percentile statistics are calculated using the method described in the Schedule 5.2 of the Revised Bathing Waters Directive. All modelled values below the minimum limits were set to the minimum limits of detection (10 cfu/100ml) and all values greater than the maximum limits of detection were set to the maximum value (10,000 cfu/100ml).

SWIM produces results at a number of fixed locations, but also at a spatially variable point. This spatially variable point (referred to as the 'walking survey') has been designed to better represent the changing nature of the EA sample point depending on the state of the tide.

Walking survey modelled results are presented alongside observed data for Seaham Hall bathing water in Table 7.

Model performance comparisons against the official bathing water classifications are shown in Table 7. SWIM isn't predicting the official classifications in 2016 & 2017. This is to be expected however as sewerage model outputs were only available from 2015 onwards so modelling data wasn't available for the whole four year period used to define the official classification. From 2018 to 2019, when SWIM was able to model the full four year period, the SWIM outputs match the observed classifications.

Table 7 - Comparing bathing water classification with the 4 year modelled predictions at Seaham Hall Beach

2016		2017		2018		2019	
Class	**Model[3]**	**Class**	**Model**	**Class**	**Model**	**Class**	**Model**
Excellent	Good	Good	Good	Good	Good	Good	Good

Looking at Table 8, SWIM is shown to match the classification for IE and E. coli but is slightly underpredicting at the 90th and 95th percentiles.

Table 8 - Key Statistics from the model calibration for Seaham Hall Beach (2016-2019)

Bacteria Type	Observed 90%ile	Observed 95%ile	Observed Class	Modelled 90%ile	Modelled 95%ile	Modelled Class
E. coli	100	156	Excellent	79	158	Excellent
IE	93	143	Good	71	133	Good

4.4.1 Water Quality Calibration

Model predictions were evaluated by comparing exceedance probability (EP) curves between SWIM and the observed sample data.

The SWIM results used to create the modelled samples were simulated for six bathing seasons. The calibration is then compared against both the whole dataset of 6 years (2015-2020) and the 4 years period between 2016-2019 to provide a broader range of values to fit the model against.

Figure 5 shows the information available from the EP curves and how it can be interpreted to investigate the model calibration.

[3] 2017 Model results based on 3 years of sewerage network model outputs rather than the full four year period

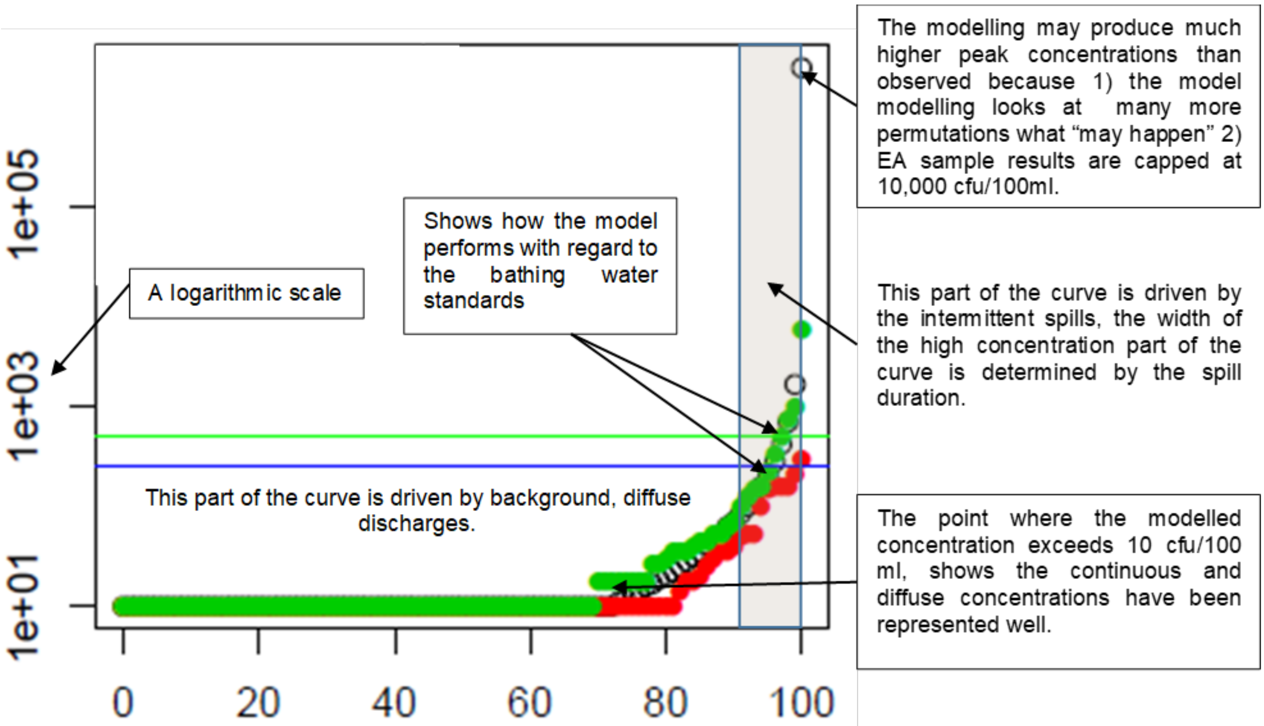

Figure 5 - The information available from comparing EP curves.

There are two adjacent bathing beaches at Seaham, Seaham Beach to the south (Excellent) and Seaham Hall Beach to the north (Good). SWIM was calibrated for both beaches, maximising the use of the available observed data to increase confidence in the calibration.

As shown in Figure 8 the modelled sources impacting Seaham discharge into or south of Seaham Beach (Excellent) bathing water. This includes the continuous discharges from Dalton Beck, Seaton Beck and Seaham WwTW final effluent and all NWG intermittent discharges. Initial modelling therefore showed that there was a deficit in the background pollution at Seaham Hall Beach (Good).

Calibration involved adjusting the concentrations in the rivers until the model matched the observed data for Seaham Beach, which shows that the southern sources had been modelled correctly. These calibrated southern sources also impact on Seaham Hall Beach, so any shortfall in the background concentrations is assumed to come from north of Seaham Hall Beach.

The differences between the modelled and observed concentrations at Seaham Hall Beach, was assumed to be from sources in the vicinity of the beach and to the north. Across the mid to upper percentile range there was a significant underprediction between the observed and modelled IE concentrations, however observed and modelled EC concentrations showed a good correlation. This is shown in Figure 6.

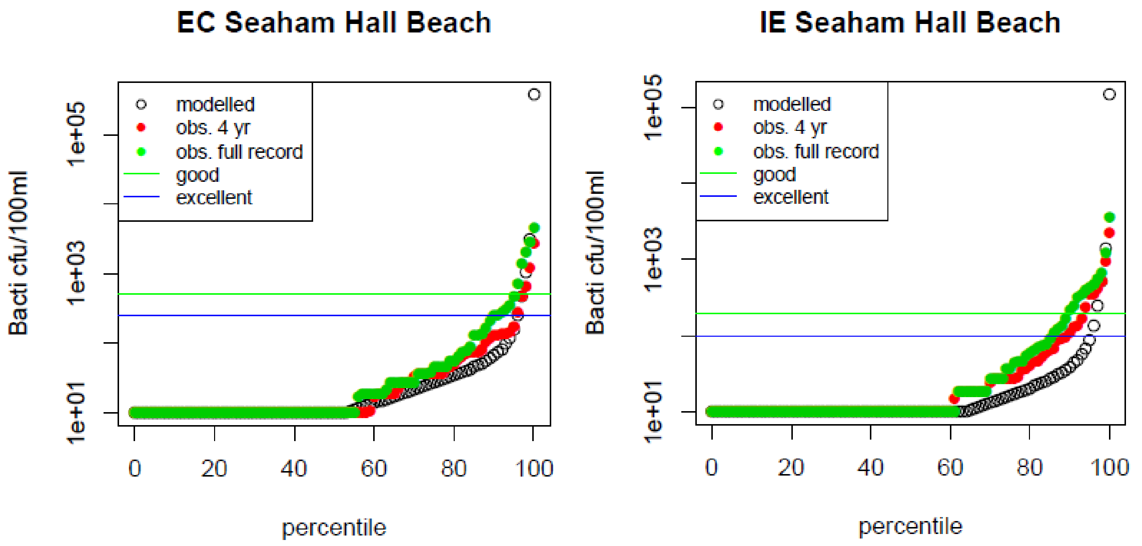

Figure 6 – Initial calibration at Seaham Hall Beach

The differences in concentrations were analysed and couldn't be modelled with a parametric distribution, consequently the deficits were represented with non-parametric distributions, which for EC varied between 0 and 60 cfu/100 ml. The missing IE required larger concentrations of bacteria, between 0 and 140 cfu/100ml but extending to 450 cfu/100ml. These additional sources were added into the SWIM model as a point source at Seaham Hall Beach. This source represents bacteria sources from the north or directly to the beach itself. The modelling suggests that although the EC sources can be largely explained by the modelled sources to the south, there is a missing IE source at or to the north of Seaham Hall Beach.

The addition of the sources has slightly increased the background concentrations of EC and had a greater effect raising IE concentrations at the beach.

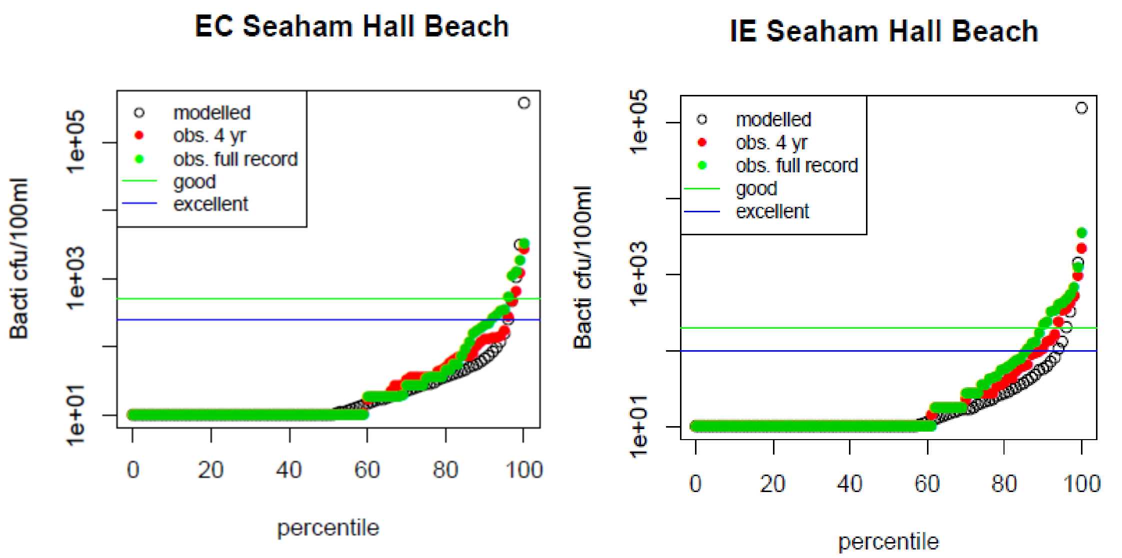

Figure 7 – Final calibration at Seaham Hall Beach after the addition of the unknown source.

The final EP curves in Figure 7 show the modelled and observed data across the percentile range for EC and IE respectively. The shape of the curve shows that the model is producing a good calibration, with R^2 values of 0.927 and 0.923 being modelled for EC and IE respectively.

The EP curves show the model simulation for the five simulated years is slightly low against the 12 year observed dataset and a little lower still against the 4 year data. For both EC and IE, the shape of the curve shows that the model is producing a good simulation.

The EP curves show the model to be underpredicting slightly for EC and a little more for IE, this underprediction could have been adjusted further to improve the model fit, but it was deemed unnecessary as this wouldn't have added any additional useful information. The shortfall in bacteria is not believed to be from wastewater sources.

4.1 Modelled Assets

All NWG discharges (continuous and intermittent) within the "impacting catchment" of the bathing water were identified and then defined in terms of their location, flow and concentration. In the case of intermittent discharges, a 6-year time series was used from the network models to provide flow hydrographs.

CSO inputs were modelled as discharging at concentrations of $5.0x10^6$ cfu/100ml and $2.0x10^6$ cfu/100ml for EC and IE respectively. Seaham STW was modelled conservatively with concentrations of $6.3x10^5$ cfu/100ml and $2.5x10^5$ cfu/100ml for EC and IE respectively; these values are in line with expected concentrations from Secondary Treated Effluent rather than UV disinfection.

Table 9 – Table of Modelled NWG Assets within the 'Impacting Catchment'

Asset Type	Asset Name	Grid Reference
CSO	Murton CSO Church Street Coronation Street	439647, 546895
CSO	Thomas S Haulage Yard	440171, 547016
CSO	Sea View Walk Murton	440315, 547525
CSO	Burnip Road (No21) EA004	439160, 547626
CSO	North Moor Farm Shotton (Haswell No18) EA057	438696, 541740
CSO	Pesspool Lane Haswell	438514, 543614
CSO	Coldwell Burn Mineral Railway EA051	438174, 544014
CSO	Coop House Wood Pond	439257, 545182
CSO	Little Coop House Farm	439836, 545852
CSO	Barwick Street EA112	440005, 546450
CSO	Easington CSO Allotment Gardens	440238, 546588
CSO	Murton CSO Hawthorn Close	439815, 546817
CSO	Murton Bakery (Haswell No7)	438181, 546836
CSO	Conishead Terr (No 1) (Haswell No4) EA009	437594, 545622
CSO	Seaham CSO 16 / Dalton le Dale 1 CSO	441471, 548335
CSO	Seaham CSO 27	441432, 548357
CSO	Daphne Crescent EA109	442099, 548419
CSO	Seaham CSO 2	442332, 548694
CSO	Seaham CSO North Terrace (Foundry Road)	443210, 549101
CSO	Seaham CSO North Terrace (Byron Place)	443128, 549337

Asset Type	Asset Name	Grid Reference
CSO	Seaham CSO 25 / Windermere Road CSO	440433, 549378
CSO	Seaham CSO 13	441530, 549818
CSO	Seaham CSO 11	439912, 549822
CSO	Seaham CSO 7	440871, 549876
CSO	Seaham CSO 10	441842, 549893
CSO	Seaham CSO 5	440676, 550372
CSO	Seaham SPS 30	439738, 550234
CSO	Seaham SPS 1	441340, 550401
CSO	Murton SPS 3	437558, 545300
CSO	Seaham SPS 4	441443, 548358
CSO	Seaham SPS 2	441680, 550053
CSO	Seaham SPS 3	442037, 550426
CSO	Overflow At STW	445400, 547135
FE	Seaham STW	445400, 547135

4.2 Other Diffuse Loads

Diffuse loadings were treated as the primary calibration parameter with known, suspected, and potential diffuse source contributions applied at various locations, flows and concentrations within the model, in order to achieve the best fit with observed data.

All modelled diffuse sources are based on findings and patterns from data analytics, historic studies or investigations or anecdotal local evidence. This approach is in line with many water quality studies including the EAs approach to Phosphorus modelling in rivers using SAGIS SIMCAT whereby diffuse load values are less certain and are used as part of the calibration.

To obtain a good calibration of the modelled and observed data, background sources of bacteria were added to the model. These background sources were assigned to the rivers, details of which are shown in Table 10. Applying a load to the rivers enabled observed background concentrations to be simulated but doesn't necessarily mean the rivers are the actual source of the background load.

All the point source discharges were included in the modelling, and then the concentrations of the rivers were adjusted until the modelled EP curves for the two bacteria types matched the observed. The flows in the rivers were time variable, either from observed data or rainfall runoff models. The concentration of these river sources was constant in all flow conditions. The concentration and a summary of the flows are presented in Table 10.

Table 10 - River input/diffuse sources applied in the SWIM model

	Applied Concentration (cfu/100 ml)		Flows (m^3/s)	
Source	**E. coli**	**IE**	**Q95**	**Q50**
Dalton Beck	12,250	7000	0.007	0.045
Seaton Burn	12,250	7000	0.002	0.015

As each of these rivers/streams join at different locations relative to the bathing waters, their concentrations were adjusted (within reason) to provide the best fit with the EP curves. Dalton Beck is three times larger than Seaton Burn, so will discharge a greater bacteria load for the same concentration, but Seaton Burn discharges a lot closer to Seaham Hall beach so will have a larger impact.

Once Seaham Beach had been calibrated the shortfall in bacteria was represented by adding background concentrations to the simulations. The background concentrations were derived from analysing the difference between observed and modelled concentrations. This deficit was addressed by adding concentration randomly drawn from two non-parametric distributions, summarised in Table 11.

Table 11 - Summary of non-parametric distribution used to model northern sources to Seaham Hall Beach

EC	**Bins: cfu/100 ml**	**0**	**>0-20**	**20-40**	**40-60**	**60-80**	**80-100**
	%	87%	5%	4%	3%	1%	0%
IE	**Bins: cfu/100 ml**	**0**	**>0-100**	**100-200**	**200-300**	**300-400**	**400-500**
	%	38%	53%	5%	1%	2%	1%

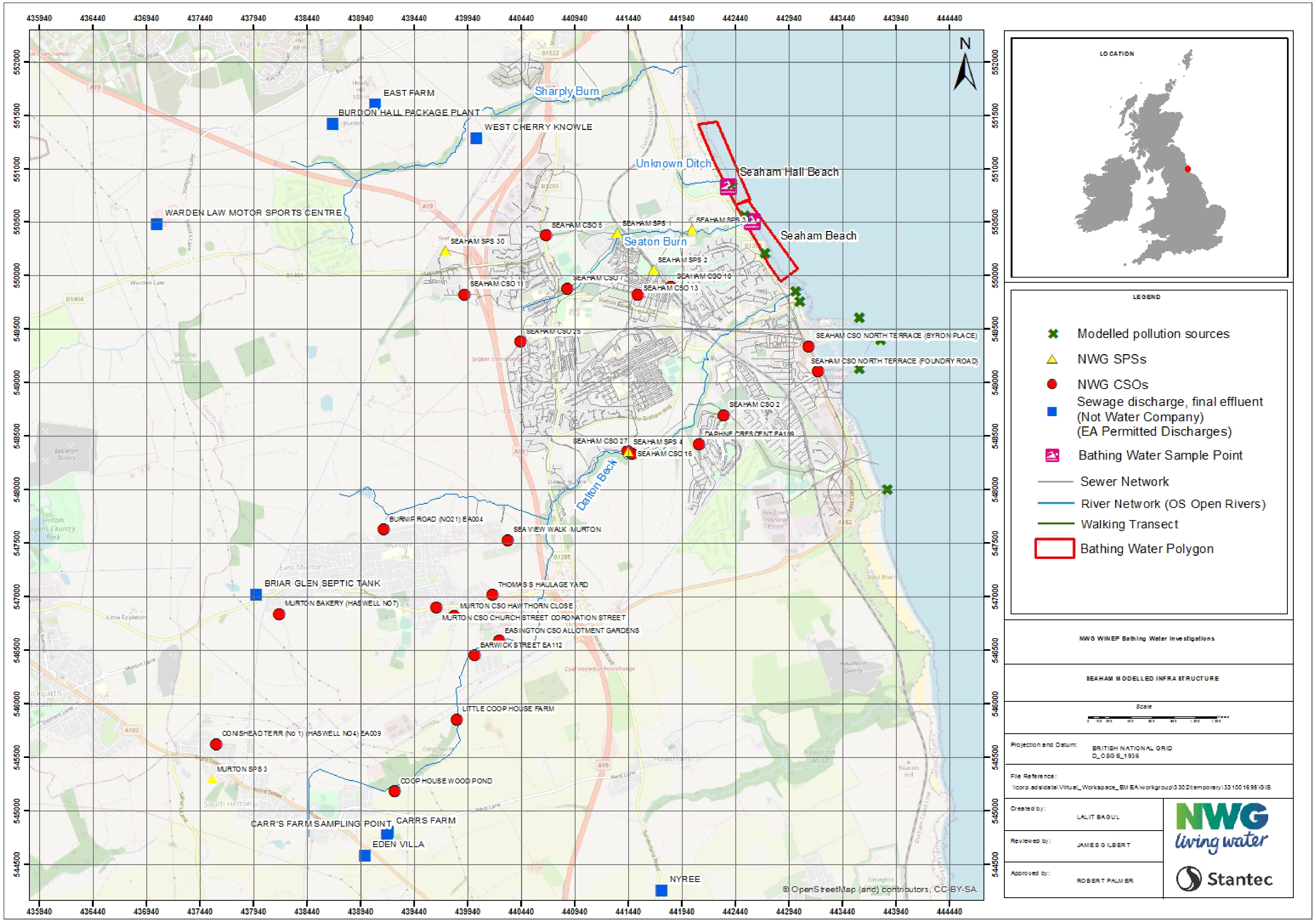

Figure 8 - Map of all catchment features and potential sources within the "impacting area" of the bathing water.

5 BATHING WATER ASSESSMENT RESULTS

5.1 Existing Results and Source Apportionment

The apportionment between the key sources at each of the sites is detailed in Table 12 and shown visually in Figure 10 and Figure 11.

The source apportionment looks what the contribution of bacteria discharged from each source makes to exceeding the threshold for the "Excellent" classification. The CSOs contribute loads of bacteria for a (relatively) short period of time, the background sources provide lower loads but high enough concentrations to exceed the standards for longer periods. The source apportionment methodology considered the percentage contribution each source made for each hour a threshold is exceeded and the contribution summed up for each source.

Table 12 – Seaham Hall Beach Source Apportionment

Name	EC Excellent	EC Good	IE Excellent	IE Good
Dalton Beck	61.7	46.6	40.3	35.3
SEAHAM CSO 25 / Windermere Road CSO	11.3	16.9	3.7	6.5
SEAHAM CSO 16 / Dalton le Dale 1 CSO	7	9.5	2.4	3.7
COOP HOUSE WOOD POND CSO	5.5	7.4	N/A	3
EASINGTON CSO ALLOTMENT GARDENS	4.3	6.3	N/A	2.4
SEAHAM CSO 7	N/A	3.3	N/A	N/A
SHB Background Source	N/A	N/A	46	43.5
Each Under 2%	10.3	10.1	7.6	5.6

The source apportionment shows that the contribution from the CSOs is small compared to those from the other sources. For EC, CSOs Seaham CSO 25 and CSO 16 make the largest contribution to exceeding the Excellent classification with an 18% contribution between them. The largest contribution is from Dalton Beck at 62%. For IE 46% of the contribution comes from the unknown local source and 40% from Dalton Beck. Seaham CSO 25 and CSO 16 are still the largest intermittent contributors providing 6% contribution.

The data analytics inferred that exceedances of the 'Excellent' classification didn't always coincide with the intermittent spills. Analysis of the CSO spill durations (Figure 1) using RIOT show that for 23 CSOs simulated for 5 bathing seasons (i.e. a total of 115 instances), there are only two instances of discharges longer than 5% of the season and the majority are 2% or less.

The SWIM and RIOT modelling support the data analytics that the majority of threat to the bathing water classification doesn't come from the intermittent discharges.

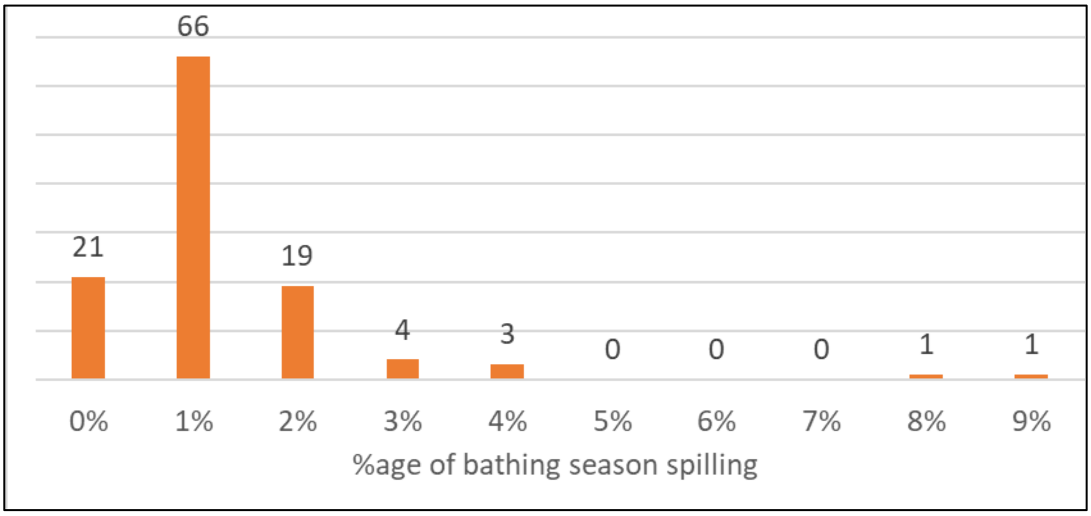

Figure 9 - Histogram showing percentage of bathing season CSOs are spilling based on 23 discharges for 5 years of simulation

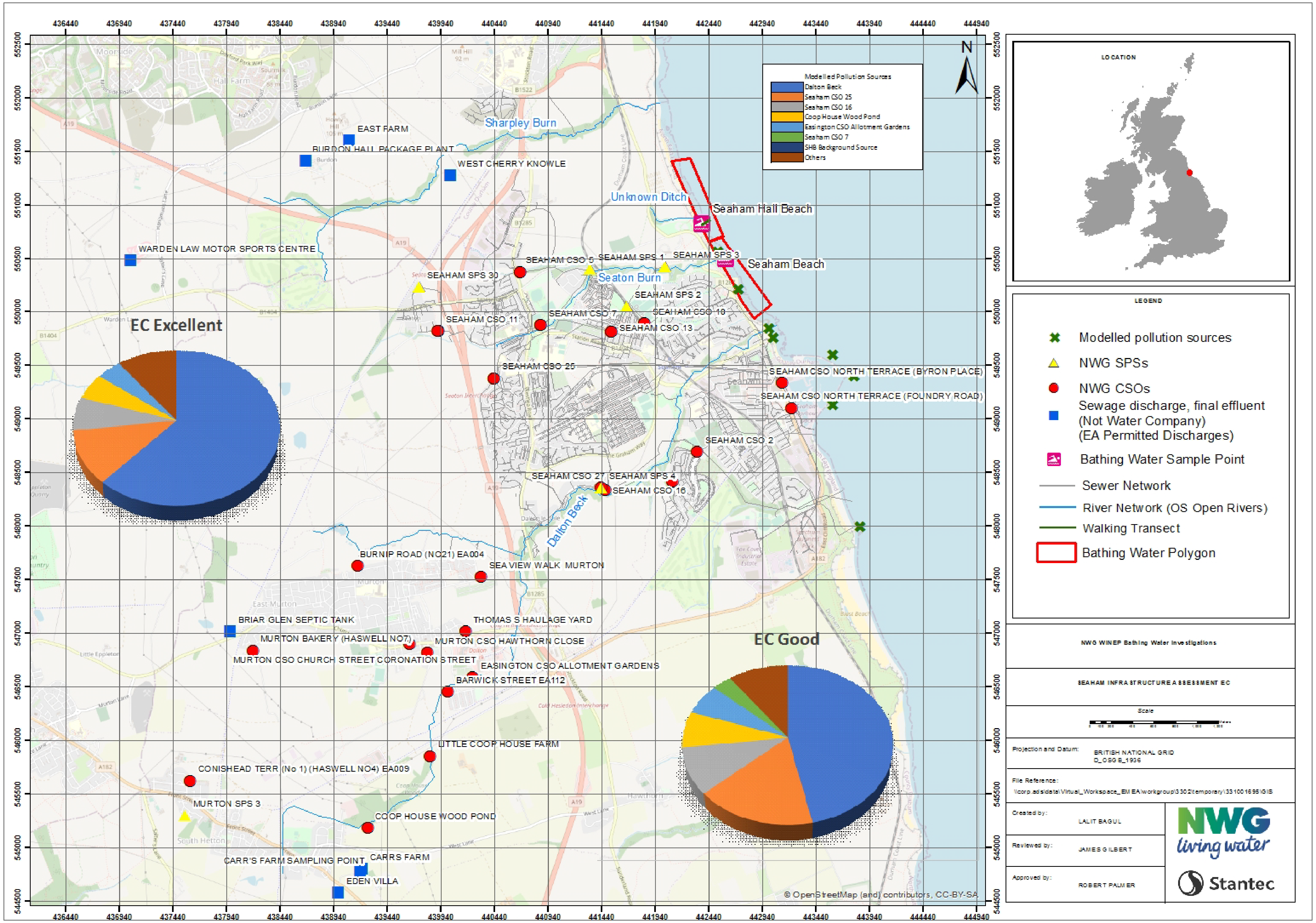

Figure 10 – Source Apportionment for E. coli at the Excellent and Good Thresholds.

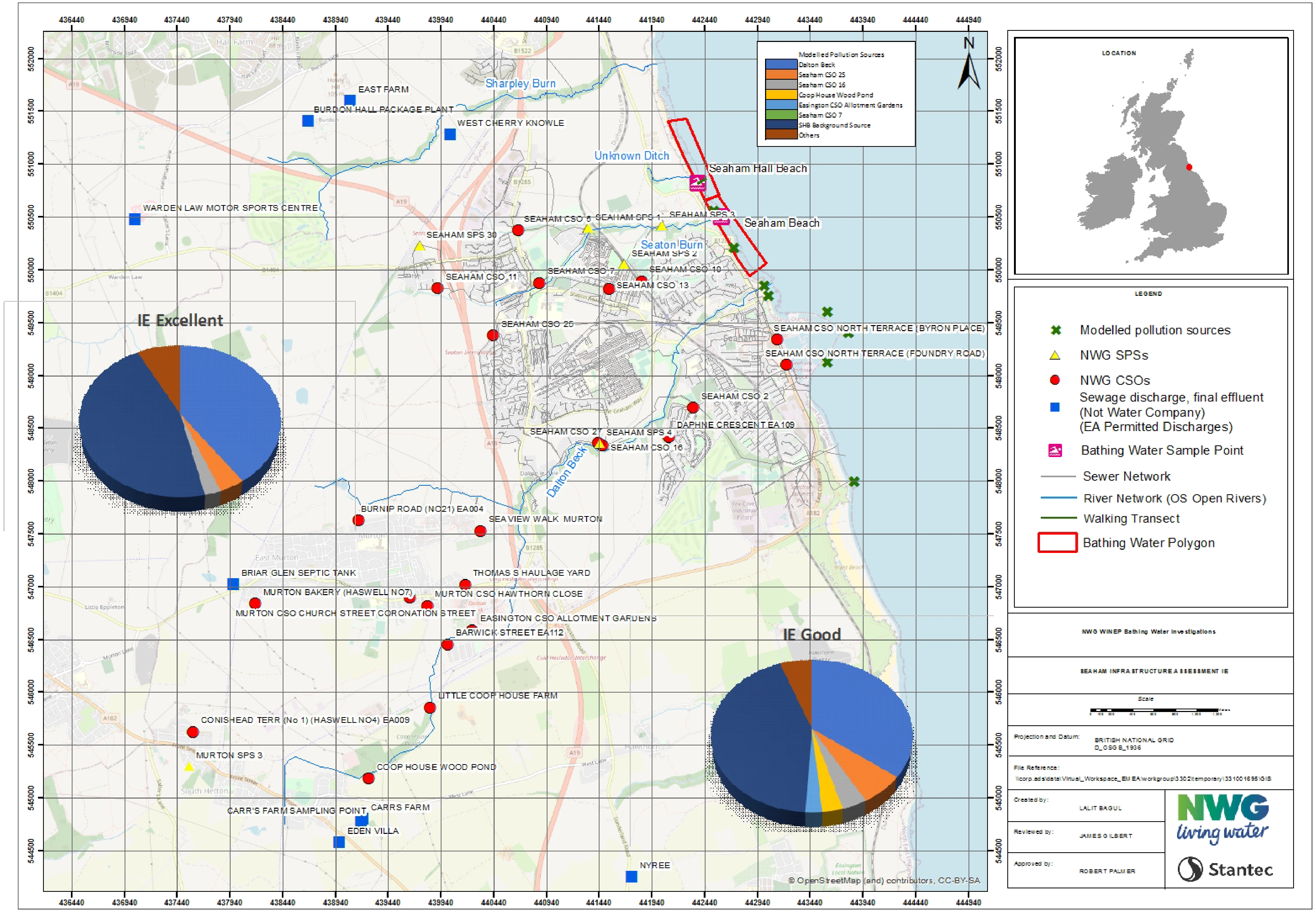

Figure 11 – Source Apportionment for IE at the Excellent and Good Thresholds.

5.2 INV4 Needs Assessment

The SWIM outputs were resampled applying the EA sampling methodology to determine the range of observed values that would be obtained from a series of routine sampling and classification exercises. The 80%ile highest value was obtained from this in order to determine the works required to achieve a robust classification with a less than 20% chance of failure.

Table 13 - Predicted concentrations at Seaham Hall Beach with <20% chance of failure

Bacteria Type	Predicted 95%ile concentrations, based on rolling four year period, achievable with <20% chance of failure (cfu/100 ml)				Excellent Threshold Value (cfu/100 ml)
	2016 [a]	2017 [b]	2018	2019	
EC	234	219	284	317	250
IE	154	141	180	196	100

[a]2 year rolling period, [b]3 year rolling period because model run for 2015-2020

The modelling shows that Seaham Hall Beach currently achieves robust 'Good' classification defined as there being a less than 20% likelihood of non-compliance. IE rather than E. coli can be seen to be the critical bacteria governing overall classification.

5.3 Solution Development

By modelling the background sources and NWG assets in isolation it can be seen that undertaking improvement works to NWG assets only will not achieve the desired robust Excellent classification. This is unsurprising given the findings of the baseline modelling and data analytics which suggest that without the presence of the unknown local source Seaham Hall Beach should be performing equal to, or if not slightly better than Seaham Beach.

Whilst it is possible to achieve a robust Excellent by other means, a combined programme of improvement works to Seaton Burn, Dalton Beck, Seaham CSO 16 and Seaham CSO 25, the same outcome can be achieved with greater confidence by finding and removing the local source.

5.4 Discussion of Local Source

The unknown source of IE local to, or just north of, Seaham Hall Beach is ultimately responsible for the differences in classification between Seaham Beach (Excellent) and Seaham Hall Beach (Good).

Data analytics supports this conclusion as the highest concentrations, highest likelihood of exceedance and largest number of exceedances occur near high water which suggests sources close to the bathing water. The majority of these exceedances (~70%) do not appear to be wet weather related.

There are very few potential sources however in close proximity to, or just north of the Seaham Hall Beach bathing water.

- It is not clear from network mapping where flows North Beach Coffee Bar discharges, and this should be investigated further.
- There is a drainage ditch (shown on the maps) in the tree line just north of Seaham Hall Beach Car Park which discharges onto the beach near the steps. This should be sampled to assess level of contamination.

- Seaham Car Boot appears to be a popular regular event which takes place in the field directly behind the beach. It would be good to confirm toilet and sanitary provisions during these events.
- Further north, Sharpley Burn has several private discharges including Burden Hall, East Farm and West Cherry Knowle. Whilst it is not clear why discharges from Sharpley Burn would impact Seaham Hall Beach particularly around high water a source high in IE and low in E. coli could be indicative of a pollutant which has been in the environment for a longer period.

MST analysis of high samples from Seaham Hall Beach would help aid source identification.

6 CONCLUSIONS

6.1 Data Confidence

The sewerage network model shows a good correlation with spills events recorded by the event duration monitor leading to a high degree of confidence in network model outputs.

6.2 Coastal Model Performance

The coastal model hydrodynamics show a good calibration with observed data in this region. The ‘dead zone’ south of the bathing water however does have a significant impact on the local hydrodynamics

6.3 SWIM Performance

SWIM was calibrated for Seaham Beach with inputs from Dalton and Seaton Becks. Further background bacteria sources added to ensure a fit at Seaham Hall Beach.

Calibrated SWIM provided a good fit against the observed bacteria concentrations at Seaham Hall Beach, providing a good match against the shape of the EP curve and providing a match against observed statistics. The R^2 values on the fits with the EP curves were 0.9 or higher. SWIM matched the classification in 2016 to 2019.

The modelling showed that a significant source of additional IE bacteria was required to obtain a fit, whereas not much additional EC bacteria were needed. This suggested that there is an unknown source of bacteria (predominantly IE) local to, or north of Seaham Hall Beach which is contributing the beach unable to achieve a robust ‘Excellent’ classification.

6.4 Source Apportionment

There are four CSOs which have an observable impact on Seaham Hall Beach, with Seaham CSO 25 (Windermere Road CSO) which discharges to Seaton Beck standing out as the most significant contributor. The source apportionment shows the combined contribution of the CSOs is smaller than from the background concentrations, so the background concentrations have a much bigger effect of non-compliance than the CSOs.

6.5 Needs Assessment

The needs assessment (based on the 2019 calibration) shows Seaham Hall Beach to currently be achieving a robust ‘Good’ classification.

The modelling showed that the CSOs did not spill frequently enough to match the observed concentrations at the beach and that there was a significant portion of the bacteria load derived from unknown background or diffuse sources. The CSOs did not spill for long enough during the bathing season to impinge on the 95-percentile standards.

6.6 Options Assessment

A robust ‘Excellent’ status can be achieved through significant improvements to Dalton Beck, Seaton Burn, Seaham CSO 16 and Seaham CSO 25. It may not be possible however to reduce the background pollution levels in the rivers enough to achieve this.

Alternatively a robust ‘Excellent’ can be achieved by identifying and removing the unknown source local to, or just north, of the bathing water.

6.7 Summary of Conclusions

IE concentrations are limiting the bathing water classification, preventing it currently achieving the 'Excellent' Classification.

NWG assets have been shown to have a very limited impact on bathing water quality, accounting for less than 15% of the IE source apportionment at the Excellent threshold.

7 RECOMMENDATIONS

It is recommended that further investigations are undertaken into the unknown local source contributing to the failure to achieve a robust ‘Excellent’ at Seaham Hall Beach bathing water.

- Investigate connectivity and integrity of sewerage arrangements at North Beach Coffee Bar and any unmapped sewerage along the foreshore
- Sample bacteria levels in drainage ditch in the tree line just north of Seaham Hall Beach Car Park
- Investigate drainage arrangements from Seaham Car Boot
- Sample bacteria levels in Sharpley Burn
- MST analysis of high samples from Seaham Hall Beach