PR14 Q Environmental Quality - Coastal Investigations

Compliance Assessment – Poppit West

3499_E_200-INT-00-XX-RP-RP-N-C-10332

Photo: Poppit West – West Wales

Issue and Revision Record

Revision	Date	Originator	Checker	Approver	Description
1.0	06/04/2017	J. Drozdzak	J. Daruvala/ P. Taylor	C. Mooij	Original
2.0	27/04/2017	J. Drozdzak	J. Daruvala	C. Mooij	Addressing partner's comments
3.0	14/06/2017	J. Drozdzak	P. Taylor	C. Mooij	Addressing client's comments

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Abbreviations

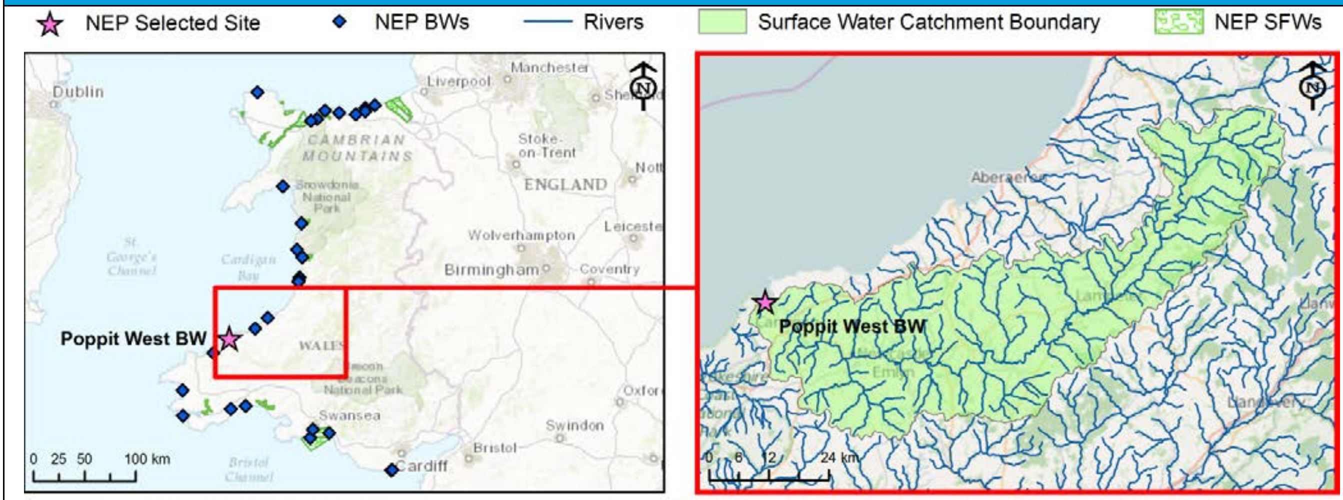
AMP	Asset Management Programme
AT	Alliance Team
BW	Bathing Water
BWD	Bathing Water Directive
CREH	Centre for Research into Environment and Health
CSO	Combined Sewer Overflow
DCWW	Dŵr Cymru Welsh Water
DSP	Designated Sample Point
DWF	Dry Weather Flow
EAW	The Environment Agency for Wales
E.coli or EC	Escherichia Coli
EDM	Event Duration Monitoring
FFT	Flow to Full Treatment
FIO	Faecal Indicator Organisms
IE	Intestinal Enterococci
NEP	National Environment Programme
NRW	Natural Resources Wales
SPS	Sewage Pumping Station
S-O	Storm-Optimiser
SFW	Shellfish Water
STW	Sewage Treatment Works
T_{90}	Decay rate
WwTW	Wastewater Treatment Works

Assessment Executive Summary

32. Poppit West

Project Name	Report Code	Assessment Type
Coastal Investigations - NN31	3499_E_200-INT-00-XX-RP-RP-N-C-10332	Full
Site Number & Name	**Study No. , Model Area**	**Region managed by**
32. Poppit West	15-Cardigan Bay (W)-West (Block 1)	Pembrokeshire (Sir Benfro)

Geographical Overview



Site and Catchment Description

Poppit West Bathing Water (BW) is located within Cardigan Bay, within the Pembrokeshire National Park and measuring approximately 600 metres in length. The coastal waters and coastal belt form part of the Cardigan Bay Special Area of Conservation, confirming the high conservation status of the area. The adjacent Poppit Sands is a sandy beach, backed with sand dunes and is divided by the Afon Teifi, which flows onto the beach. The water quality designated sample point (DSP) is located at the centre of the beach, to the north of the car park.

The natural drainage catchment surrounding the bathing water is predominantly agricultural, with the large residential town of Cardigan located three kilometres inland of Poppit West. The Afon Teifi is one of the largest rivers in Wales, draining a large agriculture catchment; therefore, it is expected that it will have a predominant impact on the microbial water quality at Poppit West BW.

Streams are typically affected by sewage or industrial run-off from further up the catchment. The Afon Teifi bacterial load has been identified by Natural Resources Wales (NRW) as a major contributor to the Poppit West BW water quality (http://environment.data.gov.uk/wales/bathing-waters/profiles/profile.html?site=ukl1402-38630). This strong connection is illustrated by low salinity levels observed in some bathing water quality samples, indicating significant freshwater influence at the BW.

NRW samplers make observations of the beach when visiting to take water samples (historically 20 times per bathing season). This includes assessments of visible polluters (e.g. sewage debris, litter), but it also reports on the phytoplankton and microalgae blooms. Trace amounts of animal faeces were noted at the site on a minority of occasions; however, sewage debris was not observed at this bathing water.

NRW worked with Dŵr Cymru Welsh Water (DCWW) to enable the replacement of the membrane biological reactors at Cardigan Wastewater Treatment Works (WwTW) prior to the 2015 bathing season.

Following discussion with DCWW operational staff, it is understood that saline intrusion can affect the operational performance of the Cardigan WwTW, restricting the efficacy of the treatment process when saline intrusion is high, i.e. around high water. However, as the effect on operational performance is variable it has not been possible to model concentrations of bacteria in the discharge accurately. Sensitivity analysis has therefore been undertaken, and compared with available water quality data to determine the best possible representation of treatment and discharge conditions.

2012-2015 Performance Data

Table 1. Current status– Compliance based on last four years (2013-2016)

Current Period	EC Classification	IE Classification	Overall Classification
2013-2016	Excellent	Excellent	Excellent

Table 2. NRW Year by Year Results and Risk Assessment [1]

Bathing water	End 2015 season	End 2014 season	End 2013 season	End 2012 season	Risk of failing Excellent	Det[2]. at risk: Excellent	Risk of failing Good	Det[2]. at risk: Good	Risk of failing Sufficient	Det[2]. at risk: Sufficient
Poppit West	Excellent	Good	Good	Good	47%	EC	0%	Neither EC nor IE	0%	Neither EC nor IE

[1] *Risk assessment predicted for 2015 as risk figures for 2016 were not available at the time of writing.*

[2] *Det. = Determinand most at risk of failing to meet the criteria for the relevant standard (either EC or IE)*.

Description of Analysis

Historical BW data indicate that Poppit West BW has improved in 2015 and it achieved Excellent classification for the 2015 bathing season, which was maintained throughout the 2016 bathing season. The NRW Risk assessment indicates that Poppit West BW has a 47% chance of failing Excellent, with *Escherichia coli* (E. coli; EC) being the determinand most at risk of failing to meet the criteria for the relevant standard.

Intertek's Storm-Optimiser (S-O) compliance assessment tool has been used to model the impact of all potential pollutant sources at the BW. The model was initially validated using three sets of four-year Validation periods – 2009-2012, 2010-2013 and 2011-2014. The model results for each Validation period were then compared against the historical sampling data collected during each bathing season (in each four-year period) by NRW. Key parameters in the model e.g. decay rate and source concentrations, which are known to naturally vary were adjusted to provide a better fit of the modelled results against the sampling data. Source concentrations (DCWW assets and rivers) were adjusted within reason, based on all available data. Where sampling data were not available, pre-defined default values, as agreed with DCWW and NRW, were used instead.

Once a good fit with the historical sampling data was achieved, a ten-year Baseline scenario was run using the same model set-up. This was done to give a long-term prediction of the BW performance, if all conditions stay the same, and takes into account long-term variations in rainfall.

Sensitivity tests were also undertaken for the period 2011-2014 to determine the change (if any) in the BW performance in response to changes in the performance of the Cardigan WwTW, T_{90} time (i.e. bacterial decay rate), DCWW asset loads and river loads. In addition, a climate change scenario was tested to examine the influence of a hypothetical increase in rainfall in the future. This scenario compared the difference in the predicted BW performance between an average year in terms of rainfall and a year with approximately 20% higher rainfall.

Two Solution scenarios were then run to determine the impact of reducing all Combined Sewer Overflow (CSO) operations to three and two discharges per bathing season on the BW water quality. In the Poppit

West area, nine CSOs were modified for these runs:

—Cardigan No 2.5 Sewage Pumping station (SPS) Storm Overflow;
—Penybryn SPS;
—Cilgerran SPS No 1 Emergency Overflow (EOF);
—Llechryd No 1 SPS;
—Cardigan Bridge SPS;
—Cardigan Penparc;
—St Dogmaels rear of PH, Maeshyfryd;
—Cardigan Hospital;
—Gloster Row Storm Overflow.

Summary of Results

The modelled results in the Validation scenarios showed a good fit with the historic sampling data at Poppit West BW, although the model tends to slightly over-predict the key (90 and 95) percentiles for Intestinal Enterococci (IE).

The performance of the Cardigan WwTW did not have a significant impact on the water quality at the Poppit West BW under modelled conditions. In terms of the main contributors to bacteria at the BW under the Baseline scenario, Poppit West BW was mainly impacted by diffuse sources, the Afon Teifi in particular, with over 40% contribution for both EC and IE. The largest impact from DCWW assets was from the Cardigan No 2.5 SPS Storm overflow which contributes 6.3% (EC) and 9.3% (IE) under the Baseline scenario.

The Sensitivity tests show that the BW performance is highly sensitive to the river loads, with Poor classification achieved when river loads are increased by a factor of ten. As a result, if there is a particularly wet summer with high rainfall, the BW performance would worsen.

The Sensitivity tests also show that the BW performance is sensitive to the asset loads, but not as much as to the river loads. A tenfold increase in the DCWW asset loads resulted in the deterioration of the EC water quality at Poppit West BW and the BW classification for EC is predicted to drop from Good to Sufficient. Similarly, the increased DCWW asset loads by a factor of ten resulted in a predicted Sufficient IE classification, instead of Excellent.

There is a significant change in the EC and IE classification with a general increase in the average bathing season rainfall. A hypothetical 20% increase in rainfall per bathing season results in the predicted classification dropping from Excellent to Sufficient for EC. Likewise, a similar trend is modelled for IE as the predicted classification changes from Excellent to Good.

The Three- and Two-spill per bathing season scenario results show that reduction in the frequency of operation of CSOs would not lead to significant improvement in the microbial water quality at Poppit West BW. Similar EC and IE standards have been achieved under Baseline, Three- and Two-spill scenarios. This is due to the dominant impact of diffuse sources and demonstrates that further improvement at DCWW assets will not lead to a measurable change in water quality at the BW.

Recommendation

It is our recommendation that DCWW should continue to monitor the performance of their assets, in particular the Cardigan WwTW and the Cardigan No 2.5 SPS Storm overflow, through the use of Event Duration Monitoring (EDM) data, to ensure they operate as designed. No further investment in asset improvement is recommended, except where this would reduce saline intrusion to the network. In order to improve water quality further, it is recommended that an investigation is carried out by the relevant stakeholders (including NRW) into river catchments as the BW performance is most sensitive to river loads.

NRW Sign Off: Please sign

Site report

Compliance Assessment Detailed Report

1 Introduction

Dŵr Cymru Welsh Water (DCWW) has commissioned its Alliance Team (AT), supported by Intertek Energy and Water (Intertek) to undertake a Coastal Investigation Programme. The aim of the project is to assess the water quality impacts at 49 sensitive receivers, namely 29 Bathing Waters (BW) and 20 Shellfish Waters (SFW). These sites were identified by Natural Resources Wales (NRW) as part of the National Environment Programme (NEP). As agreed with NRW, each of the sensitive receivers would be investigated at the relevant assessment level (Simple, Intermediate, or Full), depending on the site, local complexity, and the historical performance.

The Poppit West BW (Site no. 32) has been assessed using the Full Compliance Assessment approach, as outlined in detail in the General Methodology document[1]. The Full Compliance Assessment employs Intertek's STORM-OPTIMISER software which has been extensively used for similar studies in Wales, England, and Scotland, and has been accepted by all national environmental agencies (i.e. NRW, Environment Agency, Scottish Environment Protection Agency). This BW is designated under the 2006 Bathing Waters Directive (BWD)[2].

The Poppit West BW improved from Good to Excellent in 2015 with 47% chance of failing the Excellent standard and 0% chance of failing the Good standard. Excellent performance was maintained in 2016. The determinand most at risk of failing to meet the criteria for Excellent standard is *Escherichia coli* (E. coli; EC). However, monitoring data showed the site to achieve Excellent classification for 2013-2016.

In addition to this detailed compliance assessment report, there are two supporting documents, which provide information relevant to this study:

—Sewer report for the Newport North and Poppit West Bathing Waters[3];
—General Methodology[1].

1.1 Aim

This Full compliance assessment has been undertaken as part of the Coastal Investigation Programme. It will allow DCWW to better understand the role of its assets in Poppit West area and ultimately their role in affecting BW compliance with statutory environmental water quality requirements.

Thus, the aim of this impact assessment is:

—To better understand the impact of, and connectivity between, operation and management of DCWW assets and BW quality standards.
—To inform and influence DCWW asset management and capital investment decisions through improved information and sound scientific evidence of cause and effect.
—To provide DCWW with asset management data in order to better deliver effective management strategies for coastal assets, and other assets identified as having significance to the BW performance.

[1] General Methodology, 2016 (Ref. 3499-E-200-INT-00-XX-RP-RP-N-C-10003).
[2] EC (2006), Directive 2006/7/EC of the European Parliament and of the Council of 15 February 2006 concerning the management of bathing water quality and repealing Directive 76/160/EEC.
[3] Sewer report for the Newport North and Poppit West Bathing Waters, 2016 (Ref. 3499_E_200-MMB-00-XX-RP-RP-N-C-10415).

2 Geography & Catchment Area

The extent of the Poppit West study, in terms of the type of sources to be included, has been determined through a combination of data analysis and screening assessment model runs. These screening runs have been undertaken using an existing coastal model covering the entire west Wales area (including the Poppit West study area). This calibrated and validated model has a resolution of 200m and was built for similar studies in the Asset Management Programme (AMP) 3, and was previously accepted as fit for this purpose by the Environment Agency Wales (EAW – now NRW). The aim of the screening runs was to determine the maximum extent from the study site that a bacterial source (either point or diffuse) has the potential to lead to a contributing impact at Poppit West BW[4]. This screening exercise demonstrated that there would be minimal interaction between the Poppit West BW and nearby Newport BW; therefore, sources situated in the Dinas, Fishguard, LLanychaer and Newport (Dyfed) catchments are unlikely to have any impact on the Poppit West BW water quality and were not included in this assessment.

There are two rainfall gauging stations located in the proximity of Poppit West BW - the Verwig station, which is located in the Verwig catchment (approximately 2 km east of Poppit West) and the Aberporth station, which is situated further away, approximately 8 km east of the Poppit West BW. Rainfall patterns are likely to have an influence on the water quality of Poppit West BW, therefore a study of the rainfall at the Aberporth station has been undertaken. Due to the lack of rainfall recordings for the period 2005-2010 at the Verwig station, data collected at that rainfall station was not taken into consideration. Figure 2-1 shows annual and bathing season rainfall for the 2005-2014 period recorded at the Aberporth rainfall gauging station.

The sewerage catchments considered for this study are: Cardigan, Cilgerran, Llechryd, Pontrhydyceirt, Verwig, Penparc and Gwbert. Hydrographs have been generated for the most recent data (the 2005-2014 period) using the Cardigan and Cilgerran network models and measured rainfall obtained from the Aberporth rain gauge station. Penparc and Gwbert catchments are part of the Cardigan hydraulic model, whilst Llechryd, Pontrhydyceirt, Verwig are un-modelled catchments, and therefore donor catchments have been used to characterise these assets. A total of 32 assets are located within the immediate study area. Further information about the sewerage catchments can be found in the sewer report[2]. The 2005-2014 period was chosen to ensure the hydrographs produced are as representative of current operational performance of the assets as possible.

Figure 2-2 shows the geographical overview of the Cardigan Bay area.

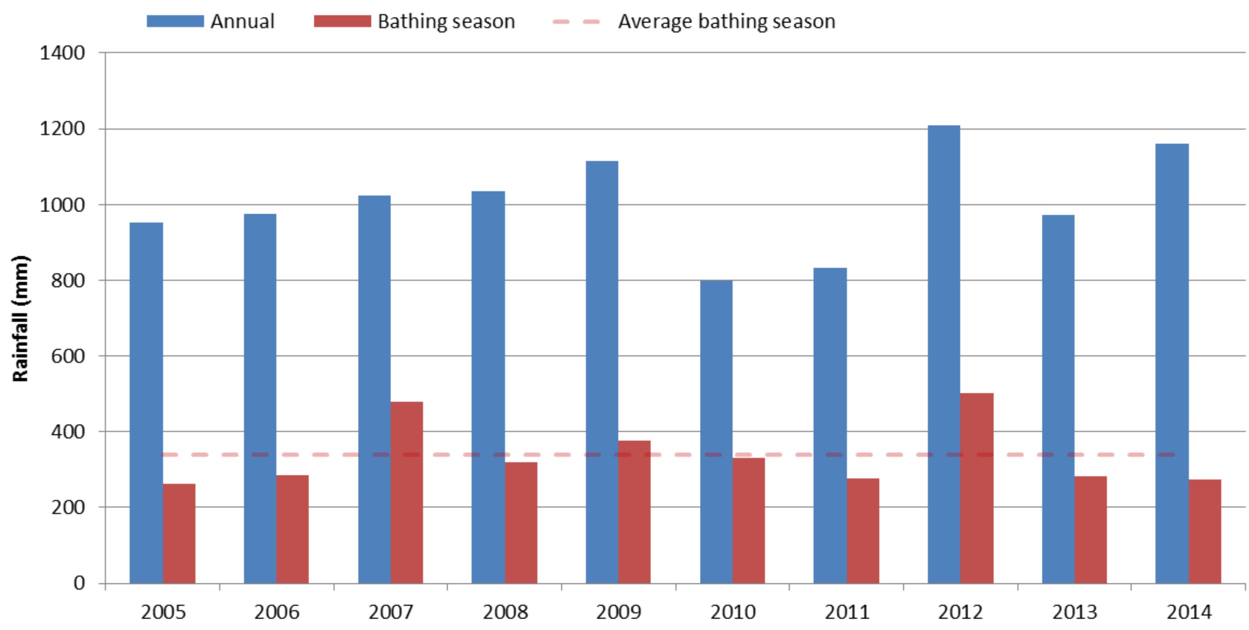
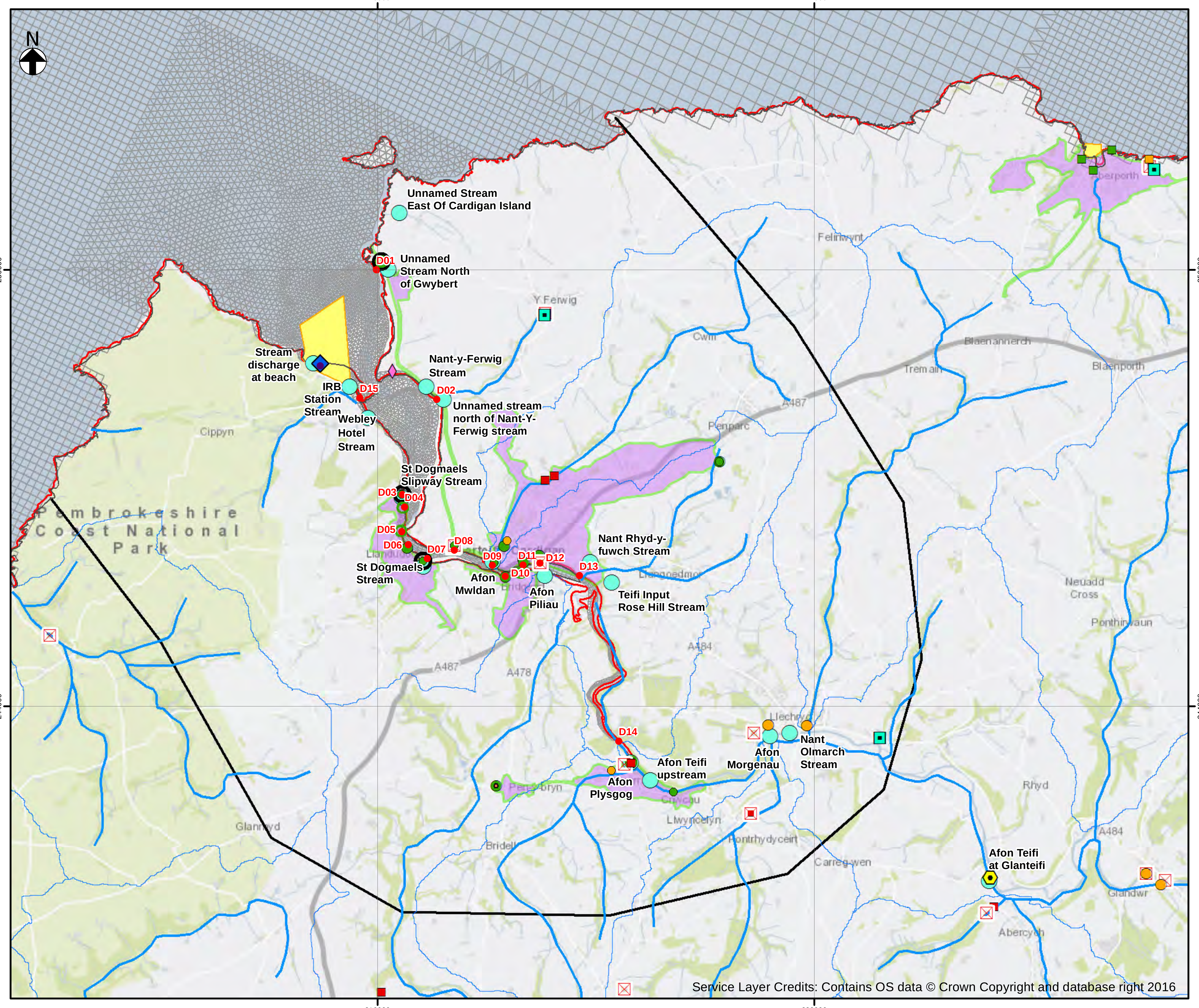


Figure 2-1 Annual and bathing season rainfall for the 2005-2014 period at the Aberporth rainfall gauging station

[4] Screening Runs results, 2016 (Intertek Ref: P1961_AAMAR07_Rev1)



Bathing Water Assessment Point
Bathing Waters

Sources

WwTWs
Private Sources

Spiller / Data Availability

Size / Shape (Spiller)
Spilling Over Threshold
Spilling Below Threshold
Not Spilling
Not Known

Colour (Data Availability)
Model Available
Telemetry Available
No Data
EDM Available

Sampling Location

Winter

Modelling

Modelled Assessment Point
Model Discharge Location
NRW River Flow Gauges
NRW Rainfall Gauges
Modelled River
Coastal Model Mesh
Coastal Model Domain

Study Site

Coastline
Boundary Of Area Of Interest
River
River Catchments
Subcatchment Modelled
Network Model Catchments

km 0 0.45 0.9 1.35 1.8

REV	DATE	DR	DESCR	CHK	APP	Date.
0	20/03/2017	RM	Draft	JA	PT	20/03/2017

Capital Delivery Alliance
Cynghrair Cyflawni Cyfalaf
Ty Awen, Spooner Close, Coed Kernew, Newport, NP10 8FZ

Intertek

Project Name. DCWW Coastal Investigation Programme COMPLIANCE ASSESSMENT STUDY AREA 15 (POPPIT WEST)

Drawing Title. Figure 2-2: Geographical Overview of the Poppit West Study Area

Suitability.	Suitability Code.	Projection Info.
FINAL	F1	British_National_Grid D_OSGB_1936 Airy_1830

Originator	Designer	Date.
Jennifer Arthur	Emma Langley	19/04/2017

Internal Project Number	Scale	Rev.
P1961	1:49,800	REV 1

Drawing Number. 2-2

3 Historical performance

The microbiological water quality of the designated bathing waters is assessed using faecal indicator organisms (FIO), typically EC and Intestinal Enterococci (IE) as it remains technically challenging, time consuming, and costly to monitor pathogens directly. EC and IE indicate the presence of faecal pollution and hence potential risk to human health.

The relevant environmental legislation and standards for BWs are explained in more detail in the General Methodology document[1]. Table 3-1 below summarizes the microbial standards set out in the EU Bathing Water Directive[2].

Table 3-1 BWD Compliance classifications

Compliance classifications for the BWD coastal waters and transitional waters				
	Parameter	Excellent quality	Good quality	Sufficient quality
1	Intestinal enterococci (cfu/100 ml)	100 (*)	200 (*)	185 (**)
2	Escherichia coli (cfu/100 ml)	250 (*)	500 (*)	500 (**)
(*) Based upon a 95-percentile evaluation. (**) Based upon a 90-percentile evaluation.				

Data for Poppit West BW over 2009-2016 period were evaluated for historical trends (Figure 3-1). Due to different sampling methodology applied before 2012, the microbiological data collected prior to 2012 refer to faecal coliforms instead of EC and to faecal streptococci instead of IE, but for clarity and completeness of the BW performance, they were included in the historical trend evaluation, and assumed to equivalent to EC and IE.

It is important to highlight a change in the lowest reportable result for the bacteria count in the microbiological data that occurred after 2012. This has been increased from 2 cfu/100ml before 2012 to 10 cfu/100ml thereafter.

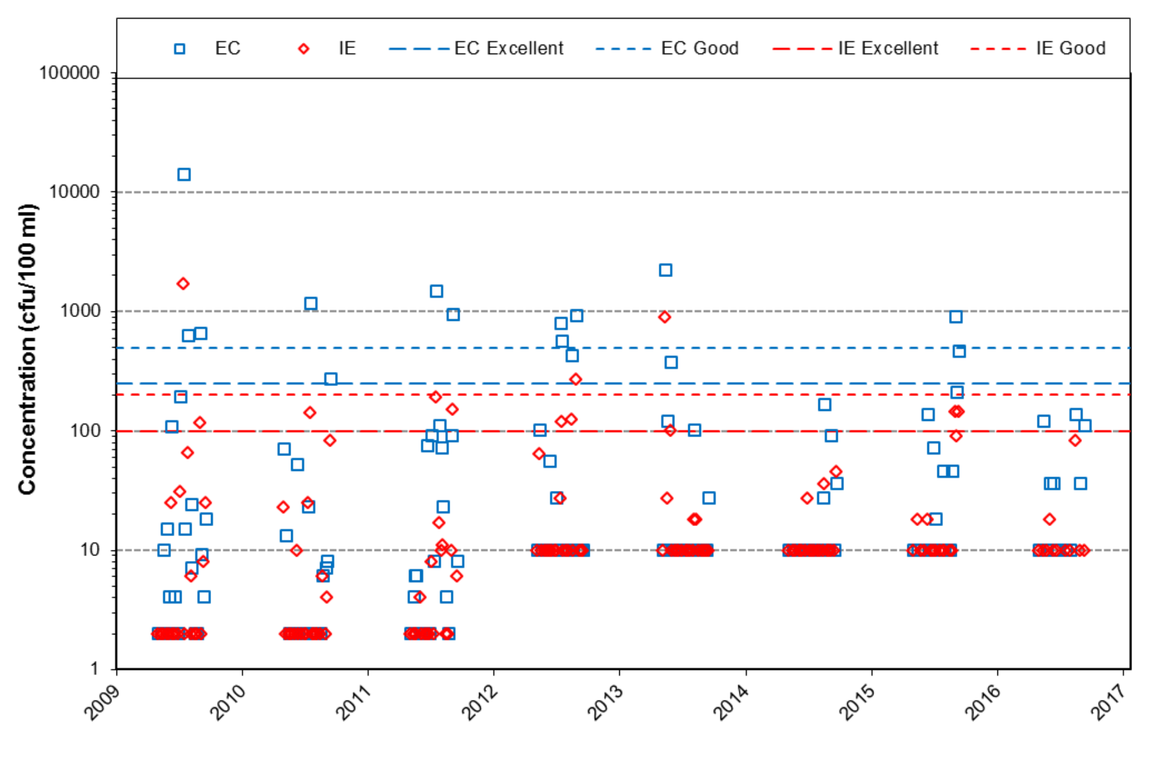


Figure 3-1 Historical microbial concentrations at the Poppit West BW

There is no visible decrease or increase in bacterial concentration recorded at Poppit West BW, although data recorded after 2012 seem to be less scattered and the number of recordings with bacterial concentrations exceeding 100 cfu/100ml) is reduced as well.

The microbial status of Poppit West BW changed in 2015, when the BW achieved Excellent status. This is slightly different from the status established based solely on the raw bacterial data provided by NRW, which indicated that Poppit West BW achieved Good Overall status in 2015. This discrepancy is probably due to exclusion of pre-season samples by NRW for compliance purposes, while the Intertek assessment uses all available sample records.

The on-going status of bathing water is evaluated statistically, based on the microbiological data collected during the current and three preceding bathing seasons, making a four-year rolling assessment period (4 x 20 samples historically). The processed microbiological data is then benchmarked against standards set out in the BWD to estimate the microbiological risk to public health and assess the BW status. In 2015, only 16 samples were taken and in 2016 the sample number was reduced further to 12 samples. The performance history of Poppit West BW for the period 2013 to 2016 is summarized in Table 3-2.

Table 3-3 shows NRW's assessment of the risk of failing to comply with the BWD for 2015. The NRW risk assessment for 2016 was not available at the time of writing.

Poppit West BW has a 47% risk of failing Excellent classification and that EC is the determinand most at risk. This suggests that, if conditions stay the same, then this BW should achieve Excellent classification, but there is 47% chance of worsening to the Good standard.

Table 3-2 Compliance classifications of Poppit West BW for the period of 2013-2016

Site	2013 (2010 to 2013)*	2014 (2011 to 2014)*	2015 (2012 to 2015)*	2016 (2013 to 2016)*
Poppit West BW	Good	Good	Excellent	Excellent

* Four-year rolling assessment period.

Table 3-3 NRW assessment of risk of failing to meet the BWD standards

Site	Risk of failing Excellent[a]	Det. at risk (Excellent)[b]	Risk of failing Good[a]	Det. at risk (Good)[b]
Poppit West BW	47%	EC	0%	Neither EC nor IE

[a] Risk assessment predicted for 2015 as risk figures for 2016 were not available at the time of writing.
[b] Det. = Determinand most at risk of failing to meet the criteria for the relevant standard (either EC or IE).

4 Potential Sources

The concentrations used to represent the DCWW assets and rivers have been defined from sampling data wherever available and the proposed default values[1] have been applied where insufficient data exists for DCWW assets.

4.1 DCWW Assets

There are five sewerage catchments with a total of 36 assets that are included in the Poppit West BW compliance study (Table 4-1). The majority of the DCWW assets included in the study are covered by the Cardigan and Cilgerran sewerage network models. The associated network models have been run to provide hydrographs for the period 2005 to 2014. The Llechryd, Pontrhydyceirt and Verwig catchments are not modelled; however, following review of the available data and through discussion with local DCWW operators, donor sites have been selected to represent the assets as accurately as possible[3]. The identification of assets requiring donors, and the selection of the most suitable donor, was undertaken by the AT following the approach agreed with NRW. Donor assets, or permit information, have been used to create hydrographs for 2005-2014 for these assets

Table 4-1 shows that, despite the Cardigan catchment being covered by network models, some assets within those catchments use a donor to create the hydrograph. This is due to some discrepancies between hydraulic model outputs, telemetry, Event Duration Monitoring (EDM) data and local operators' knowledge on the performance of some assets. Therefore, there is overall medium confidence in the sewerage data that is feeding into the compliance assessment for Poppit West BW[3].

For all Wastewater Treatment Works (WwTW), two hydrographs were created, one to represent the flow from the asset in dry weather, and a second to represent the flow in wet weather. Sampling data was collected at STWs in both wet and dry weather, so specific concentrations were applied to calculate the load in both wet and dry conditions. Wet weather conditions are defined as occurring when an asset in the surrounding network model catchment operates. This means that when Combined Sewer Overflows (CSOs) operate, the related WwTW is assumed to operate under wet weather conditions. For Llechryd, Pontrhydyceirt and Verwig Sewage Treatment Works (STWs)[5], there was no network model and no appropriate donor asset. The hydrographs for these assets were created using the Dry Weather Flow (DWF) and Flow to Full Treatment (FFT) information given in the permit. Similar to the modelled STWs, the change between the DWF and FFT was based on when CSOs in surrounding network modelled catchments were operating. The DWF was used to create the dry weather hydrograph and the FFT was used in the wet weather hydrograph.

When the Storm-Optimiser (S-O) assessment predicted that an asset with a Low or Medium confidence level was an important contributor to BW performance, sensitivity tests were carried out to test the robustness of this conclusion. For example, increasing the load from the asset to simulate it failing to perform as designed (if this was suspected).

In addition to the 'baseline' hydrographs, for selected CSOs theoretical storage volumes were used to generate two modified hydrographs with a reduced number of operations and discharge volume. This was done for any CSOs which operated more than three times per bathing season and then those that operated more than two times per bathing season in order to reduce the average number of discharges per bathing season over the ten-year period, to three times and two times. These were then used to test the environmental benefit that would result from reducing the number of discharges from key assets.

Table A-1 of Appendix A includes a complete list of sources modelled, including DCWW assets and non-DCWW assets, and the concentrations applied in the assessment.

[5] The WwTW and STW are used interchangeably throughout the report as the term STW is used by DCWW in some asset names, while WwTW is the more formal, general term for treatment plants.

Table 4-1 Summary of the catchments and DCWW assets included in the study

Catchment	Asset name	Type of the asset	Confidence level
Cardigan	Cardigan SWK (settled storm)	Model	Low
Cardigan	Cardigan Hospital	Model	High
Cardigan	Gloster Row Overflow Sewage Pumping Station (SPS) No2	Model	High
Cardigan	Cardigan No 2.5 SPS Storm Overflow	Model	High
Cardigan	Cardigan No 4 SPS Emergency Overflow (EOF)	Model	High
Cardigan	Cardigan No5 SPS EOF	Model	High
Cardigan	Cardigan WwTW	Model	High
Cardigan	Grove Park SPS CSO	Donor	Low
Cardigan	Melin-Y-Coed SPS	Donor	Low
Cardigan	St. Dogmaels No4 CSO	Model	Medium
Cardigan	St. Dogmaels Main SPS	Model	High
Cardigan	St. Dogmaels, rear of PH, Maeshyfryd	Model	High
Cardigan	ST. Dogmaels SPS No2 CSO	Model	High
Cardigan	Greenfield Square CSO, Cardigan	Model	Medium
Cardigan	Cardigan SPS No1	Donor	Medium
Cardigan	Upper Mwldan CSO, Cardigan	Model	High
Cardigan	Cardigan Bridge SPS	Model	Low
Cardigan	St. Dogmaels No3 CSO	Model	High
Llechryd	Llechryd STW	Consented	Medium
Llechryd	Llechryd No1 SPS	Donor	Medium
Llechryd	Llechryd No2	Donor	Medium
Pontrhydyceirt	Pontryhydyceirt STW	Consented	Medium
Pontrhydyceirt	Pontryhydyceirt STW Storm Overflow	Donor	Low
Verwig	Verwig STW	Consented	Medium
Verwig	Verwig STW Storm Overflow	Donor	Medium
Penparc	Cardigan Penparc	Model	Low
Cilgerran	Cilgerran Flygt SPS	Model	High
Cilgerran	Cilgerran SPS No 1 EOF	Model	Low
Cilgerran	Cilgerran STW	Model	High
Cilgerran	Cwm Plysgog CSO	Model	Medium
Cilgerran	Pen-Y-Bryn SPS	Model	High
Cilgerran	Cilgerran STW Dyfed Storm Overflow	Model	High

Catchment	Asset name	Type of the asset	Confidence level
Gwbert	Gwbert Cliff Hotel SPS CSO	Model	Medium

4.1.1 Cardigan WwTW

During discussions with DCWW operational staff, particular concern was raised about the Cardigan Wastewater Treatment Works (WwTW). The model output represents the operation of Cardigan WwTW as regulated by an environmental permit; however, it is understood that saline intrusion can affect the operational performance of the WwTW, restricting the treatment capacity of the works, particularly during periods of high infiltration around high water. EDM has recorded periods of CSO discharges in response to these operational issues in the bathing season.

As a part of this investigation, the impact of the performance of Cardigan WwTW on the bacterial water quality at Poppit West BW has been evaluated.

4.2 Rivers and Streams

As introduced in Section 4.1 there are five big catchments that potentially affect the microbial water quality at Poppit West BW. The Afon Teifi (the River Teifi) is the only gauged river, which discharges significant bacterial loads into the Cardigan Bay. Several smaller streams discharge very close to Poppit West BW. Whilst smaller than the Afon Teifi, these streams (e.g. Nant-y-Ferwig (the River Nant-y-Ferwig), have potentially large loads and therefore could be important to BW performance given their proximity. Additionally, there are several, even smaller streams, sometimes unnamed, which were identified as potential microbial contributors to the performance of Poppit West BW. For instance, during the sampling programme in the Cardigan Bay area, Centre for Research into Environment and Health (CREH) identified a small unnamed stream that discharges onto Poppit Sands, near the BW monitoring point. All the rivers and streams, which have been included in this assessment, are shown in Table 4-2 and in Figure A-1.

Diffuse loads have been derived from river flow and concentration data at the upstream limits of the rivers, i.e. upstream of CSO inputs to the rivers, wherever possible to avoid including any influence of CSOs which could lead to over-representing the diffuse river load. In cases of potential double-counting of the CSOs, available telemetry data from the DCWW assets were used to determine if an asset could have impacted a particular sampling event. Samples which were deemed to have been impacted by CSO operations were discounted. Figure A-2 shows the telemetry data collected at Cardigan No 2.5 SPS Storm Overflow and the time of sampling at the Afon Mwldan (sampling point 11615). The sampling data collected on 23/08/2015 at 03:44, 03:46 and 03:48 were not taken into account.

The method used to estimate each river load was determined as follows:

- River flows from gauged rivers (the Afon Teifi, the Afon Leri (the River Leri), the Afon Wyre (the River Wyre)) were based on NRW gauging records from 2016.
- River flows from the other smaller, ungauged streams were derived from a gauged river with catchment characteristics as similar as possible, by scaling the flow based on catchment area.
- Bacterial concentrations in the rivers and streams were based on sampling data collected by CREH in 2015 as part of the Coastal Investigation Programme.
- Several streams were not sampled by CREH, and are not gauged (Table 4-2). The bacterial load from these streams was determined by scaling the pollutograph from a river which was both gauged and sampled, with as similar catchment characteristics as possible, in proportion to their respective catchment areas.

Table 4-2 List of water bodies considered in the assessment

Name of waterbody	Catchment area (km^2)	Model Discharge ID	Coordinates of sampling location		Type of flow data	Type of concentration data
			Easting	Northing		
Stream discharging south end of Poppit Sands	4.66	D30	215615	248392	Scaled using Afon Leri flow	Sampled
Afon Teifi	941.73	D16	219740	242984	Gauged	Sampled
Afon Mwldan (River Mwldan)	12.70	D09	217579	245991	Scaled using Afon Teifi flow	Sampled
Stream south of Nant Rhyd-y-fuwch	0.69	D15	219213	245700	Scaled using Afon Wyre flow	Sampled
Stream near The Webley Hotel	0.53	D30	215867	247966	Scaled using Afon Leri flow	Sampled
Stream near Albro Castle	1.56	D03	216324	246876	Scaled using Afon Leri flow	Sampled
Stream near St Dogmaels Abbey	2.54	D06	216619	245923	Scaled using Afon Leri flow	Sampled
Nant Rhyd-y-fuwch	4.14	D15	218915	245980	Scaled using Afon Wyre flow	Sampled
Stream discharge at beach	n/a	D30	215111	248714	Constant value; occurs only during wet weather	Sampled
Stream east of Cardigan Island	0.52	D01	216295	250776	Scaled using Afon Teifi flow	Scaled using Afon Teifi sampling data
Stream north of Gwybert	0.64	D01	216146	250002	Scaled using Afon Teifi flow	Scaled
Afon Plysgog (River Plysgog)	8.18	D16	219472	243233	Sampled	Sampled
Nant-y-Ferwig	4.44	D02	216901	248215	Sampled	Sampled
Stream north of Nant-y-Ferwig	0.69	D02	216663	248393	Scaled using Afon Teifi flow	Scaled using Afon Teifi sampling data
Afon Morgenau (River Morgenau)	10.82	D16	221391	243598	Scaled using Afon Teifi flow	Scaled using Afon Teifi sampling data
Nant Olmarch (River Nant Olmarch)	1.84	D16	221657	243632	Scaled using Afon Teifi flow	Scaled using Afon Teifi sampling data
Afon Piliau (River Piliau)	0.63	D13	218290	245798	Scaled using Afon Teifi flow	Scaled using Afon Teifi sampling data

CREH samples were taken over a three-month period (from August to October 2015). The data aimed to capture at least three wet weather and three dry weather events. These concentrations were assumed to be representative of the long-term river catchment characteristics. These data, along with the gauged and scaled river flows from the same period, were used to create a flow-concentration relationship. Using the concentration, and associated flows, from multiple wet and dry weather events, allowed a more robust relationship between flow and concentration to be estimated. During dry weather conditions, both flow and concentration tend to remain low, until the occurrence of a storm event, when an increase in flow and concentration can be seen in the sampled and gauged data. Separate flow-concentration relationships were established for both EC and IE for each river and stream. In some cases, a strong correlation is observed, but in others there is a weaker relationship, with a greater spread of concentrations for the same flows, which can increase uncertainty in the diffuse load. As an example, the flow-EC concentration relationship for the Afon Teifi is shown in Figure 4-1.

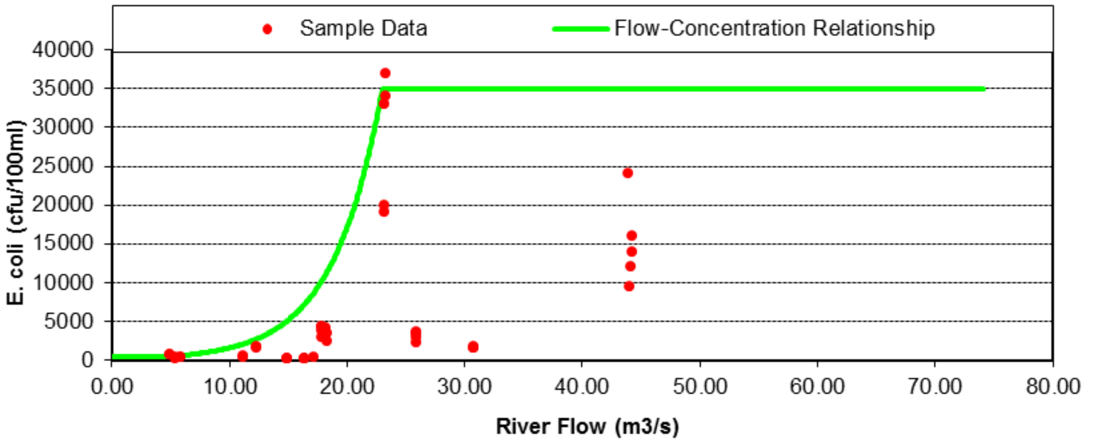


Figure 4-1 Flow- EC concentration relationship established for the Afon Teifi

The resulting relationship, based on the 2015 data, was then applied to the ten-year flow time-series (2005-2014) for each river and stream to assign a time-varying concentration at each timestep. This provided a ten-year, time-varying 'pollutograph' of diffuse river load. The pollutographs were split into wet conditions and dry conditions. Dry weather flows were defined by the 75th percentile of the ten-year flow time series. Flows higher than the 75th percentile were assumed to be in wet weather.

There are large uncertainties associated with using this approach for representing the rivers. A large range in concentrations can be seen in the sampling data, in particular between individual wet weather events (in Figure 4-1 the concentration at ~22 m^3/s flow ranges from about 20,000 to about 35,000 EC/100ml). Also, there is uncertainty in using a scaled flow for many of the streams, when no gauged flows are available. The scaling has been based on catchment size, but this may not give an accurate representation of the actual flow, especially for smaller streams, since the donor gauged river will usually have a significantly larger catchment and larger catchments can be more variable and have a different response to rainfall than smaller catchments. Lastly, the flow-concentration relationship assumes that concentrations stay at an elevated level during wet weather events when, in reality, they may decline after prolonged rainfall. Moreover, the EC and IE concentrations were estimated using only the presumptive test, which provides only a preliminary estimate of bacterial count. The bacteria concentrations in the samples collected in the Cardigan area were not validated by the confirmed test. The presumptive test usually over-estimates the actual bacterial count and should not be used without further confirmation, thus adding further uncertainty to this assessment.

These uncertainties have been tested in the Sensitivity testing scenarios (Sections 5.4.3 and 6.5) where river loads have been increased and decreased to understand their influence on predicted impacts at the BW, and any potential associated uncertainty in the model predictions.

4.3 Surface Water

No surface waters were identified for inclusion in the assessment.

4.4 Private and Trade Discharges

There are a number of private discharges within the catchments that might affect the performance of Poppit West BW. These are mainly residential dwellings as well as agricultural and recreational discharges. All but one of these discharges discharge onto or into ground and so it is unlikely that they would impact Poppit West BW water quality. The only private discharge that was agreed with NRW should be considered in this compliance assessment is the large caravan park - Patch Caravan Park, which discharges treated effluent directly to the Teifi Estuary. It is located at the mouth of the Afon Teifi near Gwbert town, overlooking Cardigan Bay and Poppit Sands.

4.5 Other Sources

It is important to mention potential input of wildlife (e.g. birds) that may find their way onto or around the beach and bathing water area and their contributions to the impairment of microbial water quality at Poppit West BW. Depending on the population, type of animal, time of the bathing season, wildlife faecal sources might contribute to microbial water quality at Poppit West BW.

For example, Teifi Marshes Nature Reserve and Coedmor National Nature Reserve, situated close to Cardigan Town are known for their significant bird populations. The Afon Piliau, which runs through Teifi Marshes Nature Reserve, is a tributary of the Afon Teifi and it has been considered in this assessment given its potential bacterial load associated with the bird populations in this area (Table 4-2). The Coedmor National Nature Reserve is the area adjacent to the southern bank of the Afon Teifi.

Bird faeces may be deposited directly onto the Poppit Sands and Poppit West BW. However, it was considered beyond the scope of this assessment to evaluate the link between bird populations and the microbial pollution load at the BW.

4.6 Input Load Analysis

An analysis of the input loads applied in the model has been undertaken. Loads from each source are defined by flows and bacterial concentrations. The total bacterial load of each source is calculated by multiplying the discharge volume by the concentration applied for each modelled timestep, and then summing over all timesteps. This analysis was done to determine which sources have the biggest bacterial loads entering the environment to help put the relative input loads from all sources into context. However, it should be noted that the largest source will not necessarily have the largest impact, as this is affected by other factors as well, such as distance from the BW and the timing and frequency of the discharge (especially for intermittent sources).

The load analysis for Poppit West BW has been performed using the Baseline scenario for ten years of data (2005-2014) and it is based on the BW seasons only. Figure 4-2 presents EC apportionments of the main sources to the total load, showing the sources which contribute more than 1% of the total load. Figure 4-3 shows IE apportionments of the main sources to the total load, for the sources which contribute more than 1% of the total load.

The analysis demonstrates that the bacterial load associated with the Afon Teifi contributes predominantly to the total EC and IE load at Poppit West BW. Figure 4-2 shows that the largest EC source is the Afon Teifi under wet conditions (high rainfall and/or stormflow), which contributes approximately 23% to the total EC load. The second largest EC load is the Afon Teifi under dry conditions (base flow) with an approximate contribution of 21%. The largest IE source is the Afon Teifi under dry conditions, which provides approximately 30% of the total IE load, followed by the Afon Teifi under wet conditions, with a 16% IE contribution (Figure 4-3).

Appendix A contains the complete list of sources ranked in terms of their load for EC and IE (Table A-2).

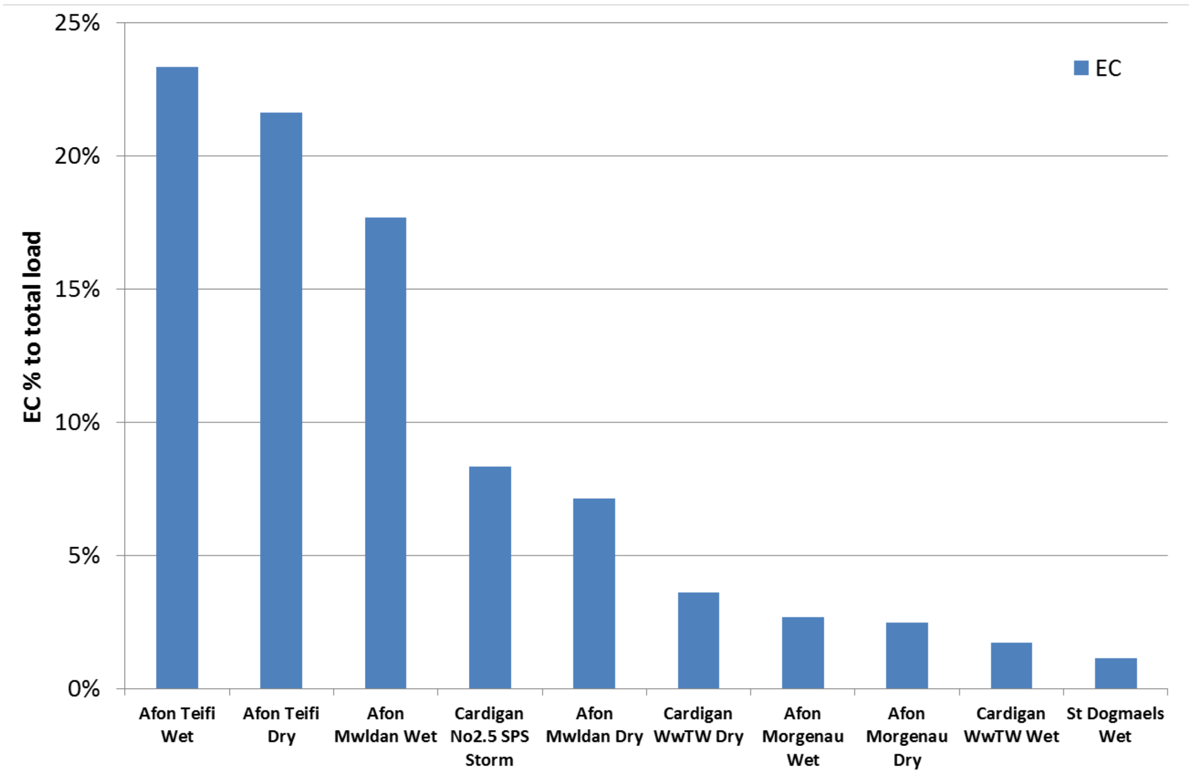


Figure 4-2 EC load analysis - showing sources with a contribution higher than 1% of the total load

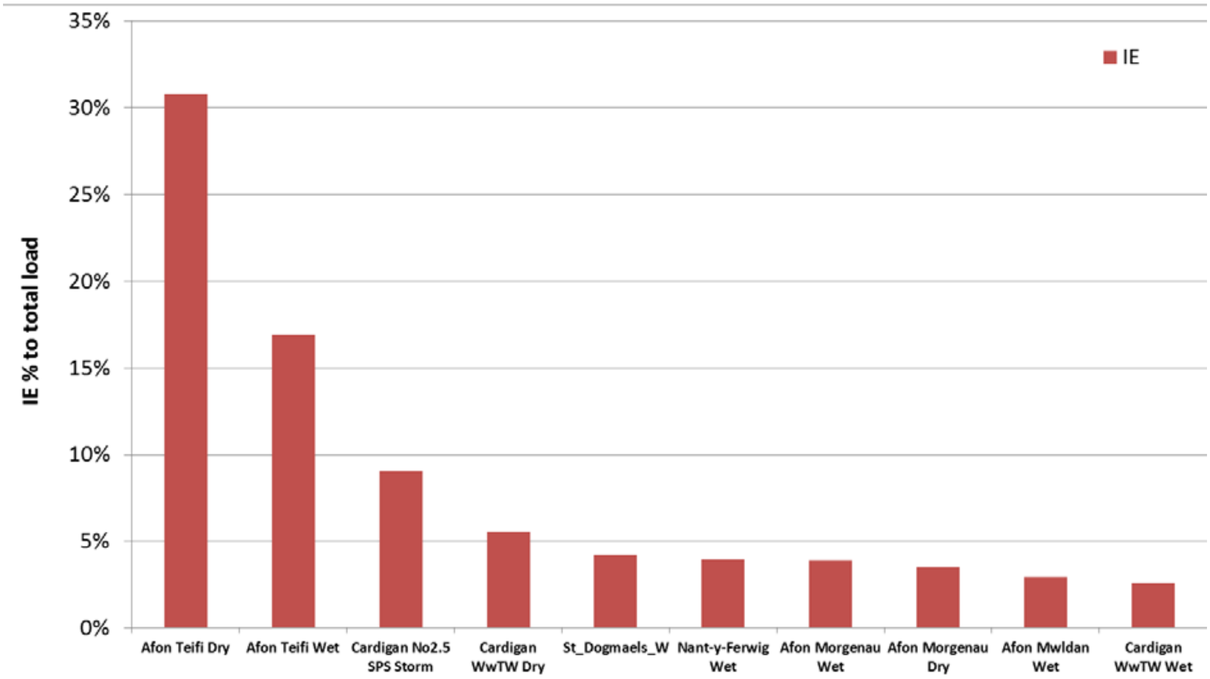


Figure 4-3 IE load analysis – showing sources with a contribution higher than 1% of the total load

5 Methodology

The General Methodology report[1] provides full details of the approach adopted for Full compliance assessment.

5.1 Performance of the Cardigan WwTW

Owing to the periodic effects of saline intrusion on the operational performance of the WwTW and the difficulty of representing a variable tidally phased discharge within the S-O setup, three different scenarios were run in order to evaluate the impact of the performance of the Cardigan WwTW on the water quality at Poppit West BW: The first two scenarios provide the range of possible bacterial loads from Cardigan WwTW (Best and Worst case) and the third scenario (Representative) provides a reasonable estimate within this range; the best possible approach.

——Best case scenario:

a) The Cardigan WwTW continuously discharges effluent with membrane filter treatment;
b) The concentration used in the compliance assessment is equal to the typical measured tertiary treated effluent concentration;
c) It is very likely that this scenario under-estimates the Cardigan WwTW bacterial input; and is therefore the least conservative approach

——Worst case scenario

a) The Cardigan WwTW continuously discharges effluent without any treatment;
b) The concentration used in the compliance assessment is equal to crude sewage concentration;
c) It is very likely that this scenario over-estimates the Cardigan bacterial input; and is therefore the most conservative approach;

——Representative case scenario

a) The Cardigan WwTW continuously discharges effluent with secondary treatment;
b) The concentration used in the compliance assessment is equal to the secondary treated effluent concentration;
c) This scenario is an attempt, within the limitations of the model, to represent the likely average daily bacterial load from the WwTW, taking into account the periods of reduced efficiency during saline intrusion events.

These scenarios were carried out at the early stage of the assessment, before establishing the parameters used in the Validation and Baseline scenarios. The S-O outputs were compared to each other in order to assess the difference in the predicted BW water quality, when different loads discharged from the Cardigan WwTW were modelled. The results are discussed in Section 6.1.

5.2 Wind Applied

The Poppit West BW impact assessment has been run under seven wind scenarios. Representative wind conditions were determined using long-term data (1998-2014) from the Aberporth Buoy (SN2549251448).

Table 5-1 shows the wind scenarios used in the assessment. The wind frequencies given in the table are used to weight the impact of individual wind conditions in the impact assessment.

Table 5-1 Wind conditions applied in Storm-Optimiser assessment.

Wind Condition	Wind Direction (N°)	Wind Speed(m/s)	Frequency (%)
No wind	0	0.0	10.4
Wind 2	30	3.6	8.8
Wind 3	90	3.6	7.1
Wind 4	150	4.0	9.9
Wind 5	210	4.8	28.8
Wind 6	270	4.2	19.3
Wind 7	330	3.9	15.7

5.3 Decay rates

The bacterial decay rate can be defined as the time required for 90% bacterial die-off (T_{90}). It is the most commonly used parameter for describing bacterial mortality and it is one of the key parameters in the S-O validation.

A decay rate of 60 hours was used for EC and 100 hours was used for IE. Those bacterial decay rates are within the range of decay rates used in previous BW compliance assessment throughout the UK, especially for estuarine environments and they were found to provide a good fit with the NRW bathing water sample data for this BW. The Afon Teifi is one of the longest rivers in Wales with variable turbidity levels and bacterial mortality, but in order to represent the longer-term average, a single T_{90} value was adopted for each indicator, as is common practice for this type of assessment, and as outlined in the general methodology[1].

5.4 Storm-Optimiser

5.4.1 Validation of Storm-Optimiser

The validation of the modelled outputs has been carried out through a comparison against the historical Poppit West BW sampling data collected by NRW during each bathing season. The validation was undertaken for three different sets of four-year periods (2009-2012, 2010-2013 and 2011-2014) in order to examine variations in rainfall and BW sampling data.

In order to get as good a fit against the sampling data as possible, some variables in the model can be adjusted, in particular T_{90}, and also the concentrations of some sources where there was no, or limited sampling data. Due to the method used to represent the river loads, and the natural variability seen in the sampling data, there is significant uncertainty in the modelled river loads, and these have been adjusted, within reason, to improve the level of agreement with the sampling data.

The results of the Validation scenarios are presented in Section 6.2.

5.4.2 Storm-Optimiser Applications

Once S-O had been validated, and agreed well with the sampling data, a ten-year Baseline scenario (2005–2014) was run, using the same set-up as in the final Validation scenario. This Baseline scenario is not compared against any sampling data, but provides a long-term indication of the likely future bathing water performance, which takes into account variations in rainfall, which in turn influences river flows and the frequency of CSO operation.

The results of the Baseline scenario are presented in Section 6.3.
The validated Baseline S-O scenario was used to create two Solution scenarios to investigate the impact of reducing discharges from any CSO operating more than three or two times per bathing season. In the first

scenario, those CSOs are given increased storage to a point where they operate only three times per bathing season (on average over the ten-year period). The second Solution scenario has an average of two CSO discharges per bathing season, achieved by further increasing the required storage.

As explained in the General Methodology[1], this was achieved by estimating the volume of storage required at each CSO to reduce the discharges per bathing season to three or two, on average over the ten-year modelled period. Therefore, in wetter years there may be more than three or two discharges, and in drier years there may be fewer.

As determined by the network models, there are nine assets in the Poppit West BW area which require increased storage in order to reduce the number of operations to three and two per average bathing season. These are:

—Cardigan No 2.5 SPS Storm;
—Penybryn SPS;
—Cilgerran SPS No 1 EOF;
—Llechryd No 1 SPS;
—Cardigan Bridge SPS;
—Cardigan Penparc;
—St. Dogmaels, rear of PH, Maeshyfryd;
—Cardigan Hospital;
—Gloster Row Overflow.

New hydrographs were generated for these assets outside of the network model, by modifying each hydrograph in isolation by 'removing' discharge volumes from each discharge up to the storage volume being applied.

The results of the Solution scenarios are presented in Section 6.4.

5.4.3 Sensitivity tests

Sensitivity tests were run to determine the response of the bathing water performance to changes in key parameters. The list of sensitivity tests carried out is given in the General Methodology[1].

As a part of the Climate Variability study specified in the General Methodology[1], an additional sensitivity test has been included. The Poppit West BW performance during the average year in terms of rainfall (2010) has been compared against a year with approximately 20% higher rainfall record (2012). This scenario was undertaken to assess the impact on BW performance from increased rainfall in future due to climate change. As requested by DCWW, an additional, site-specific sensitivity test was run in order to assess the BW performance assuming the Cardigan WwTW operates as designed (i.e. saline intrusion can be removed) together with reduced river loads by 50%.

The results of the sensitivity runs are presented in Section 6.5.

6 Results

The results for the Poppit West assessment Validation, Baseline and Solution scenarios, and Sensitivity tests are presented as follows:

—**Compliance Assessment.** Tables of S-O predictions at the key percentiles (90%ile and 95%ile). For the Validation scenario, concentration distribution comparisons are also provided. In the tables DCWW assets are highlighted and colour-coded in the same way as in the figures.

—**Source apportionment.** Table of the top contributing sources for EC and IE with the DCWW assets colour-highlighted. Pie charts are presented for the Baseline and Solution scenarios to visually identify the main contributors and their location. In the figures, all DCWW assets have a unique, solid colour, whereas the rivers have a unique hatched colour.

Source apportionment is the means of identifying the relative significance of each source to impacts at the bathing water. It is calculated from the contribution of each source to the total impact (concentration) at the bathing water for the periods when the relevant threshold concentration (i.e. Excellent threshold) is exceeded. The percentage of the total impact for each source can then be expressed in tabular form or as pie charts.

The source apportionment tables may change between scenarios, with sources appearing to have a bigger or lesser impact. However, the different measures included in each scenario must be taken into account when obtaining conclusions from, and directly comparing the tables. For example, if the contribution of a river is 25% under the Baseline scenario, and it increases to 30% under the two-spill Solution scenario, it cannot be concluded that the impact from the river has increased (as there are no changes in the representation of the river between the different scenarios) - instead this change is due to reduction in the contribution from other CSO sources due to fewer discharges, resulting in a relative increase in the contribution of the rivers to the total impact.

6.1 Performance of Cardigan WwTW

As discussed in Section 5.1, a sensitivity test was conducted prior to undertaking the full validation exercise, to understand the importance of the operation of the Cardigan WwTW on the performance of the BW.

These tests demonstrated that the predicted classification at the BW is not particularly sensitive to the operation of this source (although impact concentrations of IE are affected). Therefore, for the purpose of this compliance assessment, the Cardigan WwTW microbial input was represented as outlined in the Representative scenario (see Section 5.1).

6.2 Validation scenarios

6.2.1 Compliance Assessment

Table 6-1 compares predicted concentrations against BW data at key percentiles for the three 4-year periods (2009-2012; 2010-2013; 2011-2014) and shows the resulting BW class under the rBWD classification for Poppit West BW. The BW dataset shows lower EC impact at Poppit West BW for the period from 2011 to 2014, while the IE impact remained at the same low level throughout the three sets of years (2009-2012; 2010-2013; 2011-2014). This however didn’t change the overall classification of Poppit West BW, which remained Good. A possible factor that would diminish bacteria concentration is lower agricultural run-off associated with lower rainfall in 2013 and 2014 bathing seasons and fewer CSO operations (Figure 2-1). Although no statistical evaluation on bacteria, river flow and rainfall was performed, this simplified relationship is considered reasonable, as BW data collected in 2015 shows an increase in the microbial concentration along with higher rainfall during the 2015 bathing season (see Section 3).

Figure 6-1 to Figure 6-3 show the EC and IE concentration distributions for the three sets of years (2009-2012; 2010-2013; 2011-2014) for Poppit West BW. The top plots show the log concentration frequency distribution, and the bottom plots show the cumulative histograms. The bar charts represent the model output and sample data, while the line represents a log-normal fit to the modelled outputs and sample data as required by the 2006 BWD. A large difference between the bar chart and line indicates that the data does not perfectly fit a log-normal distribution. Overall, comparisons of the concentration distribution and cumulative histogram plots show a good fit between S-O predictions and bathing water data at Poppit West BW, given the difficulty in representing the bacteria input of Cardigan WwTW (see Section 5.1).

For 2009-2012, the model slightly over-predicts EC and IE impacts at Poppit West BW. For 2010-2013, there is excellent agreement between the modelled EC output and historical sampled data, but there is a slight over-prediction by the model for IE. For 2011-2014, there is a significant discrepancy between the model and historical BW data, with greater over-prediction for IE than for EC. However, as can be seen in Table 6-1 there is good agreement between the model and historical BW data at the high (90 and 95) percentiles and the same performance classification is predicted.

A slight over- or under-prediction of the modelled results compared to the sampling data indicates that some of the sources may not be represented completely accurately. However, this is to be expected due to the uncertainties, assumptions made, and natural variability of many of the key model parameters. Alternatively, it may indicate that the sampling data, collected approximately once per week, is not fully representative of the distribution of concentrations throughout each day of the bathing season, which is what is produced by the model. Although some discrepancies are seen between the modelled output and the historical BW data, given the difficulty in representing Cardigan WwTW, the large uncertainty in diffuse river loads, and the limitations in the BW sampling data itself, the results of the Validation scenarios are considered to be fit for purpose. The robust validation exercise, combined with the sensitivity analyses undertaken, provide confidence in the overall results of the modelling assessment and the general conclusions drawn from them.

Table 6-1 Comparison of S-O predictions against measured bacterial data at Poppit West BW.

	Validation 2009-2012		Validation 2010-2013		Validation 2011-2014	
	BW Sample Data	S-O Predictions	BW Sample Data	S-O Predictions	BW Sample Data	S-O Predictions
90-percentile (EC/100ml)	207	265	168	171	147	152
95-percentile (EC/100ml)	437	451	329	385	262	354
Indicative BWD Class (EC)	Good	Good	Good	Good	Good	Good
90-percentile (IE/100ml)	49	77	50	65	49	60
95-percentile (IE/100ml)	85	116	82	102	75	96
Indicative BWD Class (IE)	Excellent	Good	Excellent	Good	Excellent	Excellent
Overall BWD Class	**Good**	**Good**	**Good**	**Good**	**Good**	**Good**

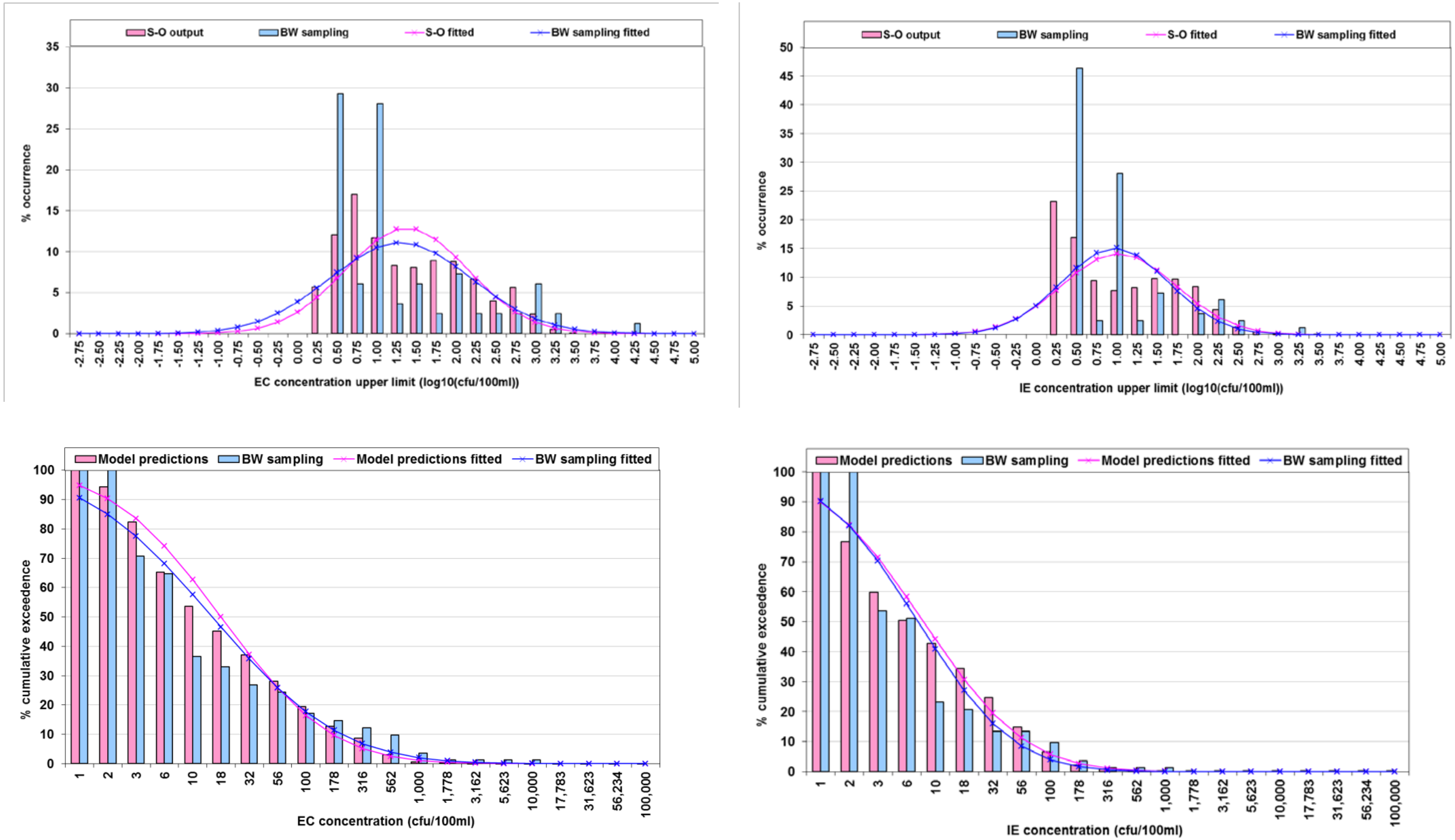


Figure 6-1 Concentration Distribution Comparisons for 2009-2012 at Poppit West BW (Top= distribution plot, bottom= cumulative histogram, left=EC, right=IE).

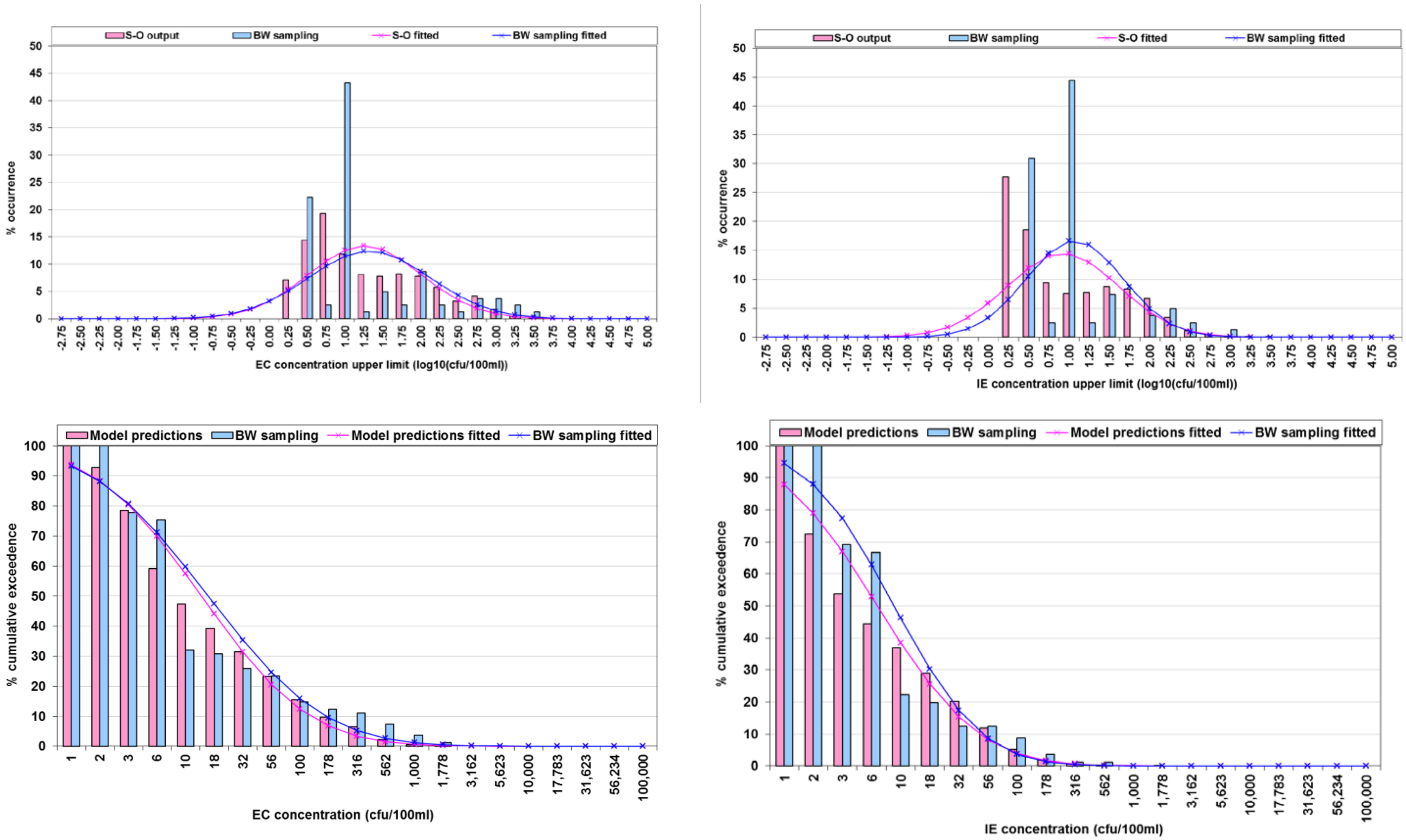


Figure 6-2 Concentration Distribution Comparisons for 2010-2013 at Poppit West BW (Top= distribution plot, bottom= cumulative histogram, left=EC, right=IE).

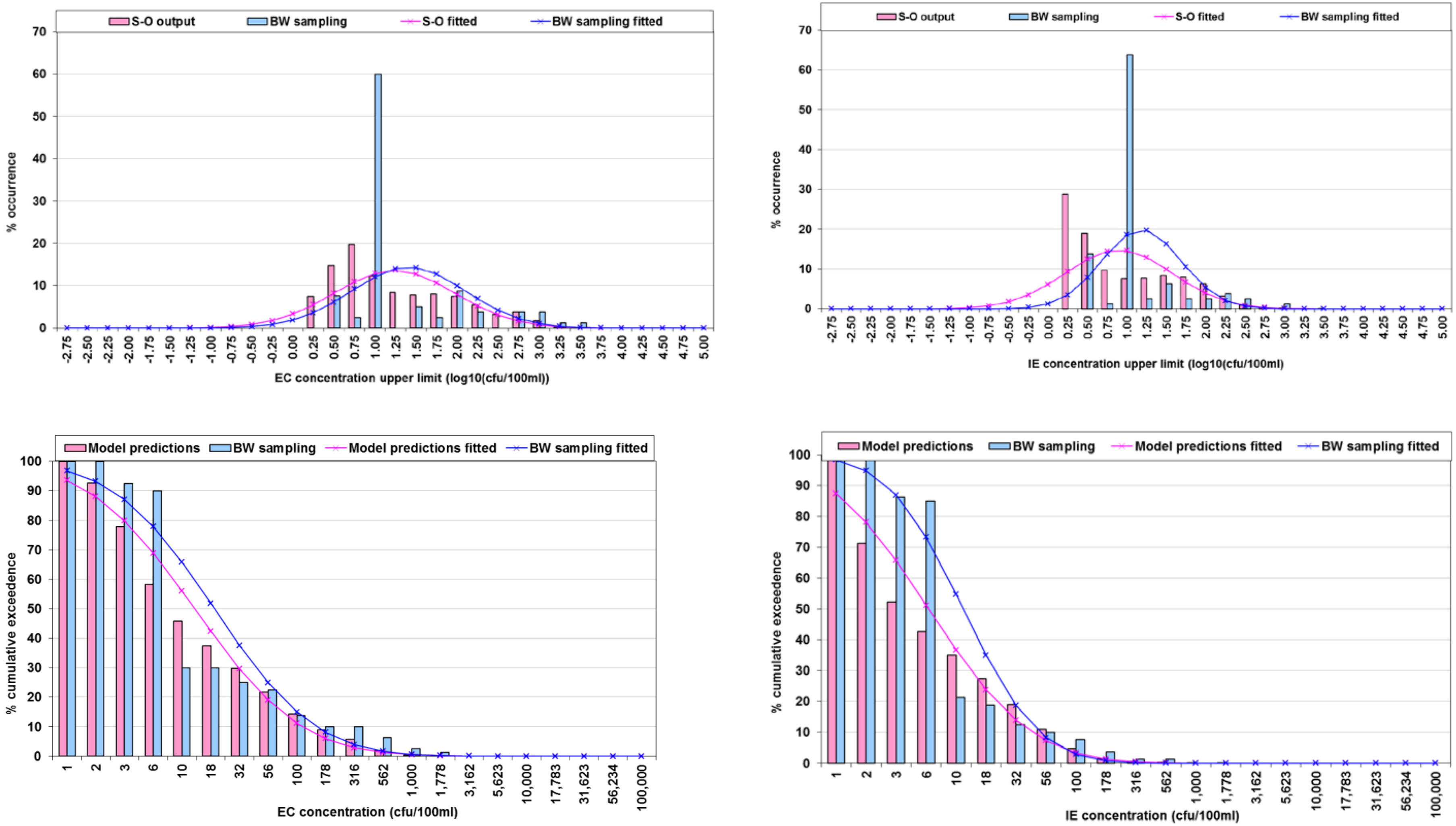


Figure 6-3 Concentration Distribution Comparisons for 2011-2014 at Poppit West BW (Top= distribution plot, bottom= cumulative histogram, left=EC, right=IE).

6.2.2 Source Apportionment

Table 6-2 and Table 6-3 show the top contributors in the source apportionment, for EC and IE respectively (only those sources which contribute more than 1% are included). Significant sources are largely the same for EC and IE at Poppit West throughout the three four-year periods, although there are minor differences in the ordering of sources. Any changes in the order of the sources is most likely due to the rainfall increasing (or decreasing) river flows in particularly wet (or dry) years.

Source apportionments show that diffuse loads in rivers dominate impacts for EC and IE at Poppit West BW, the Afon Teifi in particular. The largest DCWW asset to contribute to BW performance at Poppit West BW is Cardigan No 2.5 SPS Storm overflow (highlighted green), with contributions of 5.1-6.3% for EC and 7.6-8.6% for IE, respectively.

Table 6-2 Source contributions to the EC impact at Poppit West BW – Validation scenario.

Source	2009-2012	2010-2013	2011- 2014
	Excellent Threshold (250 EC/100ml)	Excellent Threshold (250 EC/100ml)	Excellent Threshold (250 EC/100ml)
Afon Teifi Wet	40.7%	39.6%	39.2%
Afon Mwldan Wet	32.8%	31.8%	31.5%
Cardigan No 2.5 SPS Storm	**5.1%**	**5.7%**	**6.3%**
Afon Morgenau Wet	4.7%	4.5%	4.5%
Afon Teifi Dry	2.0%	2.1%	2.1%
St Dogmaels Wet	1.3%	1.6%	1.5%
Nant-y-Ferwig Wet	1.4%	1.6%	1.5%
Afon Plysgog Wet	1.1%	1.3%	1.2%
Webley Hotel Wet	1.0%	1.2%	1.2%

Table 6-3 Source contributions to the IE impact at Poppit West BW – Validation scenario.

Source	2009- 2012	2010- 2013	2011- 2014
	Excellent Threshold (100 IE/100ml)	Excellent Threshold (100 IE/100ml)	Excellent Threshold (100 IE/100ml)
Afon Teifi Wet	34.1%	31.6%	31.2%
Cardigan No 2.5 SPS Storm	**7.6%**	**8.0%**	**8.6%**
St Dogmaels Wet	7.0%	8.1%	7.9%
Afon Morgenau Wet	7.8%	7.3%	7.2%
Nant-y-Ferwig Wet	6.0%	6.5%	6.3%
Afon Mwldan Wet	6.4%	5.9%	5.8%
Afon Teifi Dry	4.8%	4.9%	4.8%
IRB Station Wet	3.5%	4.3%	4.2%
Afon Plysgog Wet	4.0%	4.2%	4.1%

Webley Hotel Wet	2.4%	2.8%	2.7%
Nant Rhyd-y-fuwch Wet	1.7%	1.8%	1.7%
St Dogmaels Slipway Wet	1.5%	1.7%	1.7%
Cardigan WwTW Wet	**1.3%**	**1.4%**	**1.5%**
Cilgerran PS No 1 EO	**1.1%**	**1.1%**	**1.3%**
Nant Olmarch Wet	1.3%	1.2%	1.2%

6.3 Baseline scenario

6.3.1 Compliance Assessment

Table 6-4 provides the results of the ten-year Baseline scenario. This indicates that, over a long-term period and with current conditions, Poppit West BW is predicted to achieve Good classification for EC and Excellent classification for IE.

Table 6-4 Predicted EC and IE concentrations at key percentiles – Baseline scenario.

	S-O Predictions Baseline
90-percentile (EC/100ml)	160
95-percentile (EC/100ml)	387
Indicative BWD Class (EC)	Good
90-percentile (IE/100ml)	59
95-percentile (IE/100ml)	99
Indicative BWD Class (IE)	Excellent
Overall BWD Class	**Good**

6.3.2 Source Apportionment

Table 6-5 and Figure 6-4 display the main EC contributors to exceedance of Excellent standard threshold (250 EC/100 ml). Table 6-6 and Figure 6-5 display the main IE contributors to exceedance of Excellent standard threshold (100 IE/100 ml). In the tables DCWW assets are highlighted and colour-coded. In the figures, all DCWW assets have a unique, solid colour, whereas the rivers have a unique hatched colour.

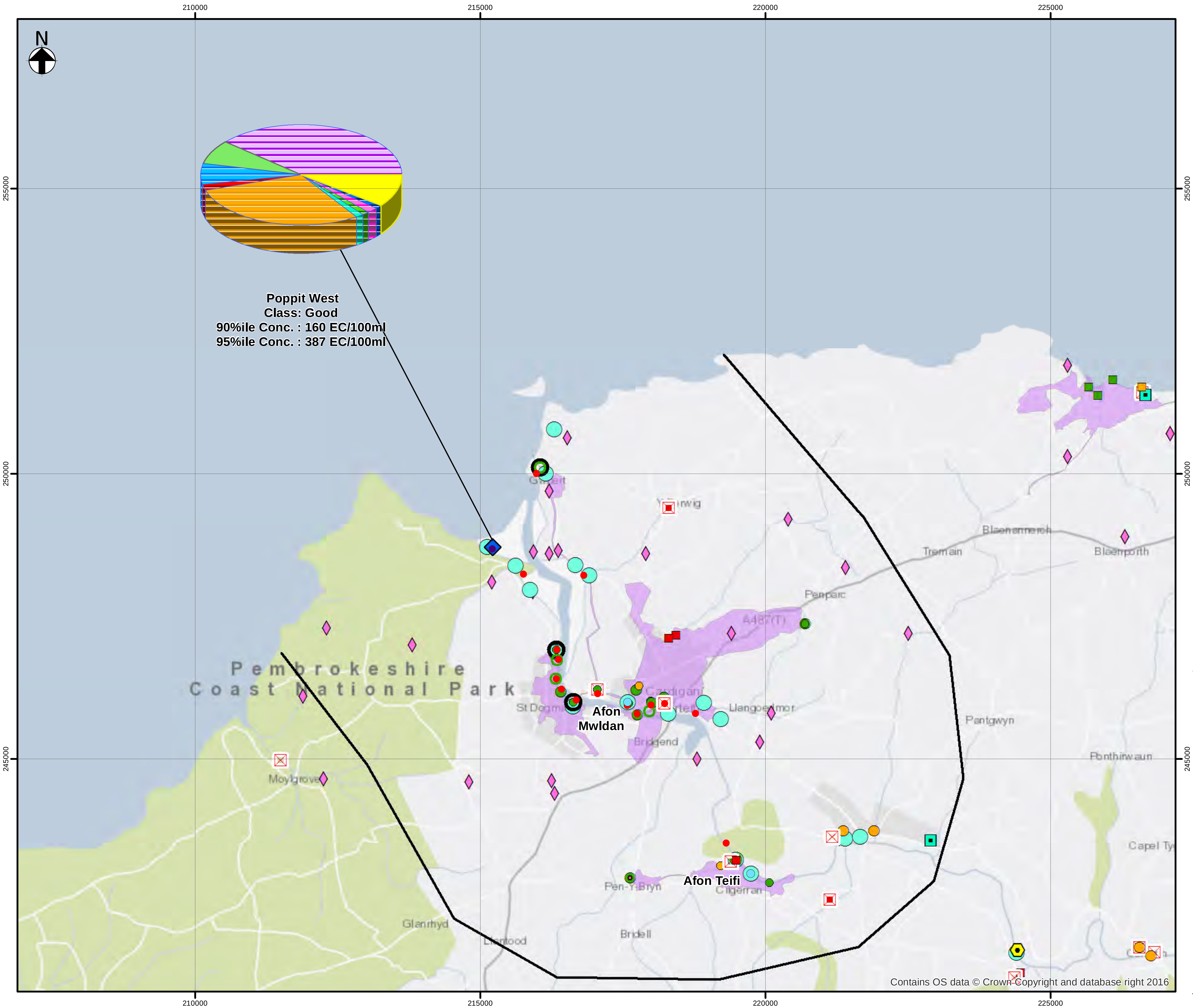
As in the Validation scenarios, the largest contributors are rivers – the Afon Teifi in particular, but also the Afon Mwldan. The biggest DCWW asset impacting BW performance is Cardigan No 2.5 SPS Storm, which contributes 6.3% and 9.3% to EC and IE impacts at Poppit West BW, respectively. Consequently, the contribution of Cardigan No 2.5 SPS Storm to the microbial quality water at Poppit West BW, while important, is relatively small compared with the contributions from diffuse river loads. It is also important to point out that the pollution contribution of the Cardigan No 2.5 SPS Storm asset is being modelled with medium confidence, as there is currently no EDM data for this asset.

Table 6-5 Source contributions to EC impacts – Baseline scenario

Source	EC Excellent Threshold (250 EC/100ml)
Afon Teifi Wet	41.2%
Afon Mwldan Wet	33.3%
Cardigan No 2.5 SPS Storm	**6.3%**
Afon Morgenau Wet	4.7%
Afon Teifi Dry	1.7%
St Dogmaels Wet	1.4%
Nant-y-Ferwig Wet	1.3%
Afon Plysgog Wet	1.1%
Webley Hotel Wet	1.0%

Table 6-6 Source contributions to IE impacts – Baseline scenario

Source	IE Excellent Threshold (100 IE/100ml)
Afon Teifi Wet	34.9%
Cardigan No 2.5 SPS Storm	**9.3%**
Afon Morgenau Wet	8.0%
St Dogmaels Wet	7.7%
Afon Mwldan Wet	6.5%
Nant-y-Ferwig Wet	6.2%
Afon Plysgog Wet	4.3%
IRB Station Wet	3.8v
Afon Teifi Dry	3.8%
Webley Hotel Wet	2.7%
Nant Rhyd-y-fuwch Wet	1.9%
St Dogmaels Slipway Wet	1.7%
Cardigan WwTW Wet	**1.6%**
Nant Olmarch Wet	1.4%
Cilgerran SPS No 1 EO	**1.1%**



Bathing Waters
Boundary Of Area Of Interest
Network Model Catchments
Main Contributor

Spiller / Data Availability

Size / Shape (Spiller)
- Spilling Over Threshold
- Spilling Below Threshold
- Not Spilling
- Not Known

Colour (Data Availability)
- Model Available
- Telemetry Available
- No Data
- EDM Available

Sources
- WwTWs
- Private Sources
- NRW River Flow Gauges
- NRW Rainfall Gauges
- Modelled River

Source Contributors
- Afon Teifi Wet
- Afon Morgenau Wet
- St Dogmaels Wet
- Afon Mwldan Wet
- Nant-y-Ferwig Wet
- Afon Plysgog Wet
- IRB Station Wet
- Afon Teifi Dry
- Webley Hotel Wet
- Nant Rhydyfuwch Wet
- St Dogmaels Slipway Wet
- Nant Olmarch Wet
- Cilgerran PS No 1 EO
- Cardigan No 2.5 SPS Storm
- Cardigan WwTW Wet
- Other

0 0.6 1.2 1.8 2.4 3 km

REV	DATE	DR	DESCR	CHK	APP	Date.
0	05/04/2017	JFA	Draft	JFA	PT	05/04/2017

Capital Delivery Alliance
Cynghrair Cyflawni Cyfalaf
Ty Awen, Spooner Close, Coed Kernew, Newport, NP108FZ
Intertek

Project Name. DCWW Coastal Investigation Programme COMPLIANCE ASSESSMENT STUDY AREA 15 (POPPIT WEST)

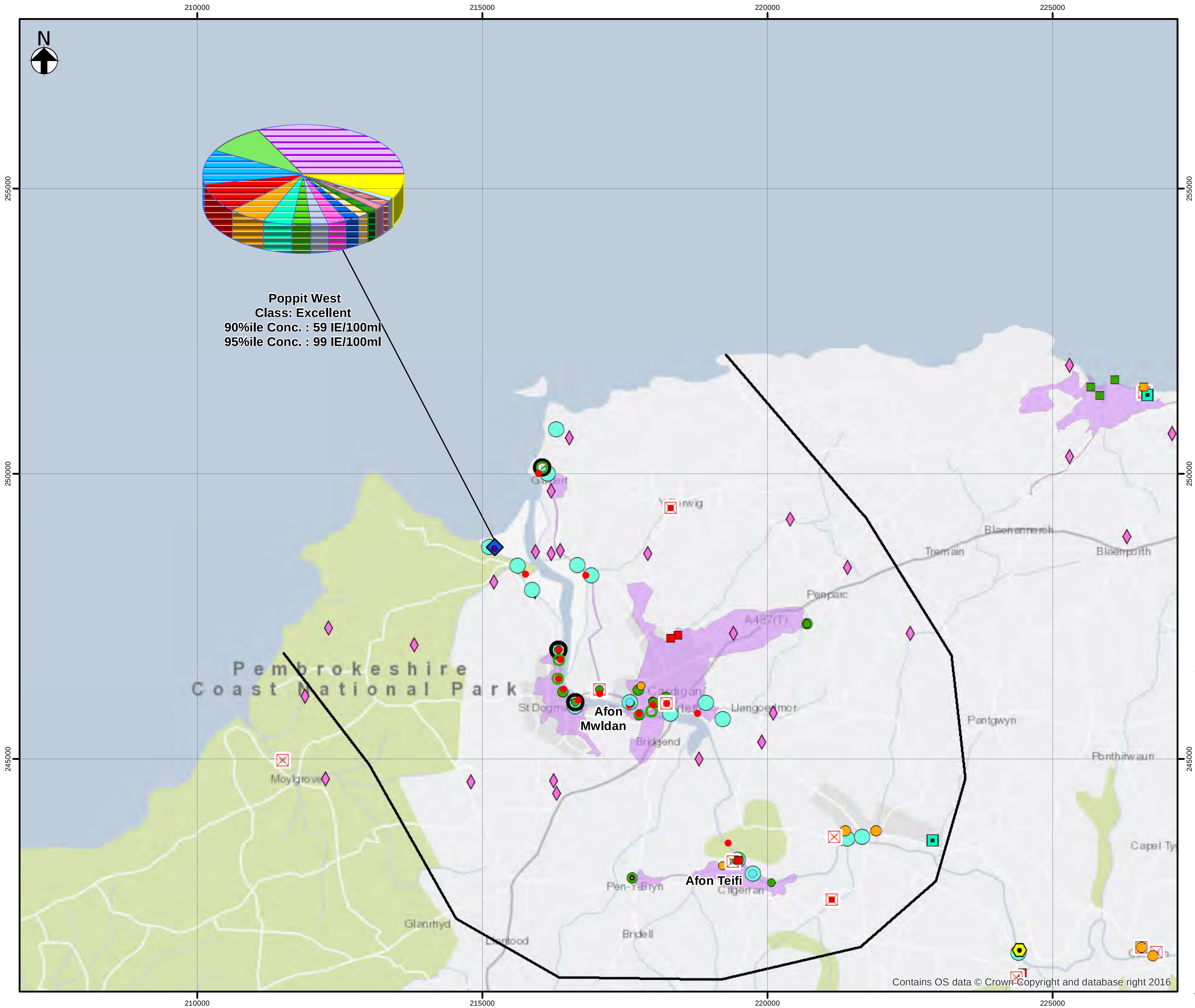
Drawing Title. Figure 6-4: Predicted perfomance against the BWD Excellent EC standards- ten year Baseline Scenario

Suitability.	Suitability Code.	Projection Info.
FINAL	F1	British_National_Grid D_OSGB_1936 Airy_1830

Originator	Designer	Date.
Jennifer Arthur	Richard Marlow	05/04/2017

Internal Project Number	Scale	Rev.
P1961	1:62,500	REV 1

Drawing Number. 6_4



Bathing Waters

Boundary Of Area Of Interest

Network Model Catchments

Main Contributor

Sources

WwTWs

Private Sources

NRW River Flow Gauges

NRW Rainfall Gauges

Modelled River

Spiller / Data Availability

Size / Shape (Spiller)

Spilling Over Threshold

Spilling Below Threshold

Not Spilling

Not Known

Colour (Data Availability)

Model Available

Telemetry Available

No Data

EDM Available

Source Contributors

Afon Teifi Wet

Afon Morgenau Wet

St Dogmaels Wet

Afon Mwldan Wet

Nant-y-Ferwig Wet

Afon Plysgog Wet

IRB Station Wet

Afon Teifi Dry

Webley Hotel Wet

Nant Rhydyfuwch Wet

St Dogmaels Slipway Wet

Nant Olmarch Wet

Cilgerran PS No 1 EO

Cardigan No 2.5 SPS Storm

Cardigan WwTW Wet

Other

0 0.6 1.2 1.8 2.4 3 km

REV	DATE	DR	DESCR	CHK	APP	Date.
0	05/04/2017	JFA	Draft	JFA	PT	05/04/2017

Capital Delivery Alliance
Cynghrair Cyflawni Cyfalaf

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Intertek

Project Name. DCWW Coastal Investigation Programme
COMPLIANCE ASSESSMENT
STUDY AREA 15 (POPPIT WEST)

Drawing Title. Figure 6-5: Predicted perfomance against the BWD Excellent IE standards- ten year Baseline Scenario

Suitability.	Suitability Code.	Projection Info.
FINAL	F1	British_National_Grid D_OSGB_1936 Airy_1830

Originator	Designer	Date.
Jennifer Arthur	Richard Marlow	05/04/2017

Internal Project Number	Scale	Rev.
P1961	1:62,500	REV 1

Drawing Number. 6_5

6.4 Solution scenarios

6.4.1Compliance Assessment

Table 6-7 summarises the modelled predictions at the key (90 and 95) percentiles under different Spill Solution scenarios against the Baseline scenario. Very little difference in impacts is predicted by reducing CSO operations to either three or two per bathing season, with no change in classification for EC or IE.

In order to apply the Two- and Three-spill scenarios, all assets that operated more than three times per bathing season required a modified hydrograph. As a result, the source apportionment (the percentage contribution from each source) is slightly different under the solution scenarios than under the baseline scenario. As is shown in Table 6-7, applying a Two- or Three-spill Solution makes negligible difference to the results. Moreover, there is no significant difference between the predicted EC and IE impacts under the Two- and Three-spill scenarios.

It is therefore unlikely that reducing existing CSO operation to three or two times a bathing season is cost effective as there will be little improvement at the BW.

Table 6-7Poppit West BW performance under the Baseline and the Solution scenarios

	Baseline scenario	Three-spill scenario	Two-spill scenario
90-percentile (EC/100ml)	160	141	141
95-percentile (EC/100ml)	387	385	384
Indicative BWD Class (EC)	Good	Good	Good
90-percentile (IE/100ml)	59	57	57
95-percentile (IE/100ml)	99	98	98
Indicative BWD Class (IE)	Excellent	Excellent	Excellent
Overall BWD Class	**Good**	**Good**	**Good**

6.4.2 Source Apportionment

The results shown in Table 6-8 and Table 6-9 are the predicted EC and IE contributions of each source to the microbial water quality at Poppit West BW under the Solution scenarios, respectively. For the comparison, the top contributors to EC and IE impacts at BW under the Baseline scenario are displayed as well.

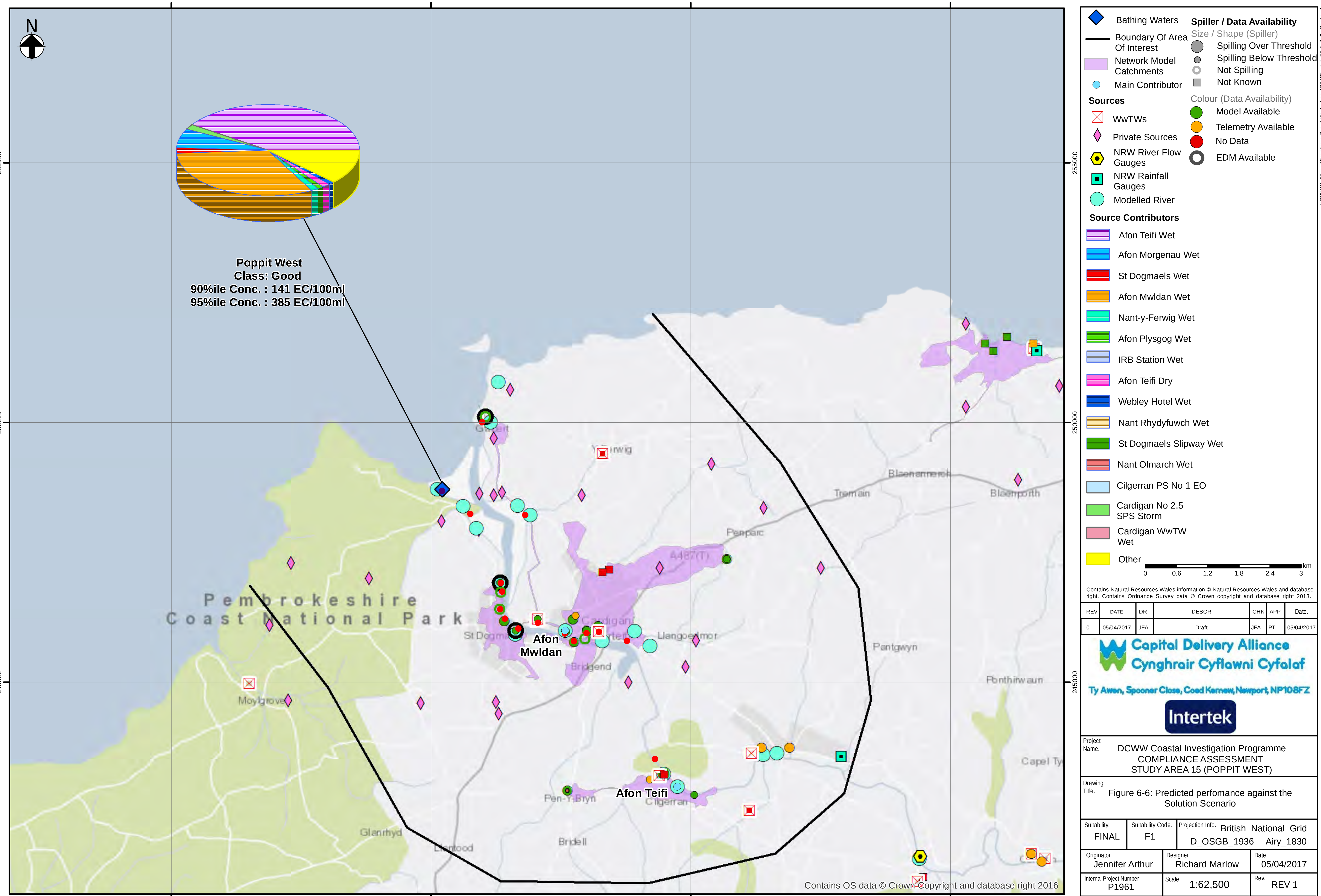
These results indicate that the diffuse sources have predominant impact on the microbial water quality at Poppit West BW. Therefore, as expected, reducing discharges from assets that operate more than two or three times a bathing season will not deliver a significant improvement to the water quality at Poppit West BW.

Table 6-8 Comparison of the source contributors to EC impacts at Poppit West BW under the Baseline and the Solution scenarios

Source	Baseline scenario	Three-spill scenario	Two-spill scenario
Afon Teifi Wet	41.2%	42.9%	43.1%
Afon Mwldan Wet	33.3%	34.7%	34.8%
Cardigan No 2.5 SPS Storm	**6.3%**	**1.5%**	**1.2%**
Afon Morgenau Wet	4.7%	4.9%	5.0%
Afon Teifi Dry	1.7%	1.4%	1.4%
St Dogmaels Wet	1.4%	1.4%	1.4%
Nant-y-Ferwig Wet	1.3%	1.4%	1.4%
Afon Plysgog Wet	1.1%	1.1%	1.1%
Webley Hotel Wet	1.0%	1.0%	1.0%

Table 6-9 Comparison of the source contributors to IE impacts at Poppit West BW under the Baseline and the Solution scenarios

Source	Baseline scenario	Three-spill scenario	Two-spill scenario
Afon Teifi Wet	34.9%	38.1%	38.3%
Cardigan No 2.5 SPS Storm	**9.3%**	**2.4%**	**1.9%**
Afon Morgenau Wet	8.0%	8.8%	8.8%
St Dogmaels Wet	7.7%	8.4%	8.5%
Afon Mwldan Wet	6.5%	7.1%	7.1%
Nant-y-Ferwig Wet	6.2%	7.1%	7.2%
Afon Plysgog Wet	4.3%	4.8%	4.9%
IRB Station Wet	3.8%	4.3%	4.3%
Afon Teifi Dry	3.8%	3.2%	3.2%
Webley Hotel Wet	2.7%	2.9%	2.9%
Nant Rhyd-y-fuwch Wet	1.9%	2.1%	2.1%
St Dogmaels Slipway Wet	1.7%	1.8%	1.9%
Cardigan WwTW Wet	**1.6%**	**1.3%**	**1.3%**
Nant Olmarch Wet	1.4%	1.5%	1.5%
Cilgerran SPS No 1 EO	**1.1%**	**0.9%**	**0.8%**



REV	DATE	DR	DESCR	CHK	APP	Date.
0	05/04/2017	JFA	Draft	JFA	PT	05/04/2017

Capital Delivery Alliance
Cynghrair Cyflawni Cyfalaf
Ty Awen, Spooner Close, Coed Kernew, Newport, NP10 8FZ
Intertek

Project Name. DCWW Coastal Investigation Programme COMPLIANCE ASSESSMENT STUDY AREA 15 (POPPIT WEST)

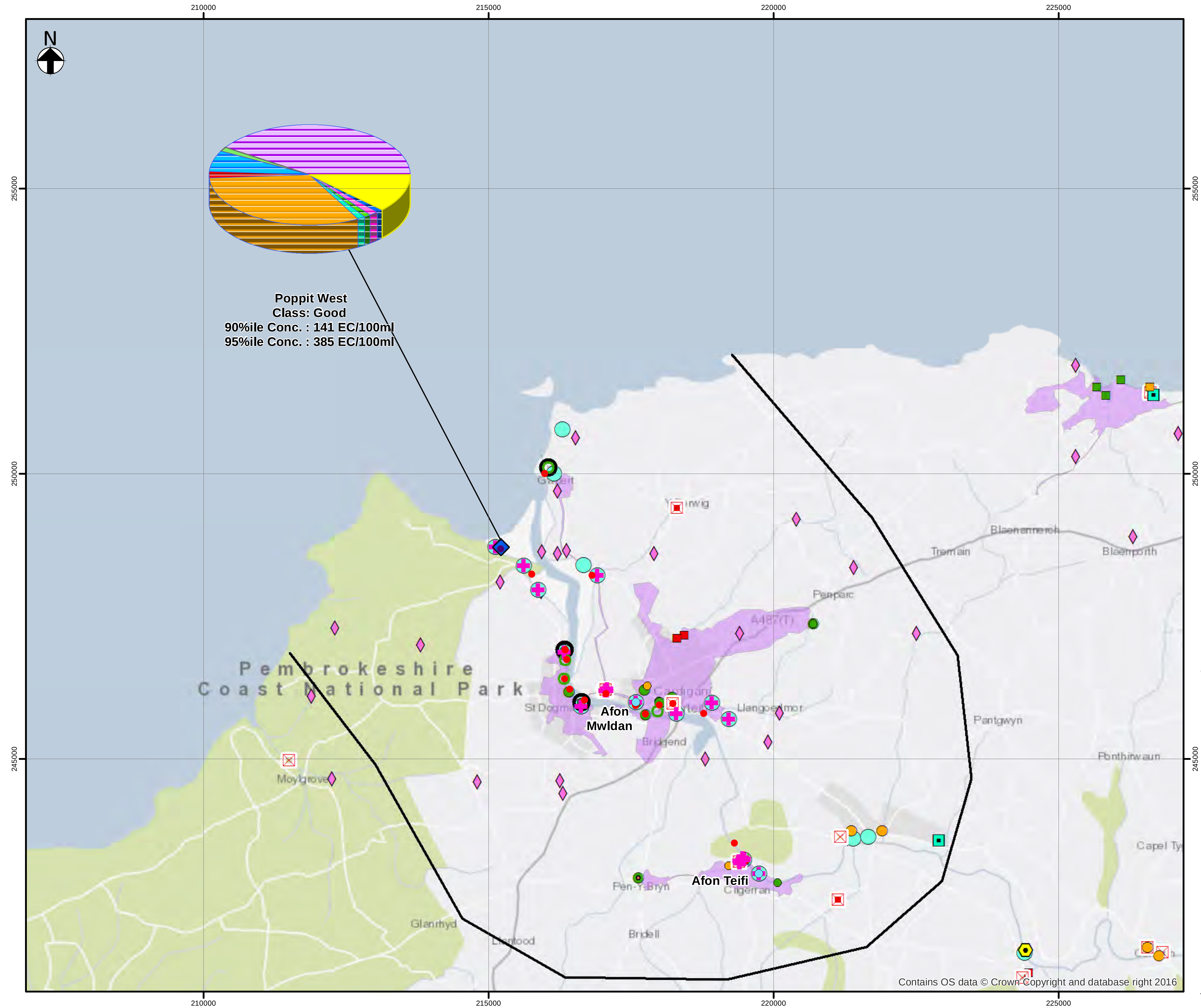
Drawing Title. Figure 6-6: Predicted perfomance against the Solution Scenario

Suitability.	Suitability Code.	Projection Info.
FINAL	F1	British_National_Grid D_OSGB_1936 Airy_1830

Originator	Designer	Date.
Jennifer Arthur	Richard Marlow	05/04/2017

Internal Project Number	Scale	Rev.
P1961	1:62,500	REV 1

Drawing Number. 6_6



Bathing Waters

Boundary Of Area Of Interest

Network Model Catchments

Main Contributor

Sources

WwTWs

Private Sources

NRW River Flow Gauges

NRW Rainfall Gauges

Modelled River

Spiller / Data Availability

Size / Shape (Spiller)

Spilling Over Threshold

Spilling Below Threshold

Not Spilling

Not Known

Colour (Data Availability)

Model Available

Telemetry Available

No Data

EDM Available

Source Contributors

Afon Teifi Wet

Afon Morgenau Wet

St Dogmaels Wet

Afon Mwldan Wet

Nant-y-Ferwig Wet

Afon Plysgog Wet

IRB Station Wet

Afon Teifi Dry

Webley Hotel Wet

Nant Rhydyfuwch Wet

St Dogmaels Slipway Wet

Nant Olmarch Wet

Cilgerran PS No 1 EO

Cardigan No 2.5 SPS Storm

Cardigan WwTW Wet

Other

0 0.6 1.2 1.8 2.4 3 km

REV	DATE	DR	DESCR	CHK	APP	Date.
0	05/04/2017	JFA	Draft	JFA	PT	05/04/2017

Capital Delivery Alliance
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Intertek

Project Name. DCWW Coastal Investigation Programme COMPLIANCE ASSESSMENT STUDY AREA 15 (POPPIT WEST)

Drawing Title. Figure 6-7: Predicted perfomance against the BWD Excellent EC standards- two spill Solution Scenario

Suitability.	Suitability Code.	Projection Info.
DRAFT	D1	British_National_Grid D_OSGB_1936 Airy_1830

Originator	Designer	Date.
Jennifer Arthur	Richard Marlow	22/03/2017

Internal Project Number	Scale	Rev.
P1961	1:62,500	REV 1

Drawing Number. 6_7

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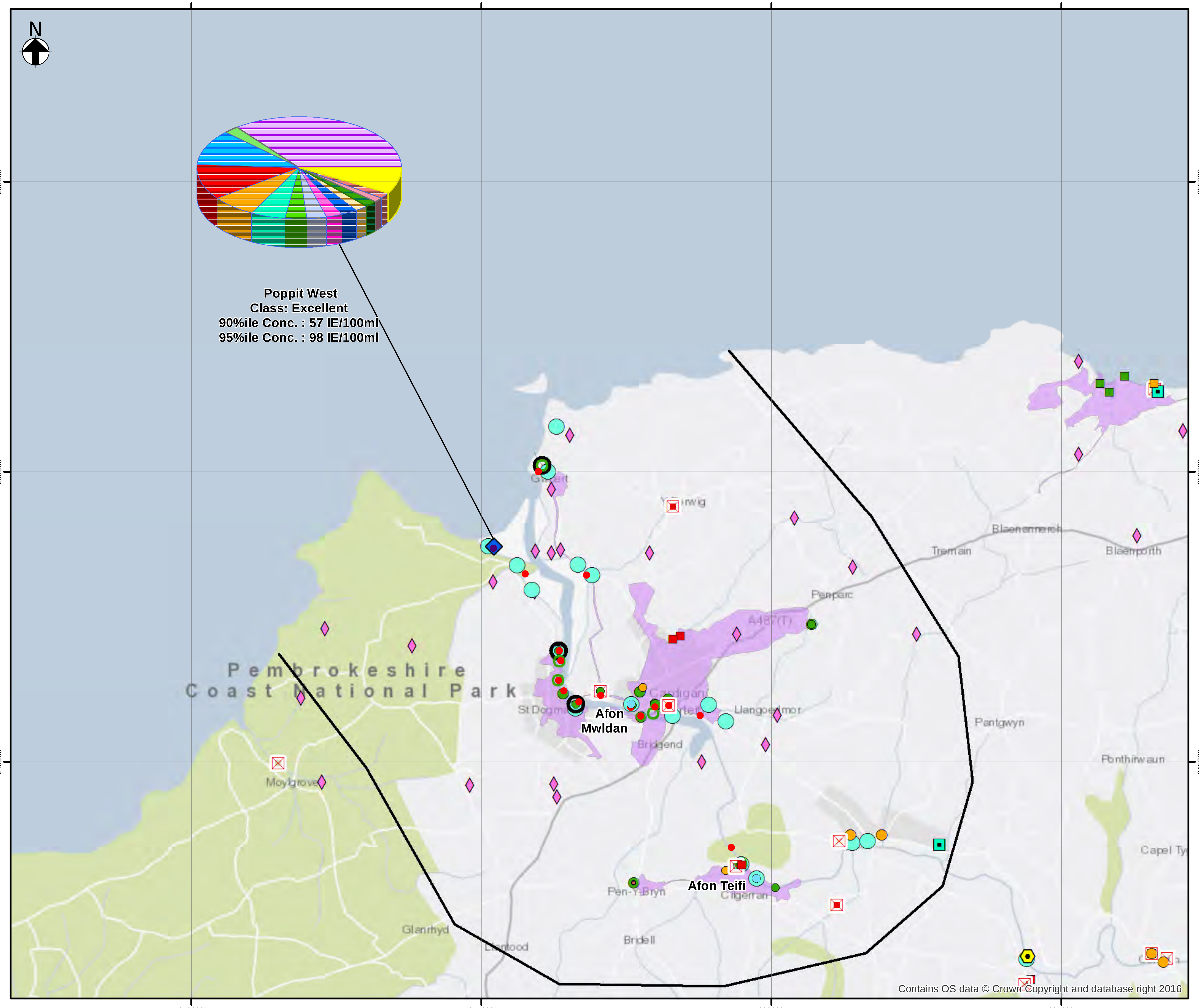

Bathing Waters

Boundary Of Area Of Interest

Network Model Catchments

Main Contributor

Sources

WwTWs

Private Sources

NRW River Flow Gauges

NRW Rainfall Gauges

Modelled River

Spiller / Data Availability

Size / Shape (Spiller)

Spilling Over Threshold

Spilling Below Threshold

Not Spilling

Not Known

Colour (Data Availability)

Model Available

Telemetry Available

No Data

EDM Available

Source Contributors

Afon Teifi Wet

Afon Morgenau Wet

St Dogmaels Wet

Afon Mwldan Wet

Nant-y-Ferwig Wet

Afon Plysgog Wet

IRB Station Wet

Afon Teifi Dry

Webley Hotel Wet

Nant Rhydyfuwch Wet

St Dogmaels Slipway Wet

Nant Olmarch Wet

Cilgerran PS No 1 EO

Cardigan No 2.5 SPS Storm

Cardigan WwTW Wet

Other

0 0.6 1.2 1.8 2.4 3 km

REV	DATE	DR	DESCR	CHK	APP	Date.
0	05/04/2017	JFA	Draft	JFA	PT	05/04/2017

Capital Delivery Alliance
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Intertek

Project Name. DCWW Coastal Investigation Programme COMPLIANCE ASSESSMENT STUDY AREA 15 (POPPIT WEST)

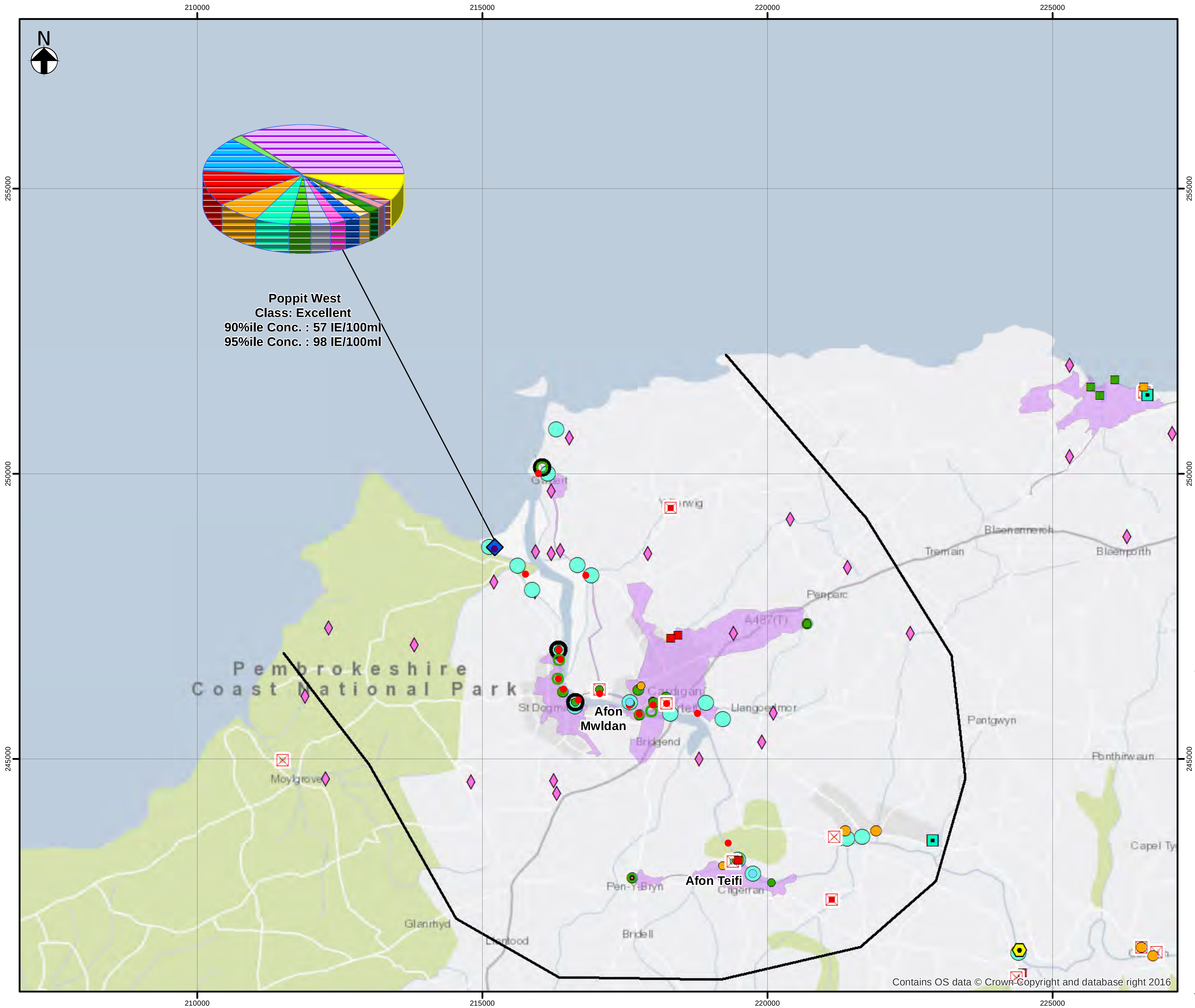
Drawing Title. Figure 6-8: Predicted perfomance against the BWD Excellent IE standards- three spill Solution Scenario

Suitability.	Suitability Code.	Projection Info.
FINAL	F1	British_National_Grid D_OSGB_1936 Airy_1830

Originator	Designer	Date.
Jennifer Arthur	Richard Marlow	05/04/2017

Internal Project Number	Scale	Rev.
P1961	1:62,500	REV 1

Drawing Number. 6_8



Bathing Waters

Boundary Of Area Of Interest

Network Model Catchments

Main Contributor

Spiller / Data Availability

Size / Shape (Spiller)

- Spilling Over Threshold
- Spilling Below Threshold
- Not Spilling
- Not Known

Colour (Data Availability)

- Model Available
- Telemetry Available
- No Data
- EDM Available

Sources

- WwTWs
- Private Sources
- NRW River Flow Gauges
- NRW Rainfall Gauges
- Modelled River

Source Contributors

- Afon Teifi Wet
- Afon Morgenau Wet
- St Dogmaels Wet
- Afon Mwldan Wet
- Nant-y-Ferwig Wet
- Afon Plysgog Wet
- IRB Station Wet
- Afon Teifi Dry
- Webley Hotel Wet
- Nant Rhydyfuwch Wet
- St Dogmaels Slipway Wet
- Nant Olmarch Wet
- Cilgerran PS No 1 EO
- Cardigan No 2.5 SPS Storm
- Cardigan WwTW Wet
- Other

0 0.6 1.2 1.8 2.4 3 km

REV	DATE	DR	DESCR	CHK	APP	Date.
0	05/04/2017	JFA	Draft	JFA	PT	05/04/2017

Capital Delivery Alliance
Cynghrair Cyflawni Cyfalaf

Ty Awen, Spooner Close, Coed Kernew, Newport, NP108FZ

Intertek

Project Name. DCWW Coastal Investigation Programme COMPLIANCE ASSESSMENT STUDY AREA 15 (POPPIT WEST)

Drawing Title. Figure 6-9: Predicted perfomance against the BWD Excellent IE standards- two spill Solution Scenario

Suitability.	Suitability Code.	Projection Info.
FINAL	F1	British_National_Grid D_OSGB_1936 Airy_1830

Originator	Designer	Date.
Jennifer Arthur	Richard Marlow	05/04/2017

Internal Project Number	Scale	Rev.
P1961	1:62,500	REV 1

Drawing Number. 6_9

6.5 Sensitivity Tests

Overview

The 2011-2014 Validation scenario was used as a comparison for the Sensitivity tests. This was chosen instead of the ten-year Baseline scenario to reduce the model run times and because this period gave the best fit of model results against the historical sampling data. Also, the results from the Baseline and Validation scenarios are very similar, so there is little difference in comparing the Sensitivity tests against one or the other. Table 6-10 and Table 6-11 summarise the modelled predictions at the key (90 and 95) percentiles, and provide the indicative BW classification which would be achieved under each condition. Table 6-12 and Table 6-13 summarize the top contributors to EC and IE impacts, respectively.

Decay rates

The T_{90} values used in the Baseline scenario were 60 hours for EC and 100 hours for IE.

Table 6-10 shows that the EC decay rate used has a large influence on the classification achieved at Poppit West BW. When a lower T_{90} (20 hours) is used, the BW classification improves to Excellent status, while with a longer T_{90} (80 hours) the predicted classification remains Good.

The decreasing (40 hours and 80 hours) IE decay rates did not have any impact on the IE classification at Poppit West BW (Table 6-11). The predicted BW classification has remained Excellent irrespective of the decay rate used in the sensitivity test.

This demonstrates that bathing water quality (in terms of EC at least) is sensitive to the decay rate, which is therefore also likely to be a contributing factor to the BW classification – assisting in achieving Excellent status in dry summers and potentially contributing (in addition to higher bacterial loads) to higher impact concentrations and therefore a lower classification in wetter years.

DCWW asset loads

The results depicted in Table 6-12 indicate that decreasing the DCWW asset loads by a factor of ten did not affect the BW classification for EC. However, a ten-fold increase in the DCWW asset loads resulted in the deterioration of the EC water quality at Poppit West BW and the predicted BW classification for EC is predicted to drop from Good to Sufficient.

Similarly, the IE classification at Poppit West BW was not affected by the decreased DCCW asset loads as it was already Excellent (Table 6-11). However, increasing the DCWW asset load by a factor of ten has resulted in a predicted Sufficient IE classification, instead of Excellent.

River loads

The results in Table 6-10 and Table 6-11 show that when the river loads are increased by a factor of ten, the BW performance for EC and IE at Poppit West is predicted to be Poor. They also suggest that a 90% improvement in the surrounding river catchments is predicted to deliver the Excellent EC classification. It is important to point out that Poppit West BW is already achieving Excellent IE classification under the Validation scenario.

Site-specific sensitivity test

The results depicted in Table 6-10 show that a 50% improvement in the river loads from the surrounding catchments along with the assumption that the Cardigan WwTW operates according to design (Best-case scenario), is predicted to deliver Excellent classification for EC. There is no change in the IE classification, as Poppit West already achieves Excellent classification under the Validation scenario.

Climate change

There is a significant change in the EC and IE classification as a result of an increase in the bathing season rainfall as shown in Table 6-10 and Table 6-11, respectively. Table 6-12 indicates that a 20% increase in average rainfall per bathing season would result in the classification dropping to Sufficient from Excellent for EC. A similar trend can be observed for IE as the predicted classification has changed to Good from Excellent.

It is important to explain the difference in the predicted BW EC classification under the Validation scenario (2011-2014), the Baseline Scenario (2005-2014) and under the Average rainfall BW scenario (2010). The predicted EC classification under the Average rainfall BW scenario was Excellent, which was better than the predicted EC classification achieved under the Validation scenario and under the Baseline scenario. This may indicate that the average rainfall bathing season (2010), in isolation, is generally drier than the period 2011-2014 and the long-term (ten-year) Baseline period (Figure 2-1).

6.5.1 Compliance Assessment

Table 6-10 Summary of bathing water performance under Sensitivity tests– EC

	2011-2014 results	20 Hours T_{90}	80 Hours T_{90}	Assets x10	Assets x0.1	Rivers x10	Rivers x0.1	Best-case scenario + Rivers x0.5	Climate change – average bathing season	Climate change – 20% wetter bathing season
90-percentile (EC/100ml)	152	66	173	414	126	7196	14	99	89	488
95-percentile (EC/100ml)	354	174	393	704	332	17484	70	211	174	654
Indicative BWD Class (EC)	Good	Excellent	Good	Sufficient	Good	Poor	Excellent	Excellent	Excellent	Sufficient

Table 6-11 Summary of bathing water performance under Sensitivity tests– IE

	2011-2014 results	40 Hours T_{90}	80 Hours T_{90}	Assets x10	Assets x0.1	Rivers x10	Rivers x0.1	Best-case scenario + Rivers x0.5	Climate change – average bathing season	Climate change – 20% wetter bathing season
90-percentile (IE/100ml)	60	38	56	138	53	2106	13	34	40	126
95-percentile (IE/100ml)	96	66	90	246	87	3178	24	57	67	179
Indicative BWD Class	Excellent	Excellent	Excellent	Sufficient	Excellent	Poor	Excellent	Excellent	Excellent	Good

6.5.2 Source Apportionment

Table 6-12 Source contributors to EC impacts under Sensitivity tests

	2011-2014 results	20 Hours T_{90}	80 Hours T_{90}	Assets x10	Assets x0.1	Rivers x10	Rivers x0.1	Best-case scenario + Rivers x0.5	Climate change – average bathing season	Climate change – 20%wetter bathing season
Afon Teifi Wet	39.2%	34.6%	38.7%	16.1%	43.3%	19.4%	4.0%	35.6%	36.3%	41.0%
Afon Mwldan Wet	31.5%	33.6%	30.3%	12.7%	34.8%	1.5%	3.6%	29.5%	29.3%	32.9%
Cardigan No 2.5 SPS Storm	**6.3%**	**6.7%**	**7.2%**	**42.8%**	**0.5%**	**1.0%**	**64.4%**	**13.9%**	**8.8%**	**4.4%**
Afon Morgenau Wet	4.5%	4.0%	4.4%	1.8%	5.0%	0.2%	0.5%	4.1%	4.2%	4.7%
Afon Teifi Dry	2.1%	0.3%	2.9%	2.0%	1.8%	69.5%	0.2%	0.8%	2.2%	2.0%
St Dogmaels Wet	1.5%	2.2%	1.5%	0.7%	1.6%	0.6%	0.7%	1.5%	1.7%	1.5%
Nant-y-Ferwig Wet	1.5%	3.2%	1.4%	0.4%	1.7%	0.4%	2.6%	1.8%	2.7%	1.4%
Afon Plysgog Wet	1.2%	1.9%	1.2%	0.4%	1.3%	0.4%	1.6%	1.5%	1.9%	1.1%
Webley Hotel Wet	1.2%	2.1%	1.1%	0.5%	1.2%	0.4%	0.8%	1.1%	1.3%	1.1%
Cilgerran SPS No 1 EO	**0.7%**	**0.9%**	**1.0%**	**4.9%**	**<0.1%**	**0.1%**	**10.2%**	**2.0%**	**1.4%**	**0.6%**
Cardigan WwTW Wet	**0.8%**	**0.7%**	**0.8%**	**2.6%**	**<0.1%**	**0.1%**	**4.4%**	**<0.1%**	**0.8%**	**0.6%**
Greenfield Square CSO	0.3%	0.3%	0.2%	0.5%	<0.1%	<0.1%	2.4%	0.2%	0.4%	0.1%
Afon Mwldan Dry	0.6%	0.1%	1.2%	0.9%	0.7%	2.8%	0.1%	0.3%	0.8%	0.8%

Table 6-13 Source contributors to IE impacts under Sensitivity tests

	2011-2014 results	40 Hours T_{90}	80 Hours T_{90}	Assets x10	Assets x0.1	Rivers x10	Rivers x0.1	Best-case scenario + Rivers x0.5	Climate change – average bathing season	Climate change – 20%wetter bathing season
Afon Teifi Wet	31.2%	25.4%	30.4%	11.3%	35.5%	6.6%	2.7%	20.7%	26.8%	34.5%
Cardigan No 2.5 SPS Storm	**8.6%**	**9.8%**	**9.3%**	**44.2%**	**0.6%**	**0.9%**	**54.2%**	**22.4%**	**11.4%**	**6.4%**
St Dogmaels Wet	7.9%	9.4%	8.2%	2.6%	9.1%	1.9%	3.3%	6.6%	7.7%	7.7%
Afon Morgenau Wet	7.2%	5.8%	7.0%	2.6%	8.2%	1.5%	0.6%	4.7%	6.2%	7.9%
Nant-y-Ferwig Wet	6.3%	10.7%	6.9%	1.2%	8.0%	1.0%	9.2%	10.8%	9.8%	5.6%
Afon Mwldan Wet	5.8%	5.2%	5.8%	2.0%	6.6%	1.1%	0.1%	4.0%	5.0%	6.4%
Afon Teifi Dry	4.8%	1.7%	4.0%	3.9%	4.3%	75.5%	0.3%	1.9%	4.7%	4.9%
IRB Station Wet	4.2%	6.5%	4.6%	1.2%	5.0%	0.8%	2.9%	4.4%	3.9%	3.9%
Afon Plysgog Wet	4.1%	5.9%	4.4%	1.0%	5.1%	0.7%	4.0%	6.7%	5.4%	3.7%
Webley Hotel Wet	2.7%	3.6%	2.9%	0.9%	3.1%	0.7%	1.3%	2.4%	2.7%	2.7%
Nant Rhyd-y-fuwch Wet	1.7%	2.3%	1.9%	0.5%	2.1%	0.3%	1.0%	2.4%	1.9%	1.7%
St Dogmaels Slipway Wet	1.7%	2.0%	1.8%	0.6%	2.0%	0.5%	0.7%	1.4%	1.6%	1.7%
Cardigan WwTW Wet	**1.5%**	**1.4%**	**1.5%**	**11.6%**	**0.1%**	**0.2%**	**5.3%**	**<0.1%**	**1.3%**	**1.2%**
Cilgerran PS No 1 EO	**1.3%**	**1.4%**	**1.3%**	**5.3%**	**0.1%**	**0.1%**	**8.9%**	**3.4%**	**2.0%**	**0.9%**
Nant Olmarch Wet	1.2%	1.0%	1.2%	0.4%	1.4%	2.6%	0.1%	0.8%	1.0%	1.3%
Nant Olmarch Dry	0.1%	<0.1%	0.1%	0.1%	0.1%	1.5%	<0.1%	<0.1%	0.1%	0.1%
Cardigan WwTW Dry	0.5%	0.1%	0.5%	4.4%	0.1%	<0.1%	<0.1%	<0.1%	1.3%	0.1%

7 Conclusions and Recommendations

This assessment investigates the impacts of DCWW wastewater discharges on the water quality at the designated Poppit West BW. The investigation included the analysis of historical data, and predictive assessments using a combination of coastal, river and sewerage network modelling tools, and Intertek's Environmental Design Optimisation assessment process using Intertek's S-O assessment tool, an established approach that has been used for the majority of detailed water quality assessments for bathing and shellfish waters in the UK. Contributions from each source to the impact of the BWs are determined in the assessment, and the most important contributors to water quality are identified.

S-O predicted outputs have been validated against historical BW data, and various scenarios have been assessed. They are:

—**Baseline scenario.** This scenario represents a long-term prediction of BW performance under current conditions, taking variations in rainfall into account.

—**Solution scenarios.** Two possible solution scenarios have been tested to determine the impact of reducing all CSOs to operate no more than two or three times per bathing season. Theoretical storage has been applied to the network modelled hydrographs for targeted CSOs to control the number of discharges and new hydrographs have been generated to represent these potential improvements.

—**Sensitivity tests.** The modelled BW performance was examined by Sensitivity runs, by changing the key parameters and assessing the influence on the results.

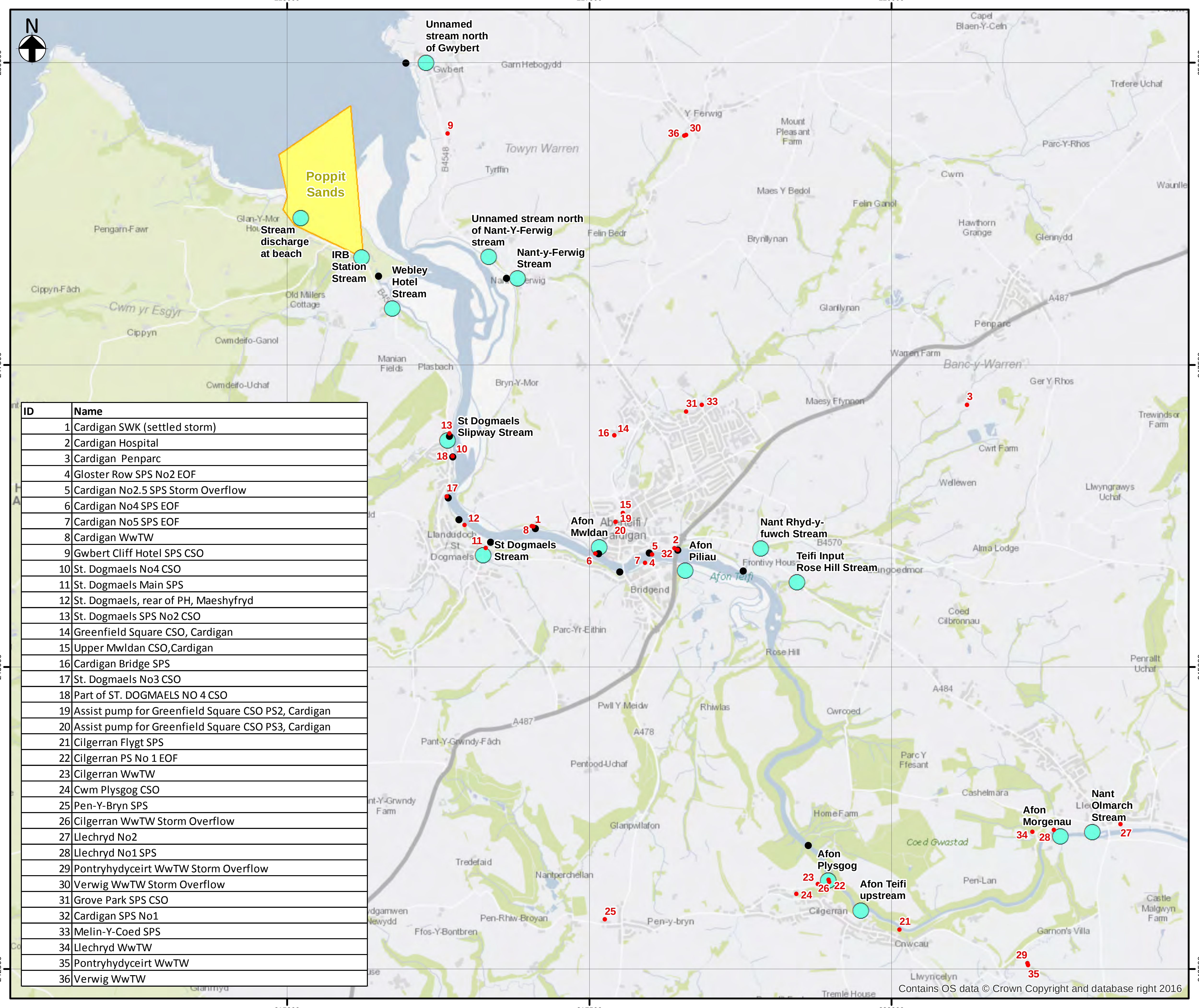
7.1 Conclusions

From the results and analysis of this assessment, the following observations and conclusions can be made:

—The BW data shows that Poppit West BW achieved Good classification up until 2014, and then improved to Excellent in 2015 and 2016.
—Poppit West BW is predicted by S-O to achieve Good classification for EC and Excellent classification for IE, under the baseline scenario (current conditions over a ten-year period).
—The main contributors to the total microbial impact at Poppit West BW are diffuse river sources, in particular the Afon Teifi (EC and IE).
—The BW performance at Poppit West BW is sensitive to river loads, with the predicted classification reducing to Poor (EC and IE) when river loads are increased by a factor of ten.
—DCWW assets have limited impact on Poppit West BW microbial water quality, in either the Baseline or Solution scenarios for EC or IE. The biggest contributing DCWW asset is the Cardigan No 2.5 SPS Storm overflow.
—The Cardigan WwTW microbial load does not contribute significantly to the water quality of Poppit West BW and improvement in the operational performance of the Cardigan WwTW would not significantly improve the water quality at Poppit West BW.
—There is negligible improvement in the BW performance under Three- and Two-spill Solution scenarios (EC and IE).

7.2 Recommendations

—It is our recommendation that DCWW should investigate the operational performance of the Cardigan WwTW to ensure it operates as design.
—DCWW should continue to monitor the performance of the Cardigan No 2.5 SPS Storm overflow through the EDM programme.
—CSO improvements to achieve two or three discharges per bathing season will not result in any significant improvement in BW performance. No further CSO improvement is recommended.
—EDM data should be continually monitored to ensure no deterioration in the current operation of CSOs.
—An investigation into the feasibility of reducing river catchment loads impacting Poppit West BW should be undertaken in order to reduce the risk of failing to achieve the Excellent classification in the longer term.
—Detailed investigations into river loads should be undertaken so that they can be more accurately represented in the model in future.



ID	Name
1	Cardigan SWK (settled storm)
2	Cardigan Hospital
3	Cardigan Penparc
4	Gloster Row SPS No2 EOF
5	Cardigan No2.5 SPS Storm Overflow
6	Cardigan No4 SPS EOF
7	Cardigan No5 SPS EOF
8	Cardigan WwTW
9	Gwbert Cliff Hotel SPS CSO
10	St. Dogmaels No4 CSO
11	St. Dogmaels Main SPS
12	St. Dogmaels, rear of PH, Maeshyfryd
13	St. Dogmaels SPS No2 CSO
14	Greenfield Square CSO, Cardigan
15	Upper Mwldan CSO,Cardigan
16	Cardigan Bridge SPS
17	St. Dogmaels No3 CSO
18	Part of ST. DOGMAELS NO 4 CSO
19	Assist pump for Greenfield Square CSO PS2, Cardigan
20	Assist pump for Greenfield Square CSO PS3, Cardigan
21	Cilgerran Flygt SPS
22	Cilgerran PS No 1 EOF
23	Cilgerran WwTW
24	Cwm Plysgog CSO
25	Pen-Y-Bryn SPS
26	Cilgerran WwTW Storm Overflow
27	Llechryd No2
28	Llechryd No1 SPS
29	Pontryhydyceirt WwTW Storm Overflow
30	Verwig WwTW Storm Overflow
31	Grove Park SPS CSO
32	Cardigan SPS No1
33	Melin-Y-Coed SPS
34	Llechryd WwTW
35	Pontryhydyceirt WwTW
36	Verwig WwTW

Legend

- Asset Location
- Model Discharge Location
- Modelled River
- River
- NEP Bathing Water

0 0.25 0.5 0.75 1 km

REV	DATE	DR	DESCR	CHK	APP	Date.
1	15/03/2017	JFA	Final	RJM	CM	24/03/2017

Capital Delivery Alliance
Cynghrair Cyflawni Cyfalaf
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Intertek

Project Name. DCWW Coastal Investigation Programme COMPLIANCE ASSESSMENT STUDY AREA 15 (POPPIT WEST)

Drawing Title. Figure A-1: Overview Of Modelled Sources In Poppit West Bathing Water Assessment

Suitability.	Suitability Code.	Projection Info.
FINAL	F1	British_National_Grid D_OSGB_1936 Airy_1830

Originator	Designer	Date.
Jennifer Arthur	Richard Marlow	19/04/2017

Internal Project Number	Scale	Rev.
P1961	1:30,000	REV 1

Drawing Number. A-1

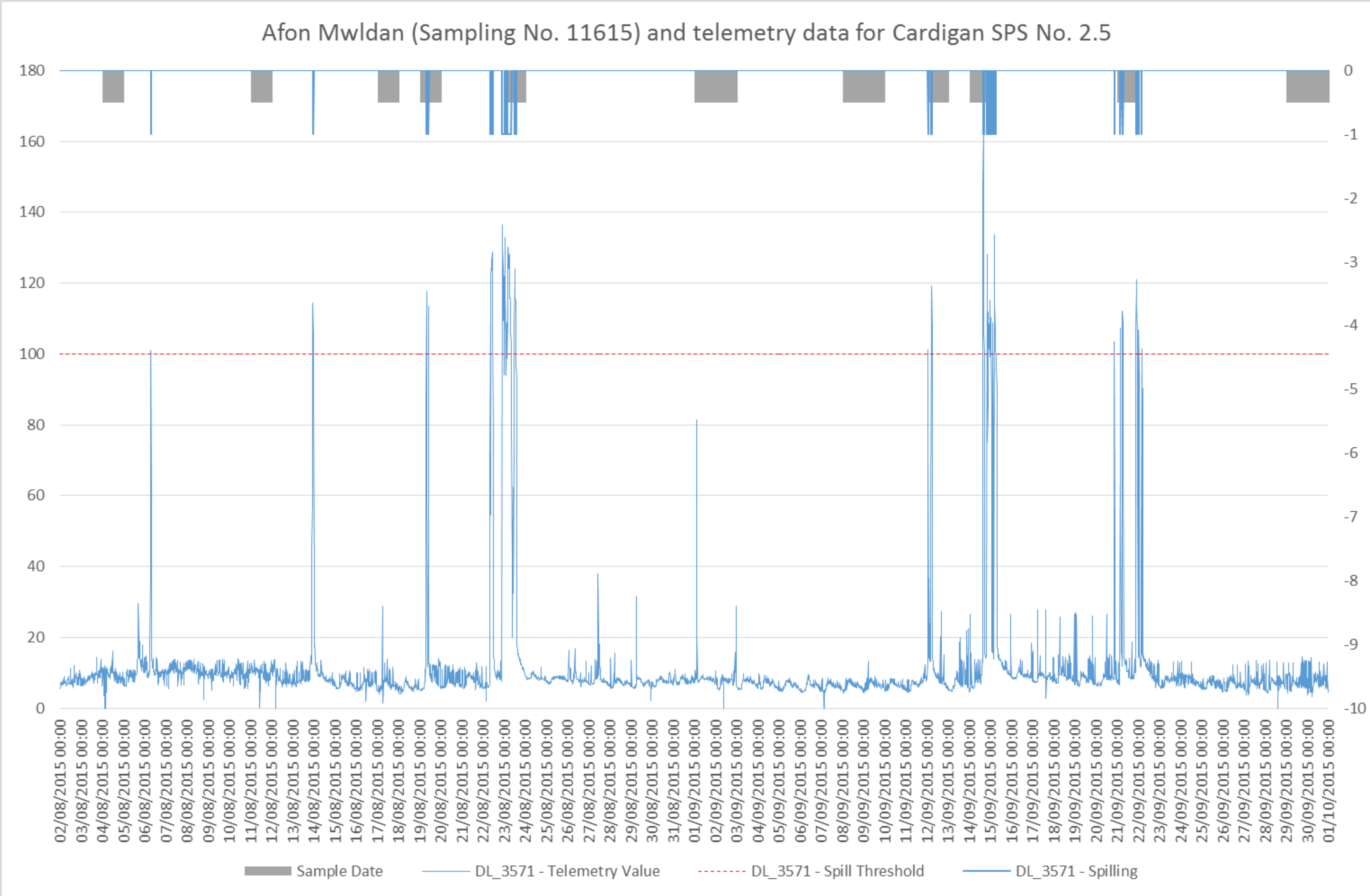

Figure A-2 The telemetry data collected at Cardigan No 2.5 SPS Storm Overflow and the time of sampling at the Afon Mwldan (sampling point 11615).

Table A-1 Modelled sources and associated model discharge location in the Poppit West BW assessment

Consent reference	Asset name	DCWW asset name	Model Discharge	Type	Easting	Northing	EC (EC/100ml)	IE (IE/100ml)
BP0275401	Cardigan SWK (settled storm)	Cardigan WwTW	W09	Storm tank	217024	246165	9.21E+06	1.64E+06
BH0074203	Cardigan Hospital	CARDIGAN 1	W12	CSO	218204	245983	2.86E+06	9.20E+05
BH0074301	Gloster Row SPS No2 EOF	GLOSTER ROW OVERFLOW SPS NO2	W12	CSO	218018	245933	2.86E+06	9.20E+05
BH0074301	Cardigan No2.5 SPS Storm Overflow	Gloster Row Overflow SPS No 2	W12	SPS	218018	245933	2.86E+06	9.20E+05
BH0074501	Cardigan No4 SPS EOF	CARDIGAN PS NO.4 (CSO & EO)	W09	SPS	217549	245939	2.86E+06	9.20E+05
BH0074503	Cardigan No5 SPS EOF	CARDIGAN SPS NO 5 (CSO & EO)	W12	SPS	217960	245861	2.86E+06	9.20E+05
BH0074101	Cardigan WwTW	Cardigan WwTW	D09	WwTW	217037	246164	1.61E+05	7.38E+04
BH0074101	Cardigan WwTW	Cardigan WwTW	W09	WwTW	217037	246164	1.81E+05	8.08E+04
BN0225901	Grove Park SPS CSO	Grove Park Estate, Cnwc-y-Dintir, Cardigan	W13	CSO	218301	247114	2.86E+06	9.20E+05
unknown	Melin-Y-Coed SPS		W13	SPS	218431	247168	2.86E+06	9.20E+05
BH0074511	St. Dogmaels No4 CSO	ST.DOGMAELS NO 4 CSO	W12	CSO	216369	246746	2.86E+06	9.20E+05
BH0074507	St. Dogmaels Main SPS	ST DOGMAELS, JEWSONS CSO (ST DOGMAELS MAIN PS CSO & EO)	W09	SPS	216642	245986	2.86E+06	9.20E+05
BH0074511	Part of St Dogmaels No 4 CSO	ST.DOGMAELS NO 4 CSO	W09	SPS	216642	245986	2.86E+06	9.20E+05
BH0074508	St. Dogmaels, rear of PH, Maeshyfryd	ST.DOGMAELS SSO 2A CSO	W09	CSO	216468	246176	2.86E+06	9.20E+05
BP0318101	St. Dogmaels SPS No2 CSO	ST DOGMAELS NORTH END SPS (CSO & EO)	W12	CSO	216343	246934	2.86E+06	9.20E+05
BP0321201	Greenfield Square CSO, Cardigan	Greenfield Square CSO, Cardigan	W12	CSO	217707	246918	2.86E+06	9.20E+05
BP0321201	Assist pump for Greenfield Square SPS2	Greenfield Square CSO, Cardigan	W12	CSO	217707	246918	2.86E+06	9.20E+05
BP0321201	Assist pump for Greenfield Square SPS3	Greenfield Square CSO, Cardigan	W12	CSO	217707	246918	2.86E+06	9.20E+05
BH0074203	Cardigan SPS No1	CARDIGAN 1	W12	SPS	218230	245970	2.86E+06	9.20E+05
BP0322701	Upper Mwldan CSO,Cardigan	DECOMMISIONED	W12	CSO	217778	246276	2.86E+06	9.20E+05

Consent reference	Asset name	DCWW asset name	Model Discharge	Type	Easting	Northing	EC (EC/100ml)	IE (IE/100ml)
BH0074403	Cardigan Bridge SPS	Cardigan Bridge PStn	W09	SPS	217707	246918	2.86E+06	9.20E+05
	St. Dogmaels No3 CSO		W09	CSO	216320	246412	2.86E+06	9.20E+05
BG0024901	Llechryd STW	Llechryd STW	D16	WwTW	221168	243635	1.00E+05	1.00E+04
BG0024901	Llechryd STW	Llechryd STW	W16	WwTW	221168	243635	1.00E+05	1.00E+04
BP0251301	Llechryd No1 SPS	LLECHRYD NO 1 SPS NEAR CARDIGAN DYFED	W16	SPS	221346	243650	2.86E+06	9.20E+05
BP0115001	Llechryd No2	LLECHRYD MAIN	W16	CSO	221895	243698	2.86E+06	9.20E+05
BG0023001	Pontryhydyceirt STW	Pontryhydyceirt STW	D16	WwTW	221131	242533	1.00E+05	1.00E+04
BG0023001	Pontryhydyceirt STW	Pontryhydyceirt STW	W16	WwTW	221131	242533	1.00E+05	1.00E+04
BG0023001	Pontryhydyceirt STW Storm Overflow	Pontrhydyceirt STW, Pontrhydyceirt	W16	Storm tank	221126	242548	1.80E+06	4.90E+05
BH0073801	Verwig STW	Verwig STW	D02	WwTW	218285	249397	1.00E+05	1.00E+04
BH0073801	Verwig STW	Verwig STW	W02	WwTW	218285	249397	1.00E+05	1.00E+04
BH0073802	Verwig STW Storm Overflow	VERWIG STW - STORM	W02	Storm tank	218302	249403	1.80E+06	4.90E+05
BH0065101	Cardigan Penparc	PENPARC CSO, CARDIGAN	W15	CSO	220625	247169	2.86E+06	9.20E+05
BP0114501	Cilgerran Flyght SPS	CILGERRAN FLYGHT P.S.	W16	SPS	220068	242826	2.86E+06	9.20E+05
NPSWQD009904	Cilgerran PS No 1 EOF	Cilgerran Sewage Pumping Station	W16	SPS	219486	243222	2.86E+06	9.20E+05
BP0217801	Cilgerran STW	Cilgerran STW	D16	WwTW	219390	243203	1.61E+05	7.38E+04
BP0217801	Cilgerran STW	Cilgerran STW	W16	WwTW	219390	243203	1.81E+05	8.08E+04
BP0341301	Cwm Plysgog CSO	PENRALLTDRAW CSO, CILGERRAN	W16	CSO	219212	243121	2.86E+06	9.20E+05
BP0114601	Pen-Y-Bryn SPS	PEN Y BRYN P.S.	W16	SPS	217627	242910	2.86E+06	9.20E+05
BP0217802	Cilgerran STW Storm Overflow	CILGERRAN STW, CILGERRAN, DYFED	W16	Storm tank	219480	243240	1.80E+06	4.90E+05
BP0350201	Gwbert Cliff Hotel SPS CSO	GWBERT SEWAGE PUMPING STATION	W01	SPS	216328	249416	2.86E+06	9.20E+05

Consent reference	Asset name	DCWW asset name	Model Discharge	Type	Easting	Northing	EC (EC/100ml)	IE (IE/100ml)
n/a	IRB Station		D30	River	215615	248392	n/a	n/a
n/a	Afon Teifi		D16	River	219740	242984	n/a	n/a
n/a	Afon Mwldan		D09	River	217579	245991	n/a	n/a
n/a	Teifi Input Rose hill		D15	River	219213	245700	n/a	n/a
n/a	Webley Hotel		D30	River	215867	247966	n/a	n/a
n/a	St Dogmaels Slipway		D03	River	216324	246876	n/a	n/a
n/a	St Dogmaels		D06	River	216619	245923	n/a	n/a
n/a	Nant Rhyd-y-fuwch		D15	River	218915	245980	n/a	n/a
n/a	Stream discharge at beach		D30	River	215111	248714	n/a	n/a
n/a	Stream east of Cardigan Island		D01	River	216295	250776	n/a	n/a
n/a	Stream north of Gwybert		D01	River	216146	250002	n/a	n/a
n/a	Afon Plysgog		D16	River	219472	243233	n/a	n/a
n/a	Nant-y-Ferwig		D02	River	216901	248215	n/a	n/a
n/a	Stream north of Nant-y-Ferwig stream		D02	River	216663	248393	n/a	n/a
n/a	Afon Morgenau		D16	River	221391	243598	n/a	n/a
n/a	Nant Olmarch		D16	River	221657	243632	n/a	n/a
n/a	Afon Piliau		D13	River	218290	245798	n/a	n/a
n/a	Patch caravan park Gwbert Cardigan		D30	Private asset	215934	248626	n/a	n/a

Table A-2 Modelled sources ranked in terms of input load (2005-2014)

Source Name	EC Rank	EC proportional load	IE Rank	IE proportional load
Afon Teifi Wet	1	23.3%	2	16.9%
Afon Teifi Dry	2	21.6%	1	30.8%
Afon Mwldan Wet	3	17.7%	9	3.0%
Cardigan No2.5 SPS Storm	4	8.3%	3	9.1%
Afon Mwldan Dry	5	7.1%	17	0.7%
Cardigan WwTW Dry	6	3.6%	4	5.6%
Afon Morgenau Wet	7	2.7%	7	3.9%
Afon Morgenau Dry	8	2.5%	8	3.5%
Cardigan WwTW Wet	9	1.7%	10	2.6%
St Dogmaels Wet	10	1.1%	5	4.2%
Nant-Y-Ferwig Wet	11	1.0%	6	4.0%
Afon Plysgog Wet	12	1.0%	11	2.6%
Cilgerran PS No 1 EOF	13	0.9%	15	1.0%
Webley Hotel Wet	14	0.7%	13	1.4%
St Dogmaels Slipway Wet	15	0.5%	16	1.0%
IRB Station Wet	16	0.5%	12	1.9%
Nant Olmarch Wet	17	0.5%	19	0.6%
Nant Olmarch Dry	18	0.4%	18	0.7%
Nant Rhyd-y-fuwch Wet	19	0.4%	14	1.0%
Cilgerran WwTW Dry	20	0.4%	20	0.6%
Greenfield Square CSO	21	0.4%	22	0.4%
St Dogmaels Dry	22	0.3%	23	0.4%
Patch Caravan Gwbert	23	0.2%	41	0.1%
Llechryd No 1 SPS	24	0.2%	29	0.2%
Teifi Input Rose Hill Wet	25	0.2%	21	0.4%
Cilgerran WwTW Wet	26	0.2%	24	0.3%
Stream north of Nant-Y-Ferwig Wet	27	0.2%	25	0.2%
Stream north of Gwybert Wet	28	0.2%	26	0.2%
Stream north of Nant-Y-Ferwig Dry	29	0.2%	28	0.2%
Afon Piliau Wet	30	0.2%	27	0.2%
Llechryd WwTW Dry	31	0.1%	44	0.1%
Stream north of Gwybert Dry	32	0.1%	30	0.2%
Afon Piliau Dry	33	0.1%	31	0.2%
Stream east of Cardigan Island Wet	34	0.1%	32	0.2%
Stream east of Cardigan Island Dry	35	0.1%	35	0.2%
Cardigan Bridge SPS	36	0.1%	37	0.1%
Llechryd WwTW Wet	37	0.1%	50	0.0%
Cardigan Hospital	38	0.1%	39	0.1%
Nant-Y-Ferwig Dry	39	0.1%	36	0.2%
Afon Plysgog Dry	40	0.1%	33	0.2%

Source Name	EC Rank	EC proportional load	IE Rank	IE proportional load
Cardigan Penparc	41	0.1%	42	0.1%
Teifi Input Rose Hill Dry	42	0.1%	46	<0.1%
Nant Rhyd-y-fuwch Dry	43	0.1%	38	0.1%
Cwm Plysgog CSO	44	0.1%	43	0.1%
Penybryn SPS	45	<0.1%	45	<0.1%
Pontrhydyceirt WwTW Wet	46	<0.1%	56	<0.1%
St Dogmaels, rear of PH, Maeshyfryd	47	<0.1%	48	<0.1%
Verwig WwTW Dry	48	<0.1%	57	<0.1%
St Dogmaels Slipway Dry	49	<0.1%	40	<0.1%
St Dogmaels Main SPS	50	<0.1%	49	<0.1%
Verwig WwTW Wet	51	<0.1%	60	<0.1%
Verwig Storm	52	<0.1%	51	<0.1%
St Dogmaels SPS No2 CSO	53	<0.1%	51	<0.1%
Pontrhydyceirt WwTW Dry	54	<0.1%	61	<0.1%
Llechryd No 2 CSO	55	<0.1%	53	<0.1%
Webley Hotel Dry	56	<0.1%	34	0.2%
Gloster Row Overflow SPS No2	57	<0.1%	54	<0.1%
Cardigan SPS No1	58	<0.1%	55	<0.1%
IRB Station Dry	59	<0.1%	47	<0.1%
Upper Mwldan CSO Cardigan	60	<0.1%	58	<0.1%
Cardigan SWK	61	<0.1%	59	<0.1%
Cilgerran Flyght SPS	62	<0.1%	62	<0.1%
Grove Park PS Cardigan	63	<0.1%	63	<0.1%
Melin Y Coes SPS	64	<0.1%	64	<0.1%
Cardigan No4 SPS EO	65	<0.1%	65	<0.1%
Pontrhydyceirt WwTW storm	66	<0.1%	66	<0.1%
Gwbert Cliff Hotel SPS CSO	67	<0.1%	67	<0.1%
Cardigan No 5 SPS EO	67	<0.1%	67	<0.1%
St Dogmaels No 4 CSO	67	<0.1%	67	<0.1%
Part of St Dogmaels No 4 CSO	67	<0.1%	67	<0.1%
St Dogmaels No 3 CSO	67	<0.1%	67	<0.1%
Assist pump for Greenfield Square SPS2	67	<0.1%	67	<0.1%
Assist pump for Greenfield Square SPS3	67	<0.1%	67	<0.1%
Cilgerran STW Dyfed	67	<0.1%	67	<0.1%