



Wrexham Solar Development

Flood Consequence Assessment

Novus Renewable Services Ltd

REPORT REF: 258/FCA/v2

May 2021

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1 Introduction

1.1 Purpose of this Report

This Report describes a Flood Consequence Assessment (FCA) that has been undertaken for the proposed Solar Farm north of the Maelor gas works.

Corylus Planning and Environmental Ltd (Corylus) has been instructed by Novus RS Ltd to undertake this assessment.

1.2 Background

This report constitutes a response to the Welsh Assembly's Technical Advice Note, TAN15 and to identify where additional work may be required, in order to satisfy the Advice Note.

A site-specific flood risk assessment must demonstrate the following¹:

- the flood risks to the development
- an assessment of the flood consequences of the development
- the development does not increase flood risk elsewhere
- how the flood risk to, or caused by, the development will be managed or mitigated against
- consideration of climate change in line with current government guidance

A specific request was made to NRW by way of a pre-application request. The response is included as Appendix B and is referred to principally in Section 2.

As part of this application, companion Reports have been prepared by Corylus:

- Baseline Flood Modelling Report Ref 258/Flood/v2i dated February 2021
- Surface Water Management Plan (SWMP) Ref 258/SWMP/v3i dated April 2021.

The Flood Modelling Report was submitted to NRW for review in June 2020. The model has been refined in light of the helpful comments provided by NRW on the model as described in v2 of the Flood Model Report.

This is v2 of the FCA and has been prepared in order to address the further comments (of March 2021) provided by NRW that have been included as Appendix C. The response to the comments is made within the Report and is summarised within the Appendix and through provision of a further Appendix D describing the hydrological modelling.

The versions of the hydraulic model have been described in Table 1-1

¹ <https://naturalresourceswales.gov.uk/guidance-and-advice/business-sectors/planning-and-development/advice-for-developers/developing-in-a-flood-risk-area/?lang=en>, accessed on 10th December 2020

Table 1-1: Versions of Hydraulic Model for River Clywedog

Date	Version	Comment
June 2020	A	Baseline modelling described in Report v1 based on hydrology for Bowling Bank GS.
Feb 2021	B	Revised baseline and post-development modelling for solar farm described in v2 of Report using scaled hydrology for Bowling Bank and taking account of NRW comments.
May 2021	B*	Revised post-development modelling for solar farm described in this Report using scaled hydrology for Bowling Bank and taking account of further NRW comments. The baseline model report was not revised at this point.
Summer 2021	C	The model will be further revised based on revised hydrology at the Site and comments by NRW and presented as a flood map challenge alongside the FCA for the proposed industrial development on an adjacent Site.

1.3 Sources of Information and Consultation

This Report has been informed by:

- Hydraulic modelling for the River Clywedog undertaken by Corylus in 2020 and 2021;
- Topographic surveys by Invar Mapping in April 2020;
- Site visit by Dr Webster on 19th November 2020; and
- Information available on internet sites.

1.4 Structure of this Report

The Report has been structured in order to deal with key flood related issues of TAN15, for which a checklist has been reproduced as Appendix A of this Report. The principal sections of this Report are as follows.

- Section 2 refers to spatial planning considerations by reference to the proposed land use and flood zoning.
- Section 3 presents an assessment of the existing flood risk at the application site.
- Section 4 presents an assessment of flood risks associated with the proposed development along with any mitigation that may be required.
- Section 5 provides a Summary and Conclusions.

Additional Appendices deal with the following:

- Appendix B is the NRW response to a pre-application enquiry.
- Appendix C provides the NRW comments on v1 of FCA and our response.
- Appendix D provides additional hydrological information requested by NRW.

1.5 Qualifications of those undertaking this Assessment

Dr Paul Webster: Project Manager and Hydrological Specialist

Dr Webster has 40 years' experience of research and practice in hydrology. He has undertaken flood risk/consequence assessments for planning applications such as those based upon NPPF, PPG/S25 and TAN15 and has been involved as Expert Witness for Planning Enquiries. He was the Head of Flood Risk Management at Hydro-Logic Services from 2000 to 2019 where he oversaw all flood related work including hydraulic modelling, surface water management and FRA/FCAs and which numbered over 1,000 individual projects. He is currently the lead hydrologist at Corylus where he fulfils a similar role. From 1991 to 2000, he was a Lecturer at the University of Birmingham where he led a floods research group with a particular focus on design flood methodologies. He was a reviewer for the Flood Estimation Handbook and was a Project Manager for the Environment Agency on the hydrological research in the joint EA/DEFRA programmes.

Latha Yellampalli: Hydraulic Modeller

Latha is an expert Hydraulic Modeller with advanced knowledge of the ISIS and TUFLOW modelling software packages, which she has applied to numerous projects in England and Wales. She has over ten years of experience in preparing 1D and 2D Rivers and Coastal numerical models and has been involved in a wide portfolio of work including Flood Risk Assessments (produced for Nuclear Power Plant, School and Supermarket projects), Flood Risk Mapping, Strategic Flood Risk Management and Flood Alleviation Schemes. This has involved 1- and 2-dimensional river hydraulic modelling, model reviews, hydrological analysis, writing proposals, project reports, assisting project manager, site visits and working closely with the clients to achieve successful projects.

2 Spatial Planning Considerations

2.1 Location and Outline Development proposals

The location of the Site is shown in Figure 2-1 along with the topography. The lower parts of the Site are located on generally flat land adjacent to the River Clywedog. The more elevated parts of the Site are on land that slopes gently towards the river. The land is currently in agricultural use, though some buildings remain from its former use as an MoD facility. An aerial view of the Site given in Figure 2-2 showing how the Site wraps around the existing solar farm.

The Site covers includes four fields where the solar arrays are to be installed. Images of the Site are shown in Figure 2-3 to Figure 2-6.

Figure 2-1: Location and topography of Site – outlined in red

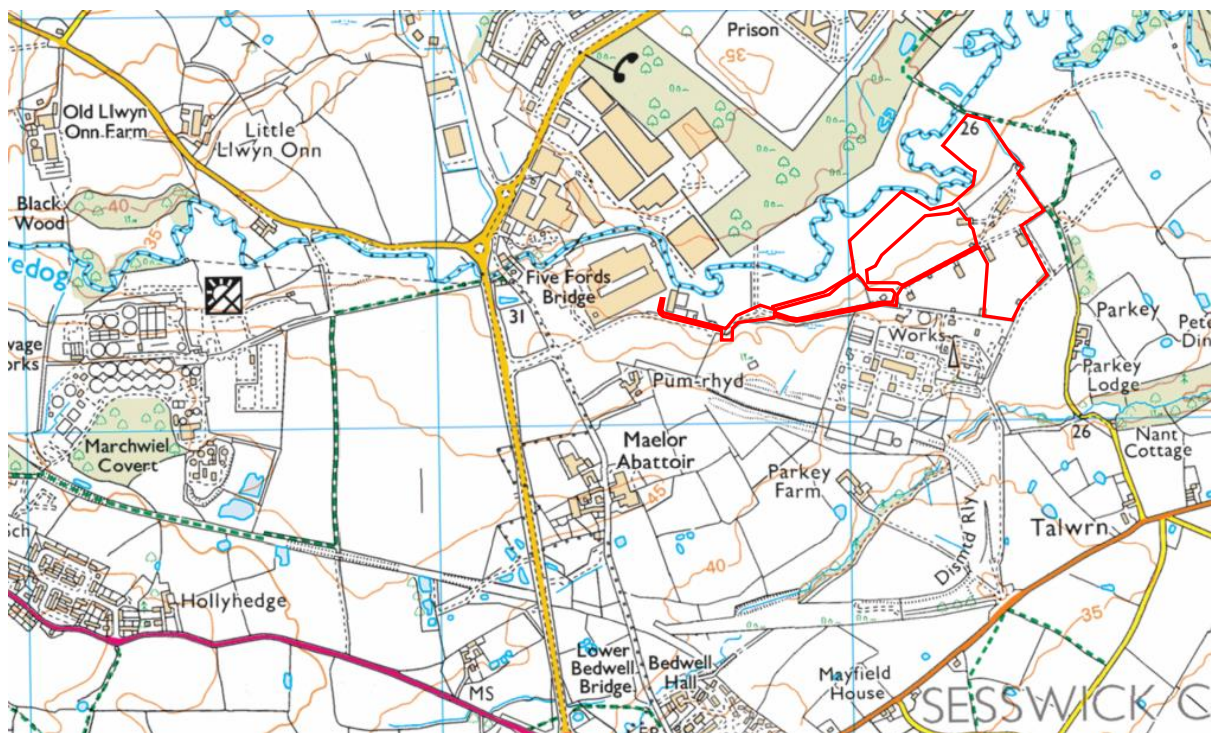


Table 2-1: Map Co-ordinates

Reference	Value
OS X (Eastings)	338371
OS Y (Northings)	348465
Nearest Post Code	LL13 0UN
Lat (WGS84)	N53:01:48 (53.029903)
Long (WGS84)	W2:55:13 (-2.920392)

Figure 2-2: Existing Site with proposed development outlined in red (excluding areas of existing solar arrays)



Figure 2-3: Field 1A

(a) North towards river



(b) South towards Field 1B



Figure 2-4: Field 1B

(a) East towards MoD building



(b) South towards Field 1C



Figure 2-5: Field 1C

(a) South-west towards existing solar farm



(b) North towards Battery facility



Figure 2-6: Field 2 – view to north from existing solar farm



2.2 DAM and NRW Flood Zones

The Development Advice Map (DAM) is shown in Figure 2-7 with the site boundary superimposed in red. This shows that two of the fields (Field 1B and 1C) are located in the Zone A and considered to be at little or no risk of fluvial flooding. However, Fields 1A and 2 lie almost entirely within Zone C2 (areas of floodplain without significant infrastructure) and B (areas known to have flooded in the past evidenced by sedimentary deposits). The implications for this are discussed in Section 2.3. Zone C2 broadly encompasses Flood Zones 2 and 3, with annual probability of flooding of greater than 0.1% and 1% respectively.

2.3 Flood Risk Vulnerability and the Justification Tests

The proposed development category for solar farms (as a power station) was **originally assumed** to be “Highly Vulnerable”. Section 9 of TAN15 states that “The flooding consequences associated with Emergency Services and highly vulnerable development are not considered to be acceptable...and that planning applications should not be proposed.” This position was confirmed in the NRW response received in October 2019 (Appendix B).

However, given the potential for renewable energy schemes to be reassigned to the category of “less vulnerable development”² and the favourable results from hydraulic modelling of the River Clywedog, this FCA has been progressed. **Support is provided for this position in the NRW comments on v1 of the FCA (Appendix C) in which NRW state that they would regard the proposed development as “Less Vulnerable”.** This would be consistent with the Inspector’s Report for a

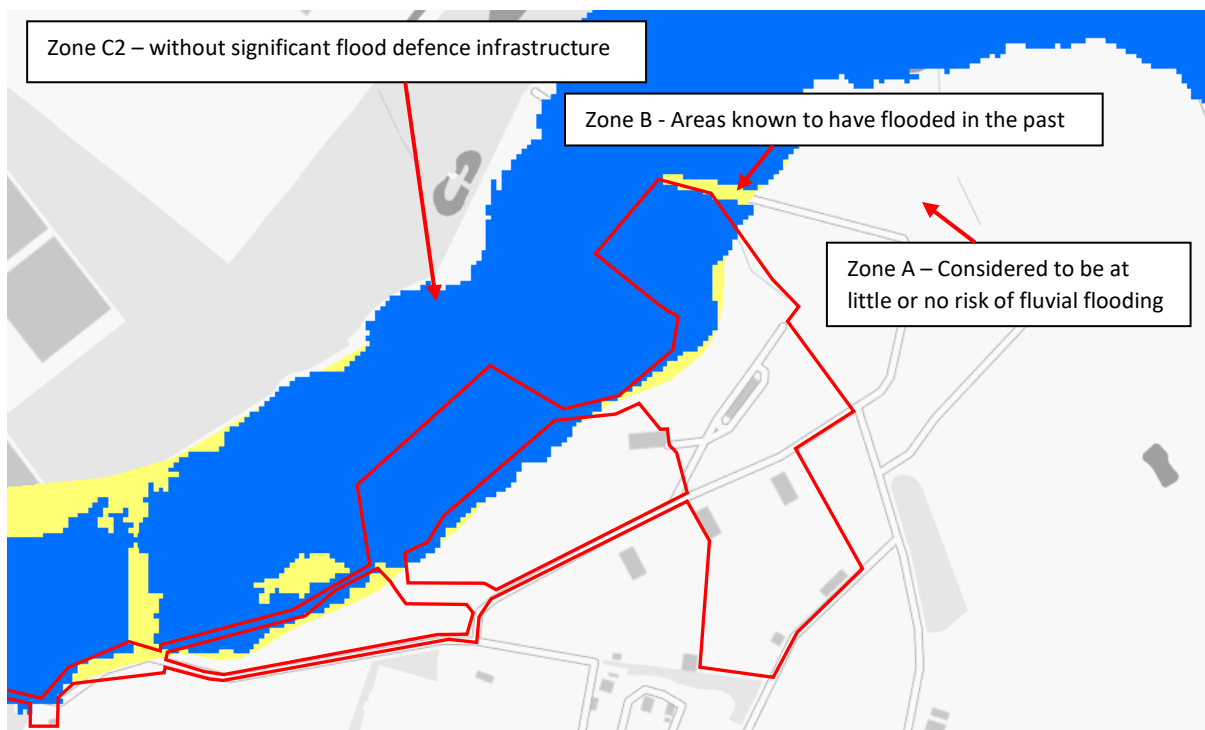
² Figure 2 in “Planning Policy Wales: Technical Advice Note 15 - Development, flooding and coastal erosion, October 2019, Consultation version

proposed solar development on the Caldicot Levels³ for which an extract is shown below and with the Decision Notice by the Welsh Government⁴:

123. The proposed development would be unmanned with no occupants. The panels are inert and would not be a safety risk if the site did flood. The development could be easily disconnected from the grid and would not involve the use of toxic or hazardous substances. In addition, solar farms have a proven record of safe operation in flood zone locations and are compatible with them. Given its characteristics, it is thus appropriate to classify the proposed development as a 'Less Vulnerable' or 'Other' form of development. This would be consistent with the 'Less Vulnerable' classification of development such as general industrial and utilities infrastructure.

TAN15 confirms that it is necessary to apply the Justification Test for Less Vulnerable Development in DAM C2. This is provided in Table 2-2 and Table 2-3 for Flood Zones 2 and 3 respectively. Technically, it is difficult to pass the test for this Site. However, there are many extenuating factors that lend weight to the proposed scheme.

Figure 2-7: Development Advice Map with approximate site boundary in red



https://maps.cyfoethnaturiolcymru.gov.uk/Html5Viewer/Index.html?configBase=https://maps.cyfoethnaturiolcymru.gov.uk/Geocortex/Essentials/REST/sites/Flood_Risk/viewers/Flood_Risk/virtualdirectory/Resources/Config/Default&layerTheme=2 (accessed on 27th April 2021)

³ Land on the Caldicot Levels to the south of the Llanwern Steelworks Site. DNS Application Ref: APP/G6935/A/16/3150137. by Siân Worden BA MCD DipLH MRTPI, an Inspector appointed by the Welsh Ministers Date: 11/10/2018

⁴ Welsh Government, Decision Notice: Ref qA1364896 by Lesley Griffiths, Cabinet Secretary for Energy, Planning and Rural Affairs, 8 November 2018.

Table 2-2: Justification Test – Flood Zone 2

1	It is located in an area benefitting from flood defence infrastructure; OR	No
2	It will assist, or be part of, a local authority initiative or strategy to sustain an existing settlement and is identified in an adopted Development Plan as a result of consideration through the SFCA;	<i>This question is more relevant to housing or employment/commercial developments. The adopted local plan has not identified sites for renewable energy and the emerging local plan directs solar farms of 5-50MW to local search areas. The development of a solar farm, with battery storage, will contribute towards the target of generating 70% of the Country's electricity consumption from renewable energy by 2030.</i>
3	AND It conforms with the placemaking policies of PPW and meets the definition of previously developed land;	<i>The site is not previously developed land but has been used for the grazing of sheep. This use can continue when the solar farm is operational. Furthermore, the site will be fully decommissioned when no longer in use and the land restored.</i> <i>PPW defines placemaking as ““Placemaking” is a holistic approach to the planning and design of development and spaces, focused on positive outcomes. It draws upon an area's potential to create high quality development and public spaces that promote people's prosperity, health, happiness, and well being in the widest sense” Although the proposed development does not include public spaces, it has been designed to retain and enhance existing landscape features and to provide ecological enhancements. Furthermore, there are wider public benefits, as previously discussed through the provision of renewable energy and contribution to a reduction in reliance upon fossil fuels.</i>
4	AND The potential consequences of a flooding event for the particular type of development have been considered, and found to be acceptable in accordance with the criteria contained in section 11.	<i>Through this Report</i>

Table 2-3: Justification Test – Flood Zone 3

a	The scheme is allocated (or part of an allocation) or identified in an adopted Development Plan, as a result of consideration through the SFCA, with evidence to justify why it is necessary to locate the development in zone 3;	<i>One of the key reasons for choosing the location of a solar farm is the proximity and availability of a viable connection point to the electricity network. In this instance, a viable connection point is available to the applicant.</i>
b	AND The potential consequences of a flooding event for the particular type of development have been considered, and found to be acceptable in terms of the criteria contained in section 11.	<i>Through this Report.</i>

After its confluence with the Redwither Brook (catchment area of 10.82 km²), the Clywedog is joined by the Bedwell Brook (catchment area of 5.55 km²). There is an NRW flow measurement station at Bowling Bank (catchment area of 103 km²) following which the Clywedog flows into the River Dee around 4 km downstream of Bangor on Dee.

Table 3-1: Catchment characteristics

	Location:	SJ 38700 48950
AREA	Catchment area (km2)	86.29
ALTBAR	Mean elevation (m)	186
ASPBAR	Mean aspect	93
ASPVAR	Variance of aspect	0.46
BFIHOST	Base flow index	0.524
BFIHOST19	Base flow index 2019	0.519
DPLBAR	Mean drainage path length (km)	14.61
DPSBAR	Mean drainage path slope	68.3
FARL	Index of lakes	0.988
FPEXT	Prop. of catchment in 1% FP	0.0624
FPDBAR	Mean flood depth (catchment)	0.533
FPLOC	Avg dist. of FP to outlet	0.844
LDP	Longest drainage path (km)	25.84
PROPWET	Proportion of time soil is wet	0.51
RMED-1H	Median 1 hour rainfall (mm)	10
RMED-1D	Median 1 day rainfall (mm)	34.7
RMED-2D	Median 2 day rainfall (mm)	43.4
SAAR	Average annual rainfall (mm)	879
SAAR4170	Ditto for 1941-1970 (mm)	886
SPRHOST	Percentage runoff	36.03
URBEXT1990	Urban extent 1990	0.0696
URBEXT2000	Urban extent 2000	0.0986

FEH Web Service

3.2 Source of Flood Risk

The flood risks are reviewed in summary form in Table 3-2. The principal source of flood risk to the low-lying parts of the Site is from **fluvial flood risk**. This is clear from the NRW draft maps for Flood Zones 2 and 3 in [Figure 2-7](#). The area has been subject to detailed flood risk modelling as described in a companion report. Flood extent and depth maps are presented in this Report.

The NRW maps suggest that small areas would be allocated to **Surface Water** Flood Zones 2 and 3 ([Figure 3-6](#)). However, site investigations confirm the occurrence of waterlogging in some flat areas, as noted in Section 3.3.

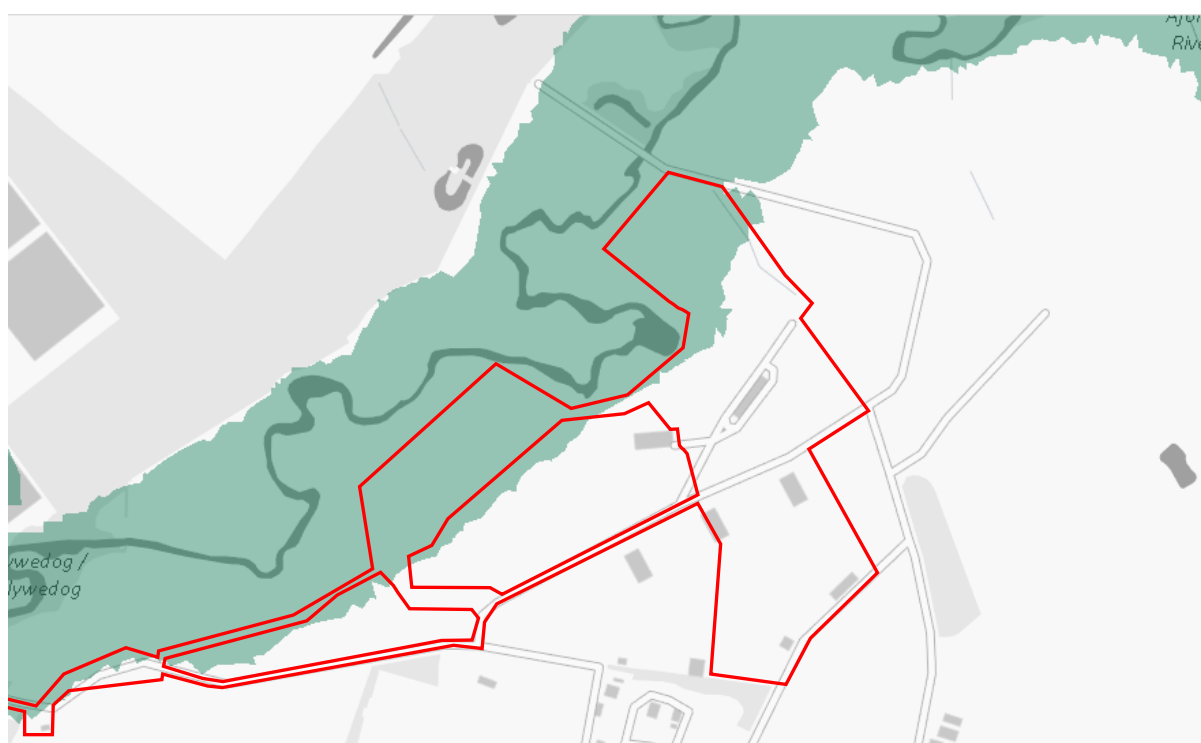
Parts of the Site are in the area that could be affected by reservoir failure. The practical risk to the Site is considered to be low because of the relatively small contribution of the reservoirs to flood risk – reflected in the FARL (flood attenuation due to reservoirs and lakes) parameter of 0.988 which is close to the limiting value of 1.0. In any case, the flood extents are similar to those shown as flood zones 2 and 3 – so the reservoirs do not pose any additional increase in risk.

Table 3-2: Sources of flood risk affecting the site

Key sources of flooding	Possibility at Site
Fluvial (Rivers)	Parts of the Site lie in Flood Zones 2 and 3 of the River Clywedog.
Tidal	N/a
Groundwater	None reported and unlikely given the elevated nature of the Site in relation to the valley of the Clywedog.
Sewers	None known to traverse the Site.
Surface water	Limited areas of surface water flooding on the Site from NRW mapping (Figure 3-6), though further comments are provided in Section 3.3
Infrastructure failure	NRW maps (Figure 3-2) suggest that low lying areas of the Site are in the reservoir flood risk zones

Based on NPPF Practice Guide

Figure 3-2: NRW Flood Risk from Reservoirs Map with approximate site boundary in red



https://maps.cyfoethnaturiolcymru.gov.uk/Html5Viewer/Index.html?configBase=https://maps.cyfoethnaturiolcymru.gov.uk/Geocortex/Essentials/REST/sites/Flood_Risk/viewers/Flood_Risk/virtualdirectory/Resources/Config/Default&layerTheme=0 (accessed on 28th April 2021)

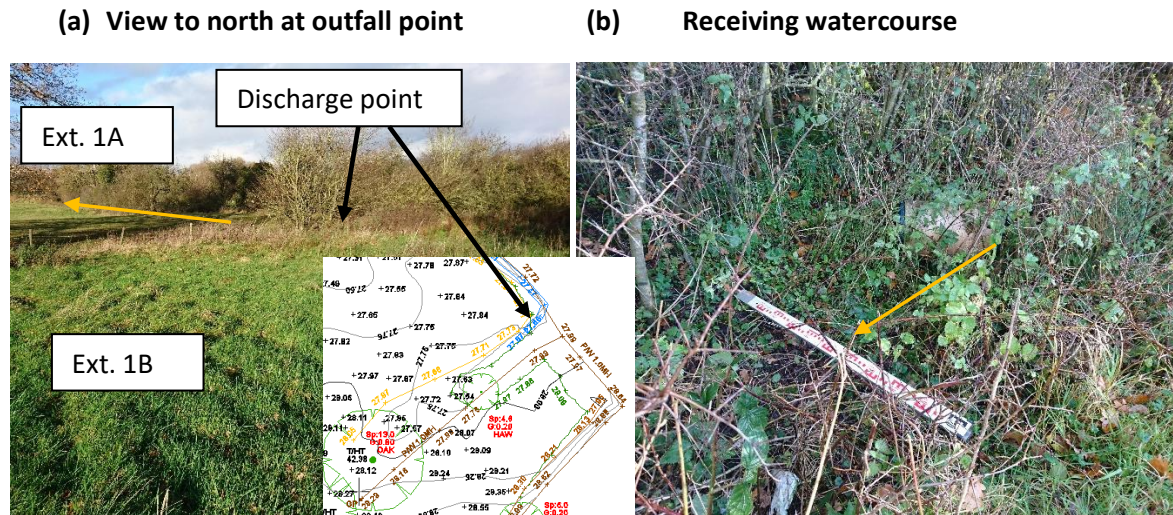
3.3 Existing Surface Water Drainage Arrangements

Site survey showed that, other than informal ditches, there are no watercourses on the Site. The only watercourse is on the north-east boundary of Field 1A. This is the receiving watercourse for the outlet from a proposed SuDS component and is shown in Figure 3-3.

The soil properties for the Site are illustrated in Figure 3-4 from the NSRI Soilscape web site. This shows that the soils over the entire Site are described as having “Impeded drainage”. Site

investigations were undertaken specifically for this application. This entailed the start of an infiltration test in Field 1C, to inform of the sizing of possible infiltration systems. However, the test was aborted following a fall in water level of only 5 mm over 3 hours on the first fill. The clay fraction is clear in the arisings and from the very smooth cut faces within the trial pit. Areas of waterlogging were noted on some relatively flat portions of Field 1C. These are discussed in the companion SWMP Report.

Figure 3-3: Proposed SuDS component – outfall to existing watercourse



Inset is from topographic survey and shows riparian watercourse in blue

Figure 3-4: Soil Properties (NSRI Soilscape Website)

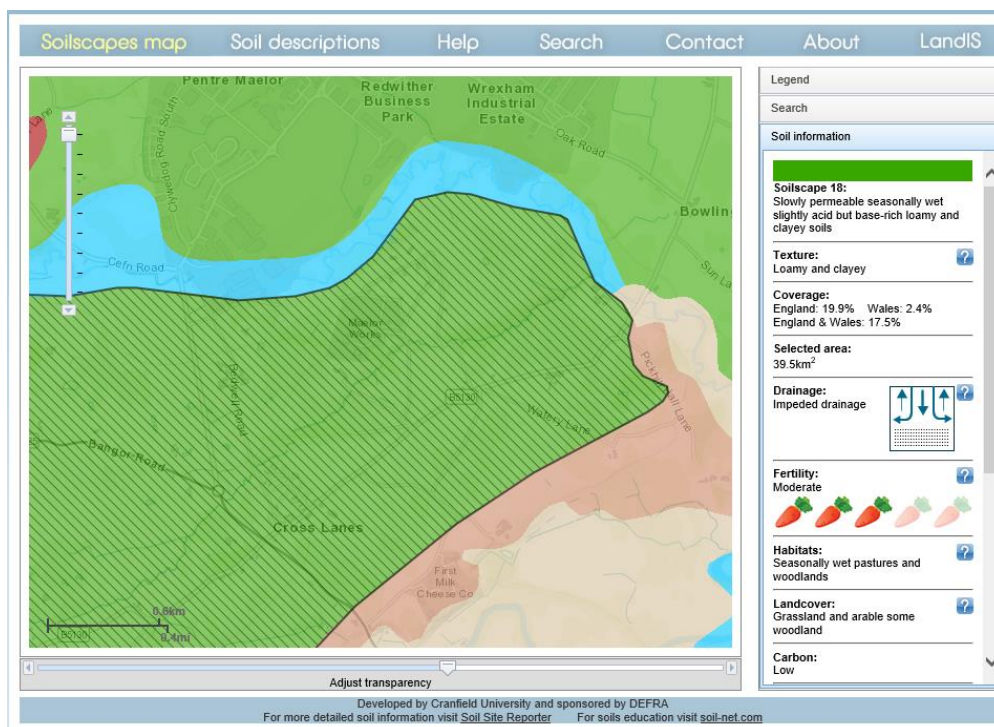
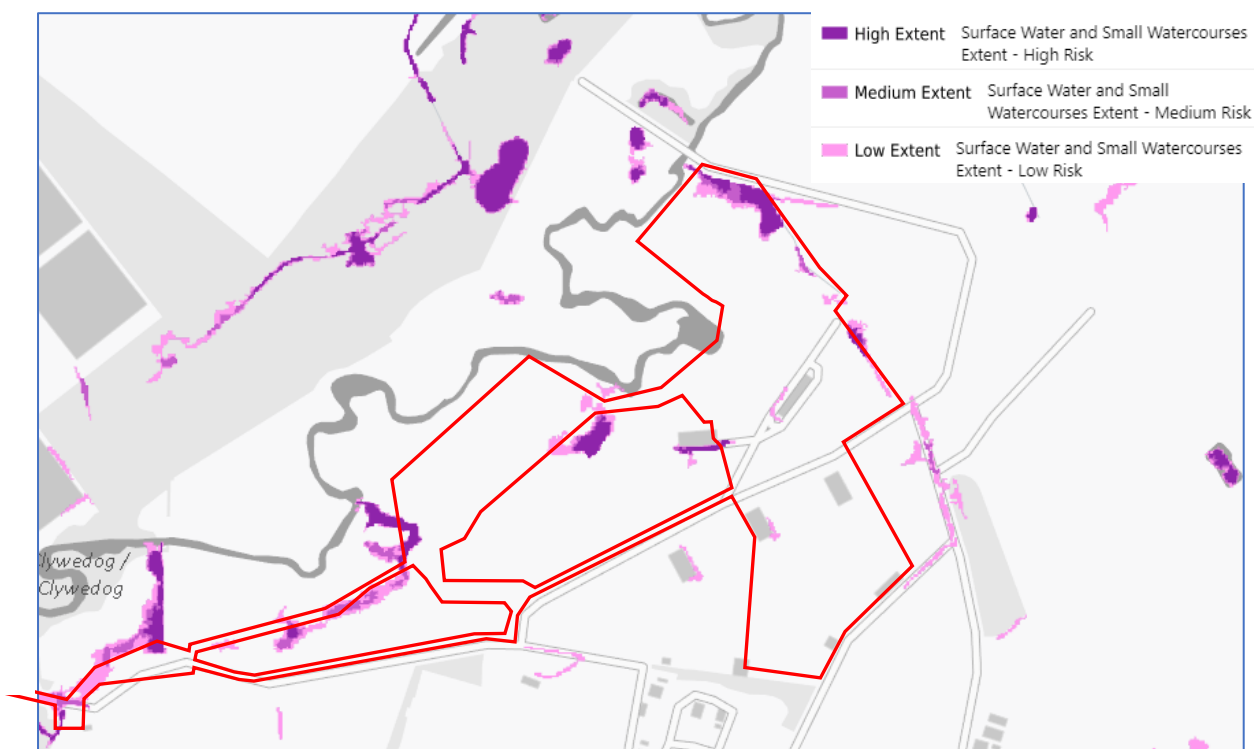


Figure 3-5: Trial Pit in Field 1C – terminated due to low observed rates of infiltration



Figure 3-6: NRW Surface Water Flood Map with approximate site boundary in red



https://maps.cyfoethnaturiolcymru.gov.uk/Html5Viewer/Index.html?configBase=https://maps.cyfoethnaturiolcymru.gov.uk/Geocortex/Essentials/REST/sites/Flood_Risk/viewers/Flood_Risk/virtualdirectory/Resources/Config/Default&layerTheme=3; (accessed on 27th April 2021)

3.4 Probability of Site Flooding

The probability of site flooding has been investigated through the development of a hydraulic model of the River Clywedog. The model was built to support a range of potential applications in the general area and has been described in a companion Flood Modelling Report. **The Model has been reviewed twice by NRW officials, who have provided comments in August 2020 and March 2021. Even though the model, as most recently reviewed by NRW officials was deemed suitable for use in this FCA, the model has been further refined. The refinements are described in Appendix C and deal with the corrections of inappropriate features in the model as reviewed. These have no practical impact on the flood extents but are clearly important for the accurate and robust representation in the model.**

All model results presented in this Report are using the corrected version (April 2021) of the model.

Since the model has already been accepted by NRW and also since the recent refinements have had no practical impact on the FCA, we have not revised the flood modelling report, previously submitted in February 2021. The model is also being used for a flood map challenge for an adjacent Site. It is the intention to revise the flood modelling report when the relevant FCA is submitted to NRW.

In this Section, the results of **baseline modelling** have been presented for AEP of 1% and 0.1% (1 in 100 and 1 in 1,000 annual probabilities). These are shown as flood extents in **Figure 3-7** and **Figure 3-8** respectively.

The main findings are as follows for the 1% AEP:

- Flood extents are broadly similar to those of NRW within the Site. However, there are substantial differences downstream of the Site that likely reflect the more detailed modelling undertaken by Corylus compared to the generalised modelling upon which the NRW flood maps have been based.
- Flood depths are in a range of 0 to 0.25 m for the majority of the flooded areas in Fields 1A and 2. There is a small area with depths up to around 0.75 m at the north-east area of Field 1A due to a topographic depression (Figure 3-9). However, within the area of panels, shown by the dashed lines, the maximum depth is around 0.5 m.

The main findings are as follows for the 0.1% AEP:

- As with the 1% flood, flood extents are broadly similar to those of NRW within the Site (Figure 3-10). However, the differences downstream of the Site are less noteworthy with flooding on the left bank downstream of the crossing point.
- Flood depths are greater than for the 1% AEP flood, with most of the flooded area being in a depth range of 0.25 to 0.5 m with maximum depths of just over 1 m. However, within the area of panels, shown by the dashed lines, the maximum depth is around 0.75 m.

Figure 3-7: Flood depth for 1% AEP

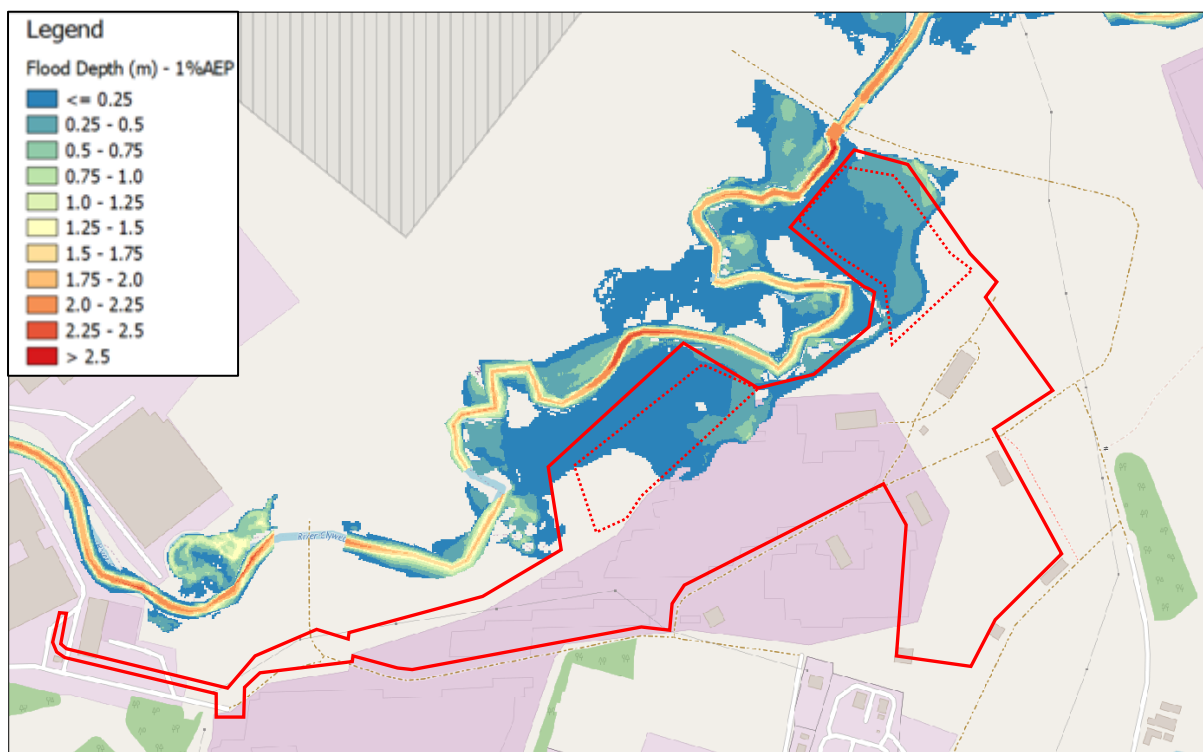


Figure 3-8: Flood depth for 0.1% AEP

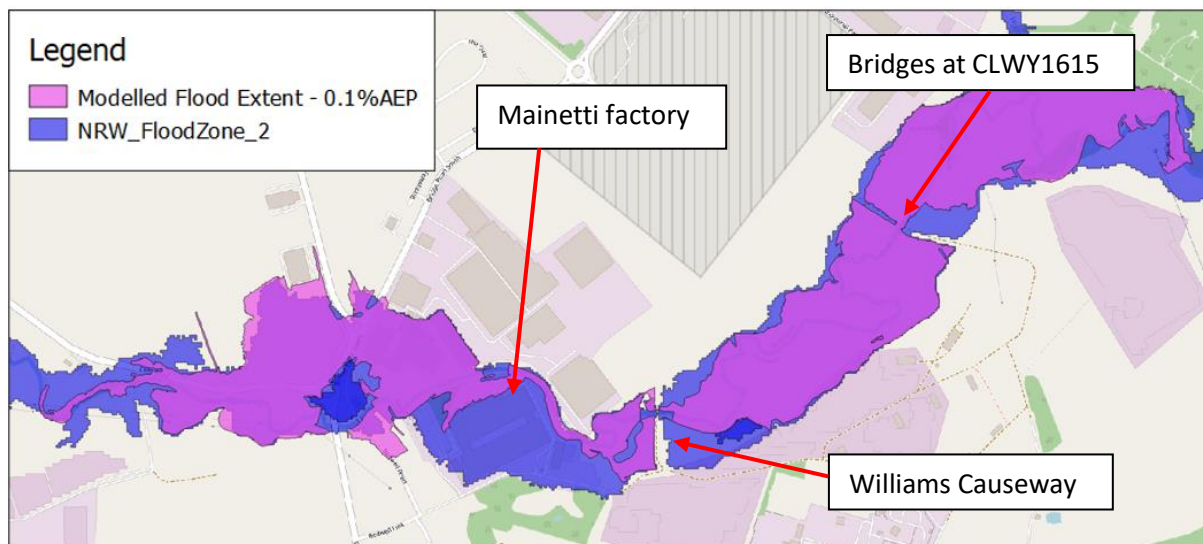


Red arrow shows direction of image in Figure 3-9

Figure 3-9: Low topography on north-east margin of Field 1A (view to north)



Figure 3-10: Comparison of NRW and model extents (0.1% AEP)



A general inference from the flood extents shown in Figure 3-10 is that the Site is protected by two hydraulic constrictions in the River Clywedog, namely those at the Mainetti factory and the Williams causeway. Conceptually, these constrictions lead to elevated flood levels and flood storage on the respective upstream faces. This in turn provides an opportunity for some attenuation which will provide protection to the Site from flooding. The hydraulics associated with these locations have been fully represented in the baseline model. Immediately downstream of the Site at CLYW1615, the River is constricted by an embankment with former railway bridge and a footbridge (Figure 3-11). These have been represented in the hydraulic model. The open nature of both bridge openings does not suggest that they will be prone to blockage. **However, blockage analysis has been undertaken with the model and is described in Section 4.3.2.**

Figure 3-11: Bridge structures at downstream end of Site (CLYW1615)



4 Flood Risk Evaluation for the Proposed Development

4.1 The Development Proposals

The components of the development are shown in Figure 4-1 and comprise the following:

- Installation of solar panels
- Gravel tracks to provide internal access and around the batteries, transformers and ancillary stores;
- Impermeable surfaces comprising the rooves and concrete pads for the batteries, transformers and ancillary stores;
- Open fencing around site perimeter; and
- Soil mound for storage of top soil removed for creation of roads and other infrastructure.

The only components of the development that are in the modelled flood zones are some of the solar arrays plus internal access tracks. The facility will be protected by an open style fence for security reasons.

There will be no ground raising within the flood zones. There will be storage of stripped top soil within the site for later restoration. However, the soil mound will be located on an elevated part of the Site in Field 1C as shown in Figure 4-1.

4.2 Flood Risk Management Measures to Protect the Site

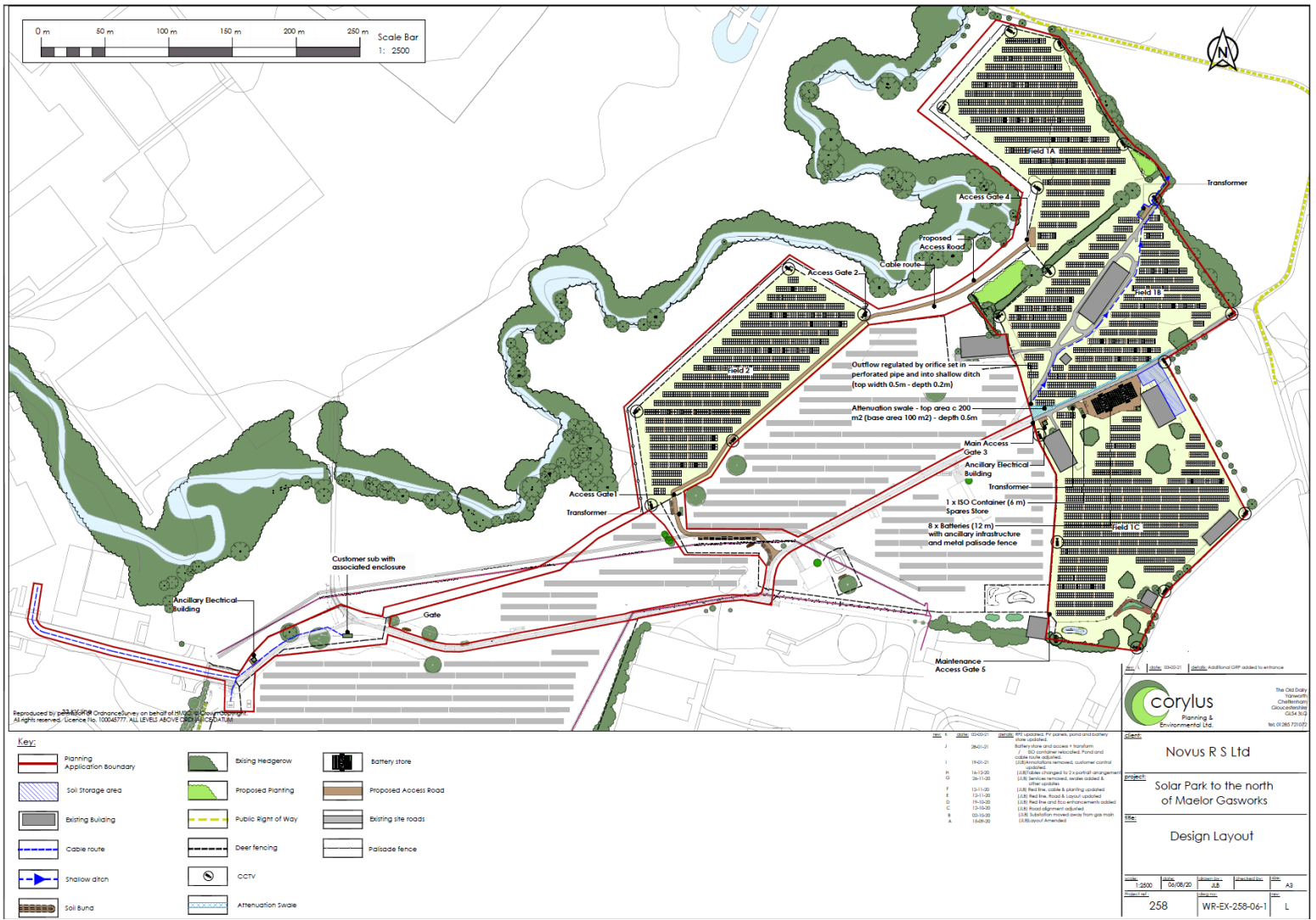
Solar farms can be safely installed and operated in areas subject to flooding provided basic principles are followed. These include:

- Mounting solar arrays so that they are above design flood levels as described in Section 4.3.2.
- The only electrical infrastructure to be located in flood areas will be the solar arrays and associated cables. All other infrastructure (batteries, transformers and storage containers) will be located in flood zone 1.

Corylus has advised on solar farms that have been constructed in fluvial flood zones and has not encountered any issues on these sites.

The Site will not be occupied, other than for routine or emergency maintenance visits. There is, accordingly, no requirement for a Flood Emergency Plan (FEP). Since all electrical infrastructure and access routes are to be located outside the flood zones, there is no need for any access to flood areas during a flood event. RAMS should include a reference to the risk of flooding being encountered and advising against any entry into areas affected by flooding.

Figure 4-1: The Proposed Development (WREX/258/06/1 L, dated February 2021)



4.3 Off-Site Impacts and Mitigation

The principal off-site impacts relate to:

- Potential for increased runoff due to the new infrastructure
- Potential for increased flood levels due to the installation of solar arrays within the flood zones.

4.3.1 Increased runoff

It is a fundamental principle of development that there should be no impact on third parties due to increased runoff from a development. This issue has been addressed through preparation of a companion Report as a Surface Water Management Plan. The main findings of the Report are as follows:

- i. The only features of the development that require mitigation are the new impermeable surfaces that total around 400 m².
- ii. Since the soils have very low infiltration rates, the only viable way to mitigate the increases in runoff is through an attenuation device.
- iii. An attenuation swale/basin has been sized that is able to attenuate runoff from the new impermeable surfaces to the greenfield rate of runoff for AEP of 50%, 3.33% and 1% (1 in 2, 1 in 30 and 1 in 100) with allowance for climate change.
- iv. This is to be achieved using an orifice set in a perforated pipe to minimise the effects of blockage
- v. Attenuated flow is conveyed to a riparian watercourse on the north-east boundary of the Site and thence to the River Clywedog.

It is thus concluded that the proposed scheme will have no adverse impact on third parties in relation to increased runoff.

4.3.2 Impact on flood levels

The interventions within the flood plain due to the development are the vertical piles of the frame on which the arrays are mounted and the perimeter fence. Although these are relatively small interventions, there is a theoretical impact due to the combined effects of a loss of flood plain storage and interruption of the “baseline” flow paths.

Given the availability of a hydraulic model for the Site, these effects can be investigated using the model. However, given their small and distributed nature, they cannot be modelled explicitly. Instead, it is necessary to approximate their impact through changing some of the model parameters.

We have chosen to do this using the same method as Footprint (2018) in their similar investigation for a proposed solar farm in New South Wales. They chose to adjust the Manning’s roughness coefficient for cells in the 2D model where solar arrays were to be located. This is a sensible, practical approach and their approach is summarised in Table 4-1. In their analysis the overall roughness is increased from 0.025 to 0.028.

Table 4-1: Modified Cowan Method for Estimation of Floodplain Roughness (Table 5 from Footprint (2018))

Roughness Component	Existing (Grazed Pasture)	Proposed (Solar Array)
Floodplain Material (nb)	0.020	0.020
Degree of Irregularity (n ¹)	0.001	0.001
Variation in Floodplain Cross Section (n ²)	N/A	N/A
Effect of Obstructions (n ³)	0.000	0.0031
Amount of Vegetation (n ⁴)	0.004	0.004
Total (n)	0.025	0.028

Note 1 Based on an obstruction of 2.5% of the available flow area (i.e. 150 mm piers at 6m intervals)

We have chosen a simpler approach of selecting a conservatively high value of roughness as a way of exploring a limiting case. The fields with solar arrays (Figure 4-1) were represented in the model by increasing the **roughness value from a default of 0.04 to 0.06** to account for the impact of the steel support structures on flow. Fencing of the site has not been modelled, as it is expected to have minor impact on overall water levels. This is a far more stringent assumption than for the referenced case study by Footprint (2018).

The results of the development run are shown in:

- **Figure 4-2** for the 1% AEP
- **Figure 4-3** for the 1%CC20 (20% climate change) AEP and
- **Figure 4-4** for the 0.1% AEP.

These are “difference” maps where the baseline flood levels have been subtracted from the post development levels. Increases are shown by red/brown shades and decreases by green shades. Most of the model domain is shaded yellow denoting level changes within +/- 0.005 m (5 mm); this is well within any model tolerance and confirms no practical impact in these areas.

For the 1%CC20 AEP, there are increases of up to 0.03 m in Field 2 and 0.08 m in Field 1A and within the floodplain. For the 0.1% AEP, these increases are 0.04 and 0.09 m respectively. The increases are confined to the right (south) bank with no increases on the left (north) bank.

For completeness, the impact of the development on river nodes has been investigated for nodes shown in Figure 4-5. The relevant flood levels and increases are shown in Table 4-4 and show that for most nodes, the increase is of the order of a few mm. The maximum increase is 8 mm which occurs on the western edge of Field 1A and will have a very minor impact on design flood levels on the opposite (northern) bank. Although this should strictly require some mitigation, this is a very small projected increase that is close to the model tolerance. Furthermore, it results from a “conservative” scenario, where the roughness was increased from 0.04 to 0.06, a profound increase.

Figure 4-2: Change in flood levels due to development (1% AEP)

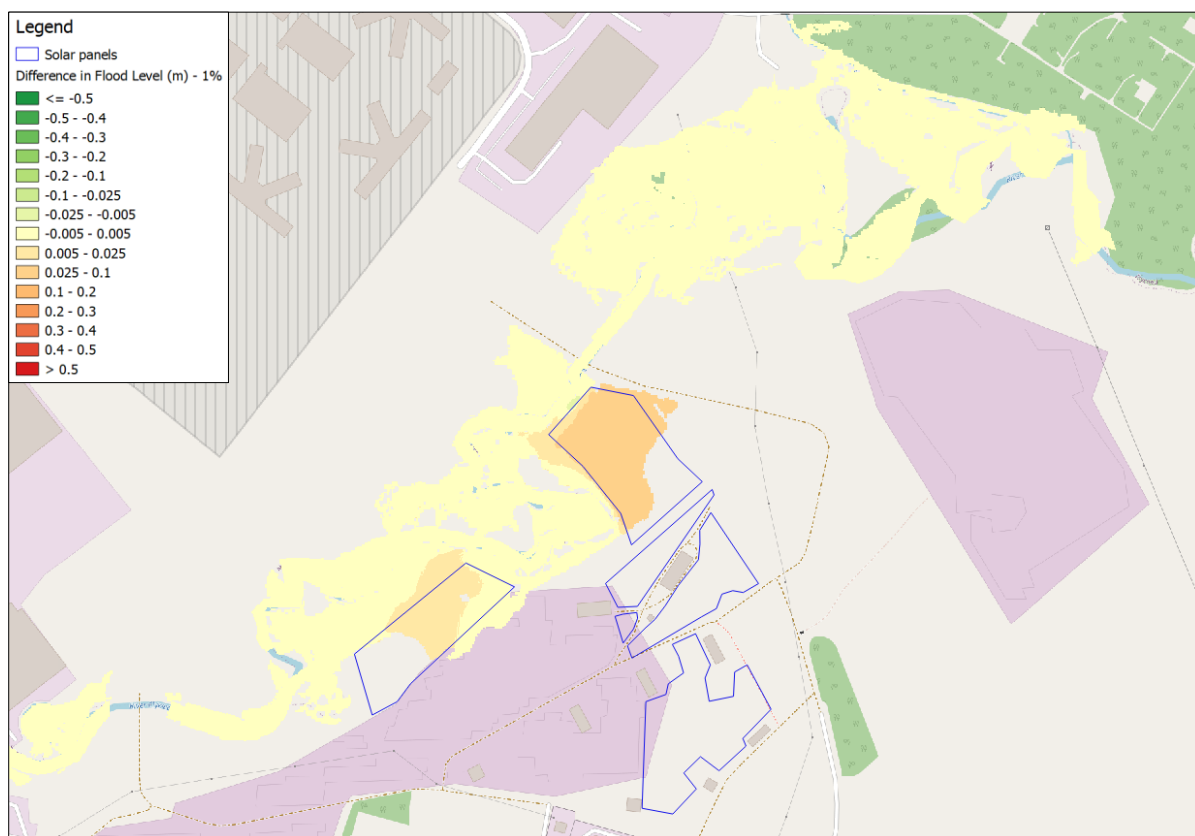


Figure 4-3: Change in flood levels due to development (1%CC20 AEP)

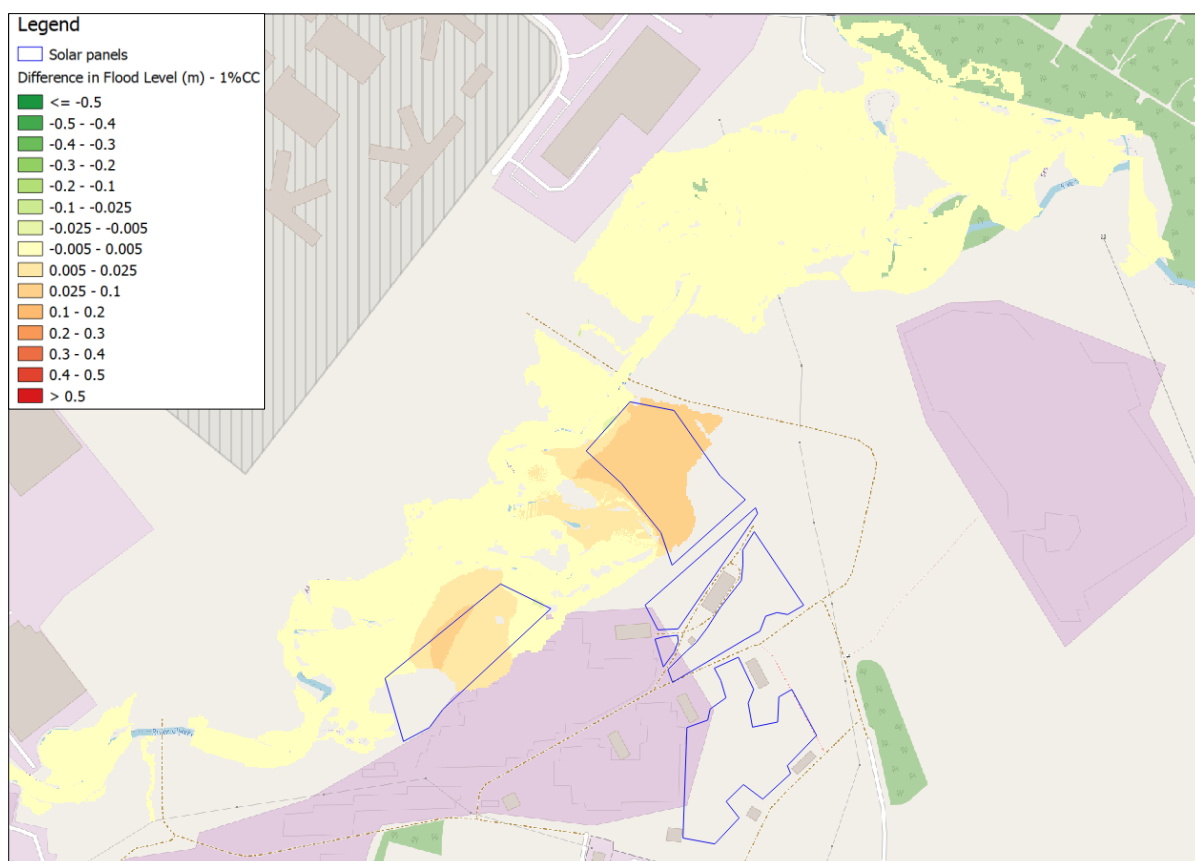


Figure 4-4: Change in flood levels due to development (0.1% AEP)

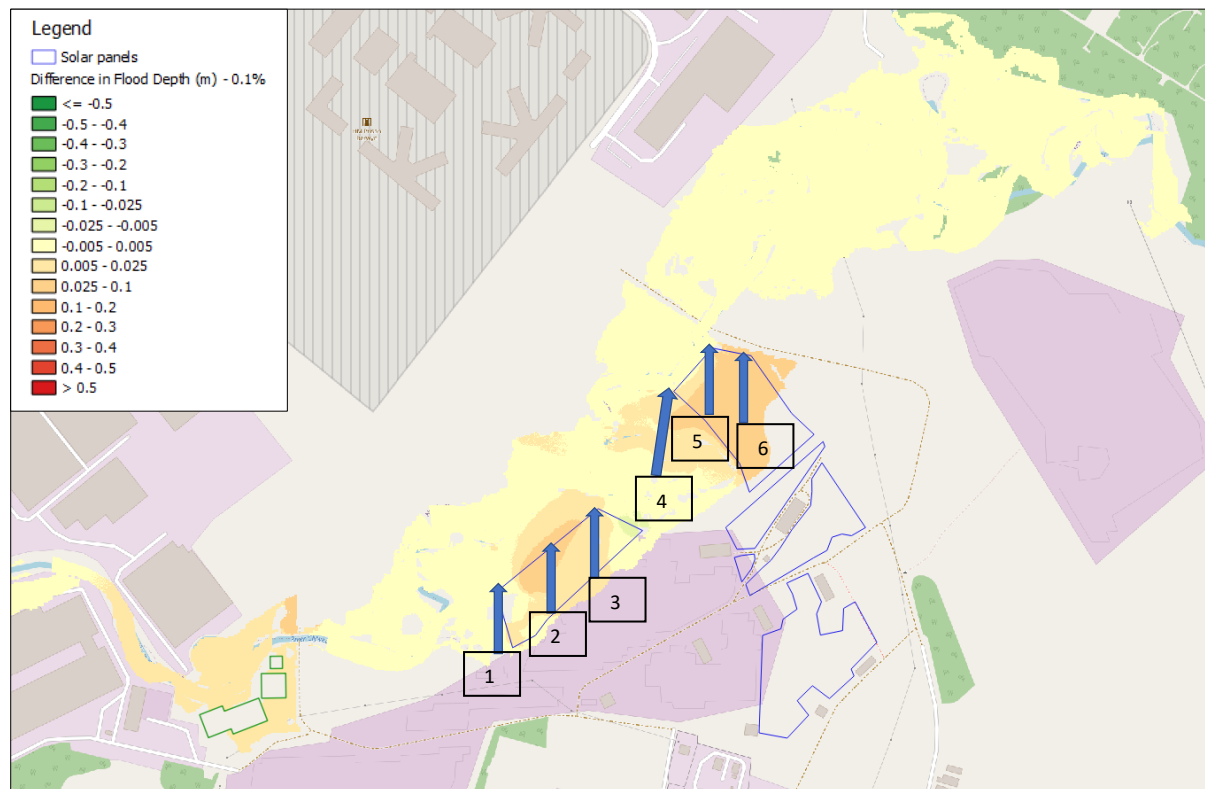


Table 4-2: Modelled flood levels (1% AEP)

Node	Baseline (mAOD)	Post development (mAOD)	Difference (Post dev – baseline) (m)
1	26.26	26.26	0.00
2	25.63	25.65	0.02
3	25.58	25.58	0.00
4	24.48	24.49	0.01
5	24.39	24.39	0.00
6	24.61	24.64	0.03

Table 4-3: Modelled flood levels (0.1% AEP)

Node	Baseline (mAOD)	Post development (mAOD)	Difference (Post dev – baseline) (m)
1	26.33	26.33	0.00
2	25.82	25.86	0.04
3	25.74	25.75	0.01
4	24.69	24.70	0.01
5	24.62	24.62	0.00
6	24.78	24.81	0.03

Figure 4-5: Location of the “river” model nodes.

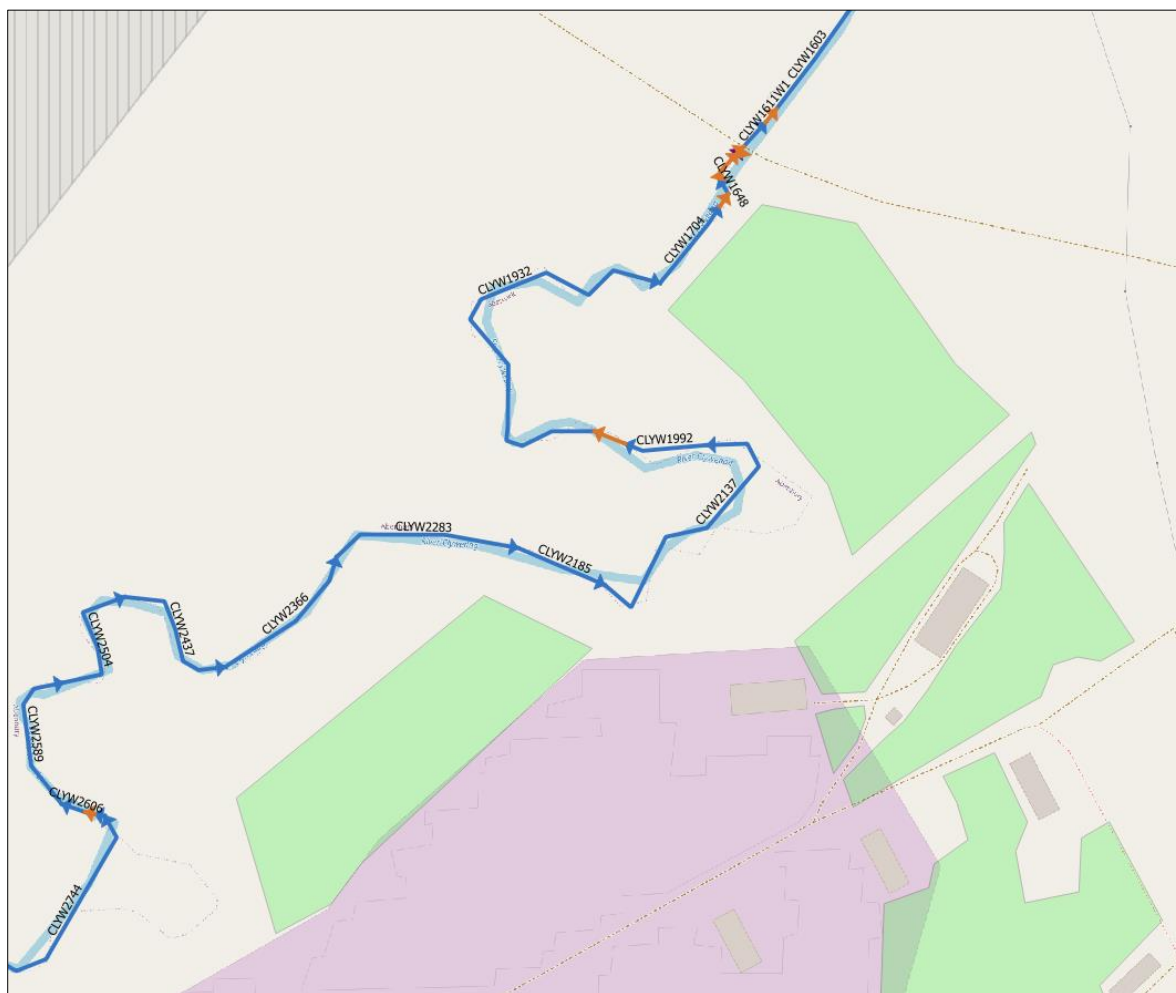


Table 4-4: Modelled channel flood levels (1% CCAEP)

Node Label	Baseline (mAOD)	Post development (mAOD)	Difference (Post dev – baseline) (m)
CLYW2366	25.948	25.948	0.000
CLYW2283	25.842	25.843	0.001
CLYW2185	25.634	25.637	0.003
CLYW2137	25.511	25.511	0.000
CLYW1992	24.946	24.954	0.008
CLYW1932	24.748	24.755	0.007
CLYW1704	24.372	24.373	0.001
CLYW1648	24.339	24.339	0.000
CLYW1634W	24.315	24.315	0.000

In summary, it has been shown through the modelling that the impacts of the development on flood levels can be safely managed. An ultra-conservative model run has shown that the maximum increase in flood levels due to the development would be 0.08 m and occurs within the Site (for the 1%CC20 case). Small increases are noted for river channel nodes of a few mm and locally up to 8 mm. However, given the small magnitude and conservative nature of the post-development run, no mitigation measures are suggested for this development.

The design flood extents are shown in Figure 4-6; these are for the post-development 1% annual probability with climate change. Since there is a requirement that design levels should reflect blockage, this model run also reflects the blockage of the bridge structures immediately downstream of the Site (Figure 3-11). The NRW (2020) Guidance is shown in Table 2 of GN43 and reproduced below. The blockage risk is assessed as “Medium” in view the numerous structures in the River Clywedog and the limited source of material that may lead to blockage immediately upstream of the Site. The design runs have therefore included a 25% blockage.

Table 2 – Standard blockage proportions

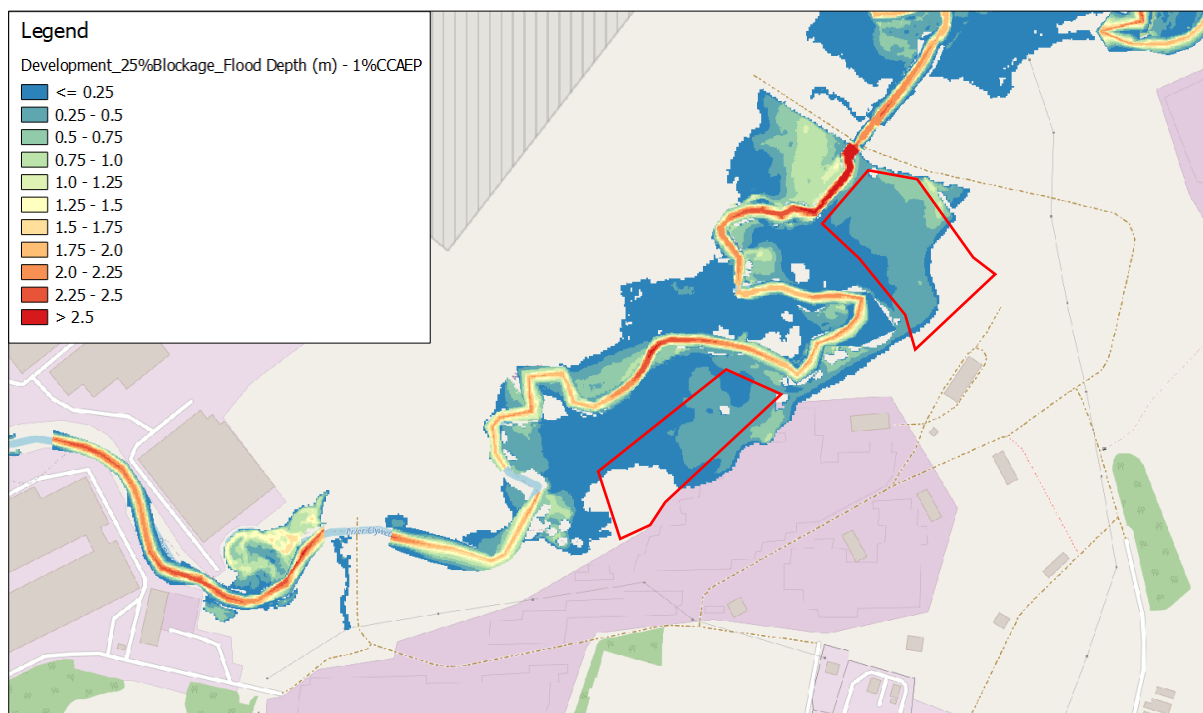
Blockage Scenario	Culvert blockage proportion	Bridge blockage proportion
Low	30%	5%
Medium	67%	25%
High	100% ¹	80%

The areas of panels for Fields 1A and 2 have been superimposed on the flood extents enabling an estimate of the range of flood depths under the panels. This shows that the maximum depth under the panels is 0.6 m. The minimum height of all panels across the Site has been set accordingly, namely at 0.9 m at their front end.

The panels would also be above the 0.1% levels across the Site.

Figure 4-6: Post-development flood depths (1%CC with blockage)

(a) General



(b) Alternative legend

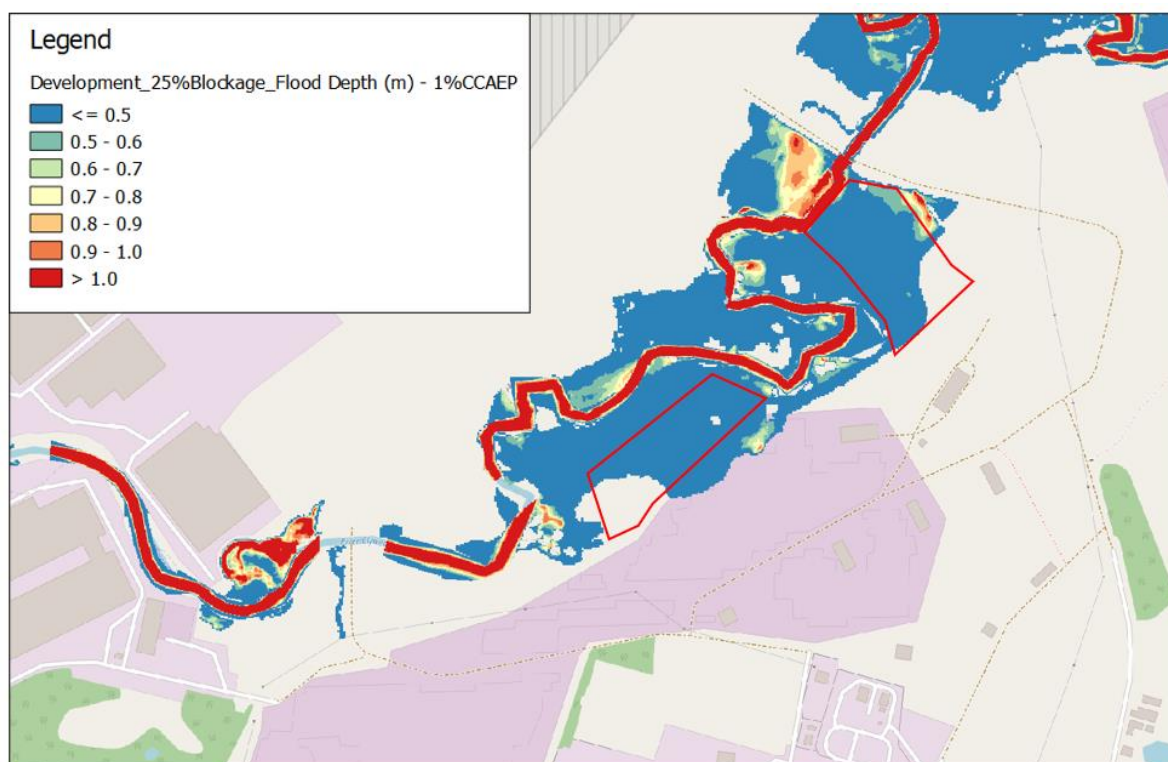


Table 4-5: Modelled flood levels (1% CC with blockage)

Node	Baseline (mAOD)	Post development (mAOD)	Post development Blockage (mAOD)	Difference (Post dev – baseline) (m)
1	26.27	26.27	26.27	0.00
2	25.71	25.74	25.74	0.03
3	25.65	25.66	25.66	0.01
4	24.54	24.55	24.63	0.01
5	24.41	24.42	24.57	0.01
6	24.68	24.71	24.72	0.03

4.4 Residual Risks

The residual risks arise from failure to undertake the required maintenance and from storms in excess of those for which the scheme has been designed.

The maintenance requirements for the SuDS components have been addressed in the companion SWMP Report. The components are mostly adjacent to internal roads which will facilitate access for maintenance. Furthermore, all solar sites are subject to a strict monthly maintenance schedule for operational reasons. The SuDS maintenance requirements can thus be included within this broader operational maintenance schedule.

There are no “fluvial” components that need to be maintained. However, given the location of fences within the flood plain, there is a risk that debris may become attached to the fences resulting in a small blockage. The impacts of such a blockage would be small but nevertheless, the inspection and clearance of debris will be added to the routine maintenance schedule.

Should floods in excess of the design flood occur, there would be negligible impacts on the Site and no impact on third parties.

4.5 Climate Change Impacts

Climate change assumptions have been incorporated into the SWMP and flood modelling for the Site. The 1% AEP flows have been increased by 20% in line with guidelines shown in Table 4-6. Rainfall has been increased by 20% to account for projected increase in rainfall over the design life of the scheme.

Table 4-6: Peak river flow allowances by river basin district (use 1961 to 1990 baseline)

	Total potential change anticipated by the 2020s	Total potential change anticipated by the 2050s	Total potential change anticipated by the 2080s
Severn			
Upper end estimate	25%	40%	70%
Change factor /central estimate	10%	20%	25%
Lower end estimate	0%	5%	5%
West Wales			
Upper end estimate	25%	40%	75%
Change factor /central estimate	15%	25%	30%
Lower end estimate	5%	10%	15%
Dee			
Upper end estimate	20%	30%	45%
Change factor /central estimate	10%	15%	20%
Lower end estimate	5%	5%	5%

Source: Welsh Government - <http://gov.wales/docs/desh/publications/160831guidance-for-flood-consequence-assessments-climate-change-allowances-en.pdf>

5 Summary and Conclusions

This Report is an FCA for the proposed Solar Farm north of the Maelor gas works . This Report should be read in conjunction with companion Reports that deal with Flood Modelling and the Surface Water management.

The main findings are as follows:

- i. The Site is located on land that in all three flood zones (1, 2 and 3) based on NRW draft flood zone maps. The appropriateness of these extents has been confirmed through baseline hydraulic modelling.
- ii. The proposed development is currently classed as “Highly Vulnerable” and would not be permitted in Flood Zones 2 and 3. However, it is possible that renewable energy schemes will be classed as “Less Vulnerable” following consultation that is currently underway. This may enable development subject to the application of the “Justification Test”.
- iii. Although the strict requirements of the Justification Test cannot currently be met, the minimal impacts of the development on flood risk and wider environmental benefits to the community from such a scheme make it worthy of special consideration.
- iv. The proposed solar development can be undertaken safely in flood risk areas without special mitigation. Key principles have been applied in its design – namely locating all electrical infrastructure outside flood zones other than cabling and panels.
- v. The base of the majority of panels will be 0.8 m above ground level, thereby providing a minimum clearance of 0.3 m above the post-development reference flood level (1% AEP with allowance for climate change and blockage). However, on the eastern edge of Field 1A, the front edge of some of the panels will need to be raised to either 0.9 m or 1.0 m in line with the modelled flood depths. This affects a relatively small number of the panels.
- vi. Since the Site will only be visited intermittently for maintenance and operational purposes, there is no need for any Flood Emergency Plan.
- vii. A companion Surface Water Management Report has shown that the increases in runoff due to the new impermeable surfaces created by the development can be mitigated a SuDS scheme. This will comprise an attenuation swale/basin, regulated by an orifice and outfalling to an internal ditch that, in turn will outfall to a riparian watercourse.
- viii. Hydraulic modelling has confirmed that the maximum flood depths under baseline conditions will be around 0.75 m for the 0.1% AEP. Post-development model runs using an ultra-conservative hydraulic roughness assumption have confirmed that the maximum increase in flood level due to the panels would be 0.09 m for the 0.1% AEP and occurs within a small part of the Site.
- ix. The model runs showed that there were no significant increases outside the red line boundary. There were localised increases of up to 8 mm for the 1% AEP with allowance for climate change. However, these are close to the model tolerance, are very localised and result from a very conservative model assumption for roughness. In summary, the development has no practical impact on third parties and no mitigation is required.
- x. Residual risks include those due to insufficient maintenance or due to conditions outside the design assumptions. Maintenance of the proposed SuDS component is straightforward and can be undertaken as part of routine monthly inspections, required anyway for the electrical infrastructure. The Site is considered robust in its ability to deal with conditions beyond the design assumptions.

- xi. Climate change assumptions have been incorporated into the SWMP and the hydraulic flood modelling.

In summary, it is considered that the proposed scheme plus associated mitigation will have no practical impact on flood risk.

6 References

Author	Date	Title/Description
Centre for Ecology and Hydrology.	2018	The Flood Estimation Handbook Web Service. Available from: https://fehweb.ceh.ac.uk/
CIRIA	2015	C753, The SuDS Manual.
Footprint	2018	Proposed Solar Farm, Wellington, New South Wales. Hydrological and Hydraulic Analysis. Project No. 1724, Date: 28 February 2018.
Institute of Hydrology	1999	The Flood Estimation Handbook and subsequent guidance.
Marshall D.C.W. & Bayliss A.C	1994	Flood estimation for small catchments, IH Report No. 124, Institute of Hydrology, Wallingford and Hall, Hockin & Ellis
Natural Resources Wales	2020	Flood Risk Management: Modelling blockage and breach scenarios. Guidance Note GN43 v3.0 09-2020.
Welsh Assembly Government	2004	Technical Advice Note for development and flood risk (TAN15).
WHS	2016a	WINFAP-FEH v4. Technical Guidance.
WHS	2016b	Revitalised Flood Hydrograph Model ReFH2: Technical Guidance.

Appendix A Site Specific Flood Consequence Assessment Checklists

Table A-1: Conditions of Acceptability Criteria (Section A1.12 of TAN15)

No	Condition	Response
1	Flood defences must be shown by the developer to be structurally adequate particularly under extreme overtopping conditions (i.e. that flood with a probability of occurrence of 0.1%)	<i>No flood defences present.</i>
2	The cost of future maintenance for all new/approved flood mitigation measures, including defences must be accepted by the developer and agreed with the Natural Resources Wales	<i>N/a</i>
3	The developer must ensure that future occupiers of development are aware of the flooding risks and consequences	<i>This will be through any site maintenance schedules that will include SuDS components.</i>
4	Effective flood warnings are provided at the site	<i>The site will not be occupied. RAMS for any maintenance work will reference flood risks.</i>
5	Escape/evacuation routes are shown by the developer to be operational under all conditions	<i>No escape/evacuation needed; in any case, escape is clearly to higher ground from any flooded areas.</i>
6	Flood emergency plans and procedures produced by the developer must be in place	<i>None needed, save through the relevant RAMS.</i>
7	The development is designed by the developer to allow the occupier the facility for rapid movement of goods/ possessions to areas away from the floodwaters	<i>N/a</i>
8	Development is designed to minimise structural damage during a flooding event and is flood proofed to enable it to be returned to its prime use quickly in the aftermath of the flood	<i>All electrical infrastructure, other than cables and panels are located outside areas at risk of flooding. Solar panels will be set above flood levels (1% AEP plus climate change plus blockage) with cable connections able to withstand inundation.</i>
9	No flooding elsewhere	<i>Demonstrated through hydraulic modelling (Section 4.3.2) that there are no practical impacts on third party land.</i>

Table A-2: Technical Requirements Checklist (Section 12/Fig 7 of TAN15(Consultation version))

Nr	Description	Cross Reference
1	A location plan identifying all possible sources of flooding including overtopping and/or breach of existing defences and any in-channel structures that may be prone to blockage.	<i>The flood risk is primarily due to fluvial flooding from the River Clywedog. Baseline flood extents are shown in Section 3.4 with a detailed summary in the Companion Report on Baseline Flood Modelling.</i>
2	A plan of the site showing existing and proposed levels related to Ordnance Datum.	<i>The ground levels will not change due to the development, save due to the SuDS features and soil mound in Fields 1B and 1C that are outside the areas at risk of flooding.</i>
3	A plan identifying any flood alleviation measures already in place.	<i>None present.</i>
4	An assessment of all sources of potential flooding including, but not confined to rivers, tidal, coastal, groundwater, surface flow or any combination of these.	<i>Section 3 and specifically Table 3-2.</i>
5	Existing and proposed cross-sections of the site showing proposed development and site levels relative to the source of flooding, and to anticipated water levels and associated probabilities.	<i>Ground levels are shown on the topographic survey by Invar mapping submitted with this Report. Given the extensive nature of the Site, flood extents and depths have been provided in Section 3.4.</i>
6	An assessment of peak flood depth and velocities at which various parts of the site might flood, the likely duration of flood events and impacts of flooding.	<i>Flood depths are provided in Section 3.4. Durations and velocities are not relevant for this development as the Site will not be occupied.</i>
7	Information regarding the extent and depth of past flood events and future predictions.	<i>Climate change allowances have been incorporated based on Welsh Government Guidance (Section 4.5).</i>
8	A plan of the area to show overland flow routes and appropriate access/evacuation routes from the proposed development site that are operational under all conditions.	<i>Levels are provided in Table 4-3 and depths and extents in Section 3.4.</i>
9	A plan and description of any structures which may influence local hydraulics, including bridges, pipes/ducts crossing the watercourse, culverts, screens, embankments or walls, overgrown or collapsing channels.	<i>The River Clywedog is characterised by a natural channel/floodplain system and does not feature any embankments. The embankment and bridges at the downstream end of the Site are described in Section 3.4 and Figure 3-11.</i>

10	An assessment of the implications of any drains or sewers, existing or proposed, on the site during flood events.	<i>The only drain of relevance is the outlet from the SuDS which outfalls to a riparian watercourse outside areas at risk of flooding.</i>
11	An assessment of the flood storage volume that would be lost and/or displaced from the site.	<i>There is no loss of floodplain storage, other than associated with the stanchions for the solar arrays. An ultra-conservative modelling approach has been used to investigate the impacts of these features on flood levels through adjustment of the Manning's roughness coefficient as shown in Section 4.3.2.</i>
12	An assessment of the run-off likely to be generated from the development.	<i>This has been addressed in a Companion SWMP.</i>
13	Details of flood avoidance, mitigation and resilience measures to be implemented.	<i>N/a</i>
14	Details to demonstrate that the development will not cause or exacerbate the nature and frequency of flood risk elsewhere.	<i>Hydraulic modelling has confirmed that any practical impacts on flood levels will be confined to the Site itself (Section 4.3.2).</i>
15	An assessment of the risks after the construction of any necessary mitigation measures.	<i>n/a</i>
16	A clear and comprehensive summary of the assessment describing the outcomes and recommendations.	<i>Section 5.</i>

Appendix B Pre-Application Response from NRW



Ein cyf/Our ref: CAS-101338-S4D2
Eich cyf/Your ref:

Maes y Ffynnon,
Penrhosgarnedd,
Bangor,
Gwynedd,
LL57 2DW

northplanning@cyfoethnaturiolcymru.gov.uk
03000 654099

04/10/2019

FOA: Paul Webster

Dear Mr Webster,

BWRIAD / PROPOSAL: Solar Farm Development

LLEOLIAD / LOCATION: Land off Tetrapak Road, Wrexham

Thank you for consulting Natural Resources Wales (NRW) about the above, which was received on 16/09/2019.

Thank you for consulting Natural Resources Wales regarding the above.

Please note that our comments are without prejudice to any comments we may wish to make when consulted on any subsequent planning application or permit (either at pre-application or application stage) for the proposed development. At that time, there may be new information available which we will need to take into account in making a formal response.

Flood Risk

The application site lies partially within Zones C2 and Zone B as defined by the Development Advice Map (DAM) referred to within TAN15: Development and Flood Risk. The NRW Flood Risk map confirms that the site lies partially within the 1% (1 in 100) and 0.1% (1 in 1,000) Annual Probability Event (AEP) flood outlines on the NRW Flood Risk Map.

We note that the development proposals are for mixed use proposals. The proposals include a large area of land which would be used for solar development, and a smaller area which would be used for industrial development.

We have reviewed the letter submitted with the pre-application request, and would provide the following comments in respect to the questions raised:

www.cyfoethnaturiolcymru.gov.uk www.naturalresourceswales.gov.uk

Croesewir gohebiaeth yn y Gymraeg a'r Saesneg
Correspondence welcomed in Welsh and English

Hydraulic modelling and Flood Consequences Assessment (FCA) for industrial land use

We note that the intention is to develop a detailed hydraulic model to inform the flood risk associated with the proposal for industrial land use adjacent to the River Clywedog.

As you are aware, the current flood outline on the NRW Flood Risk Map has not been developed using a detailed hydraulic model. We are not aware of any detailed hydraulic models that have been developed by others along this reach of the Clywedog.

In terms of our specific requirements for the modelling, at this stage we would direct you to our [external guidance](#) which provides some guidance on the approach that should be taken for developing a hydraulic model, and for flood estimation. The model should use an appropriate upstream and downstream boundary and model extent, in order to identify and consider all possible flood flow routes.

We would require the model to assess a range of return periods, including the 1%, 1% plus 20% allowance for climate change and 0.1% AEP events. We note that the proposed industrial land use area is located adjacent to a culvert, and we would expect a blockage at this location to be modelled. Our typical requirement is for a 95% blockage to be applied, as outlined in [OGN100: Modelling blockage and breach scenarios](#).

In respect to the proposal to remove the causeway, in principle this may be acceptable, although as noted in the pre-application letter, it would need to be demonstrated that this does not adversely impact flood risk elsewhere, as a result of its removal resulting in an increase in flows downstream.

In respect to the requirements for a Flood Consequences Assessment (FCA), we would require a FCA for the industrial land use proposal to demonstrate the following:

- The site should be designed to be flood free in the 1% AEP event with an allowance for climate change (and blockage of any relevant structures), in accordance with A1.14 of TAN15
- The FCA would need to demonstrate that the proposals do not adversely impact flood risk elsewhere, as a result of displacing floodwaters or interfering with flood flow routes, in accordance with A1.12 of TAN15. This should be the case in up to the 0.1% AEP event with blockage of any relevant structures
- The FCA would need to demonstrate that the flood risk posed to the access/egress route is within the tolerable conditions outlined within A1.15 of TAN15, in the 0.1% AEP event with blockage of any relevant structures

We note that the site boundary includes the River Clywedog, and discussions may be needed regarding the development layout and proximity to the watercourse in due course.

Acceptability of solar development in Zone C2

We note that the preapplication letter requests some advice on the acceptability of solar development within Zone C2.

Figure 2 of TAN15 outlines the land use vulnerability for various types of development. Given the scale of the development proposals, we would consider the proposals to constitute 'especially vulnerable industrial development' (such as a power station), and would therefore be classified as highly vulnerable development. However, it is the Local Planning Authority's role to decide on a proposal's land use vulnerability, and you may therefore wish to discuss this point further with them.

Based on the proposals being highly vulnerable development, siting such proposals within Zone C2 would be contrary to Section 6.2 of TAN15. It should be noted that this is the case for sites that are either partially or wholly within Zone C2. We note that the letter refers to the proposals not passing the Justification Tests as the land is not previously developed; it should be noted that the Justification Tests do not apply for highly vulnerable development within Zone C2 (as outlined in Appeal Decision APP/L6940/V/16/3163541) as TAN15 is clear that such development proposals should not be permitted.

The preapplication letter asks if there is any flexibility for providing solar development in Zone C2 where it is demonstrated that all impacts are mitigated, and whether raising of parts of the site outside of Zone C2 would be acceptable. Providing mitigation to offset the policy implication of no highly vulnerable development being allowed in Zone C2 is not appropriate. We would refer you to Appeal Decision ref: APP/A6835/V/17/3190167 which reinforces this.

If hydraulic modelling is undertaken which results in a change in the flood outline compared to those published on the NRW Flood Risk Map you may wish to investigate submitting a Flood Map Challenge (FMC). Further guidance on this process can be found [here](#).

Flood Risk Activity Permit (FRAP)

The site boundary incorporates sections of the River Clywedog, which is a Main River. A bespoke Flood Risk Activity Permit (Environmental Permitting Regulations England & Wales, 2016) may be required for any works in, over, under or near a Main River or within a flood plain, or to structures within a Main River. Further advice and guidance is [here](#).

Please do not hesitate to contact us if you require further information or clarification of any of the above.

Yn gywir / Yours faithfully,

Daniel Davies

Daniel Davies

Cynghorydd, Cynllunio Datblygu / Advisor, Development Planning
Cyfoeth Naturiol Cymru / Natural Resources Wales

Appendix C Response to comments from NRW to v1 of FCA

This extract is the opening part of the response from NRW. Since it is a lengthy response and deals with issue other than flooding, the points relevant to the application have been extracted and are presented in this Appendix along with how they have been responded to.



**Cyfoeth
Naturiol
Cymru
Natural
Resources
Wales**

Ein cyf/Our ref: CAS-138608-T5Y1
Eich cyf/Your ref: LL13 0LU

Maes Y Ffynnon,
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LL572DW

By email: hd@corylus-ltd.co.uk

ebost/email:
northplanning@cyfoethnaturiolcymru.gov.uk

26/03/2021

Dear Helen Donnelly,

**STATUTORY PRE-APPLICATION CONSULTATION - TOWN AND COUNTRY
PLANNING (DEVELOPMENT MANAGEMENT PROCEDURE) (WALES) ORDER 2012 AS
AMENDED.**

BWRIAD / PROPOSAL: Solar park and battery storage facility

LLEOLIAD / LOCATION: Land to the north of Maelor Gas Works, Wrexham

Thank you for providing a requisite notice to us under Article 2D of the above Order. We received a copy of your proposed application on 17/02/2021.

Table C-1: Response to NRW Comments of March 2021

Ref	NRW Comment	Response
Hydrology	Despite not fully following NRW guidance, the inflows for the upstream boundary on the Clywedog are reasonable for the purposes of a FCA. However, we reiterate that as NRW guidance GN008 has not been followed, this will not be acceptable for a future flood map challenge. (please see further comments on the hydrology in Appendix 1.)	<i>Noted in respect of the FCA and modelling for the adjacent Site. Additional description has been given in Appendix D of the derivation of the inflow boundary.</i>
Hydraulic Model	The comments are based on the nature of development (i.e. solar farm development) and are unlikely to change the results/outcome of the FCA. Therefore, in this instance the hydraulic model is considered suitable for this FCA. However, if the model is used to support any future proposals/applications, it would require an additional review in order to check that it is suitable for the nature of development proposed (please see further comments on the model in Appendix 1.)	<i>Noted again in respect of the FCA and modelling for the adjacent Site. In responding to these comments, some refinements have been made to the model. However, these are not sufficient to fully address the concerns of NRW in respect of further use of the model. We appreciate that this interim, revised version of the model is potentially confusing and apologise accordingly.</i>
PV1	We note that the draft Flood Map for Planning has been included within the FCA. As this has yet to be published, the map should not be referred to in the FCA, and it does not hold any weight for the purposes of a planning application. The Development Advice Map (DAM) remains the key flood map for planning purposes.	<i>Figure 2-7, Figure 3-2 and Figure 3-6 have been replaced with the appropriate maps with links shown beneath each map.</i>
PV2	We note that the FCA refers to the proposal being classified as 'highly vulnerable development'. In accordance with the Caldicot Levels appeal (APP/G6935/A/16/3150137) we consider the proposal to be less vulnerable development, although the Local Planning Authority should be consulted to provide clarification on this.	<i>Text amended in Section 2.3 with reference to the captioned case.</i>
PV3	The hydraulic modelling has assessed a range of events for the site. The key event for the proposal is the 1% Annual Exceedance Probability (AEP) event with an allowance for climate change. The flood levels for this event are not included within the FCA. For completeness, the report should be updated to include these. However, the FCA does include some model outputs	<i>Table of flood levels included as Table 4-4. Flood depth maps have been amended to show the maximum depths of flooding within areas of solar panels (Figure 4-6).</i>

	which show the expected flood depths within the parcels of land where the new solar panels would be located. The outputs show that the maximum flood depth for the parcels is up to 0.5 m, although the eastern parcel is on the border of the 0.5 to 0.75 m depth band.	
PV4	In terms of flood mitigation, the FCA recommends that the base of any panels are located at least 0.8 m above ground levels. Based on a maximum flood depth of 0.5 m, this approach would ensure that all the solar panel bases would be set at least 0.3 m above the predicted flood level. All electrical infrastructure (aside from the panels and cabling) will be located outside of the modelled flood extent. However, this assessment does not consider the impact of the blockage of nearby structures (the bridge immediately downstream of the site), which should be considered as part of the design event. The FCA states 'the open nature of both bridge openings does not suggest that they will be prone to blockage. If this did occur, there would likely be localised impacts upon flood levels with no practical consequence for the proposed development.' This should be quantified through examining the impact this would have on localised flood levels, particularly given the proximity of the solar panels (Field 1A) to this structure. Blockage proportions should follow the guidance in GN43: Modelling blockage and breach scenarios. It should be ensured that the solar panel bases have sufficient freeboard above the 1% AEP event with an allowance for climate change and blockage.	<i>Blockage has now been included in the model runs with modelled flood depths shown in (Figure 4-6). Recommendations for the minimum height of panels (front edge) are made in Section 4.3.2 and which provide a minimum freeboard of 300 mm between the reference flood level and the base of the panels.</i>
PV5	The FCA has undertaken a detailed assessment of the potential impact of the proposals on flood risk elsewhere. We appreciate the difficulties in modelling this for a solar farm development. This has been investigated through adopting an increased roughness value to account for the impact of the solar panel supports on flood flows. The analysis indicates that some increases in flood depth would be expected for the 0.1% AEP event, but these are generally within the modelling tolerance of 5 mm. However, some increase in excess of this are indicated, up to a maximum of 90 mm. The FCA states that all increases are within the red line boundary and do not impact third party land. There is no redline boundary shown on the depth difference maps; however, based on a comparison with the application documents, it appears that some of this increase is outside of the redline boundary. If all increases are within the redline boundary (or land ownership boundary) this would be considered acceptable but increases to third party land would be more of a cause for concern. We require that the FCA is updated to provide some clarification on this. If depths are increased outside of the redline boundary (or the landownership boundary) further information should be submitted to clarify how significant	<i>We have investigated the occurrence of these increases. They are spurious, since the interventions cannot lead to "downstream" increases in flood water levels. Our review has identified some errors in parameterisation. Their correction has led to a general improvement in the model, including for these spurious increases. It is this revised model (April 2021) that has been used to produce the flood extents and depths presented in this Report. There is accordingly, some inconsistency with the model version described in the Flood Model Report. The model is due to be</i>

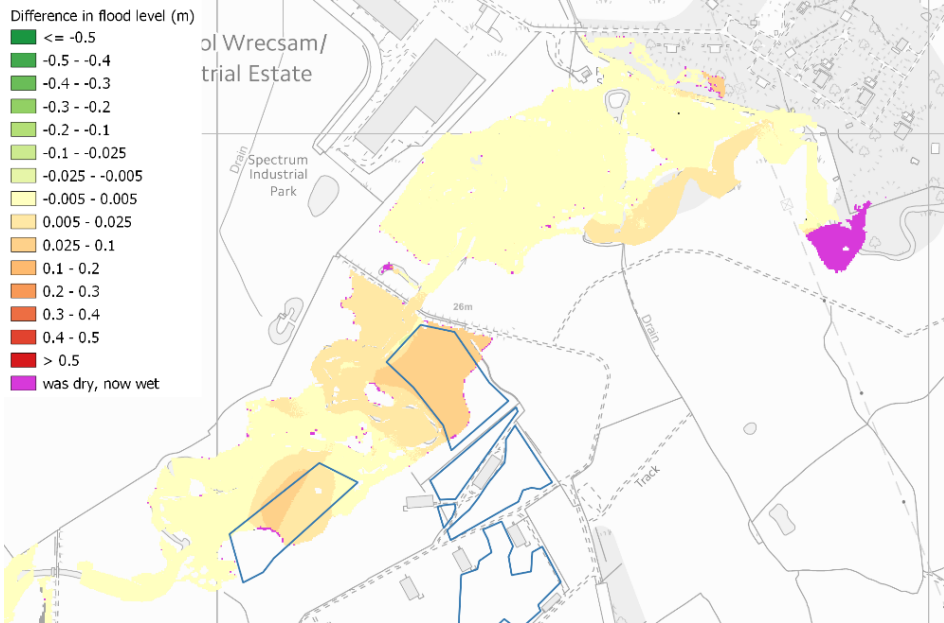
	these increases are. We note that the FCA states that no ground raising is proposed within the flood outline.  Difference in flood level (m) <= -0.5 -0.5 - -0.4 -0.4 - -0.3 -0.3 - -0.2 -0.2 - -0.1 -0.1 - -0.025 -0.025 - -0.005 -0.005 - 0.005 0.005 - 0.025 0.025 - 0.1 0.1 - 0.2 0.2 - 0.3 0.3 - 0.4 0.4 - 0.5 > 0.5 - was dry, now wet	revised further, in light of NRW comments, as part of its use on an adjacent Site for which a Flood Map Challenge will be undertaken. The Report has been amended to clarify the increases in flood levels arising from the development (Section 4.3.2).
PV6	The water level difference between the post-development and baseline model results for the 1% Annual Exceedance Probability (AEP) event with an allowance for climate change is different to that shown in the FCA report (please see attached). We would expect this issue to be clarified in the report that is submitted in support of the planning application.	Please see response to comment PV5 (above).
PV7	Based on the proposed plan, all development is set back from the Afon Clywedog. We advise that at least an 8-metre easement is provided from the top of bank to any structures (such as perimeter fencing). As the Afon Clywedog is a Main River, we may undertake maintenance activities along its length under our permissive powers. An 8-metre easement would ensure that our access along the watercourse remains uncompromised.	Noted and client has been advised.

Table C-2: Response to NRW Comments of March 2021 (Appendix 1 relating to the modelling)

Ref	NRW Comment	Response
HY1	The hydrographs and inflows have been derived using revitalised flood hydrograph (ReFH) at the three sites of interest and ratioed to the statistical peak at Bowling Bank further downstream. NRW guidance advises to ratio to the statistical peak at the site of interest. In this instance, it makes a small difference and will be acceptable for an FCA. For any other inflows derived this way, we can't guarantee that it would be acceptable as each study is audited on a case by case basis .	<i>Statistical peak to be obtained at site of interest for further modelling (flood map challenge).</i>
HY2	the 'river Clywedog upstream inflow' is not located at the site of interest, rather, it is located approximately 1km downstream of the site at the confluence with Redwither Brook. As previously advised, whilst this is likely to be conservative, this would not be sufficient for a flood map challenge.	<i>Noted.</i>
HY3	the ReFH work detailed in section 2.4 'derivation of inflow boundary hydrographs' has not been detailed in Appendix A (hydrological modelling report) or B (NRW Calculation Record) and no details are given for the storm parameters for the upstream Clywedog which is used for the 3 boundaries. Confirmation of whether or not the storm durations for the two tributaries have been sensitivity tested should be presented.	<i>See Appendix D and Table D-3 to Table D-5 confirming the same storm duration. Sensitivity testing was not consistent with the methodology and in any case, would have had little practical impact given the scaling approach that was used.</i>
HY4	All final peak flows for the 3 boundaries need documenting in the report in the same manner as Table 2.2 (Design flood peaks for Bowling Bank). Table 3.3 does not list all the inflows for the 3 boundaries.	<i>See Appendix D and Table D-2.</i>
HM1	topo_survey.asc' has several areas of erroneous data, red spots in Figure 3-3 of the modelling report. The level at 338200, 348510 indicates it is 885.495 mAOD. While several of these are located within/nearby the proposed solar panels, it is unlikely to significantly alter the results of this FCA.	<i>To be addressed in modelling for the flood map challenge for the adjacent Site.</i>
HM2	Near the western edge of the topo_survey.asc boundary near the channel, there is about a 10m change in levels as it merges with the underlying 'Dtm_1m.asc' potentially restricting the floodplain flow.	<i>To be addressed in modelling for the flood map challenge for the adjacent Site.</i>
HM3	The weir structures used for stability are affecting the representation of the open channel immediately upstream. For example:	<i>To be addressed in modelling for the flood</i>

	Geometry of channel CLYW3691 is interpolated with 80% from CLYW3691.csv and 20% from CLYW3650.csv - Not utilising the cross-section survey from CLYW3667.csv. Additionally, the bed slope from the survey (CLYW3691.csv to CLYW3667.csv) is -2.24%. The CLYW3691 has been modelled with a bed slope of +0.25% . Geometry of channel CLYW3650 is interpolated with 91% from CLYW3650.csv and 9% from CLYW3566.csv - Not utilising the cross-section survey from CLYW3633.csv.	<i>map challenge for the adjacent Site.</i>
HM4	Inclusion of CLYW3566B.csv has changed the bed slope of open channel section CLYW3566 to 0% from -0.38% (slope between surveyed section CLYW3633.csv and CLYW3504.csv.	<i>To be addressed in modelling for the flood map challenge for the adjacent Site.</i>
HM5	The roads land use has been applied to one cell along the alignment of the road, using 2m cell size, all roads are modelled as 2m wide.	<i>This is a consequence of the chosen grid size. It has no practical impact on model results.</i>
HM6	The 2D code boundary changes significantly between the baseline and post-development model. The changes are to areas outside of the flood extent; however, the post-development downstream code extent does not align with the outflow boundary.	<i>See response to PV5 (Table C-1).</i>
HM7	The modelling report discusses the model performance and it is noted that the 1D and 2D individual mass balance errors are within the quoted toleration range of $\pm 1\%$. However, the combined mass balance is not. Inspection shows that the HX links near the downstream boundary has poor mass balance.	<i>To be addressed in modelling for the flood map challenge for the adjacent Site.</i>
HM8	A 50% blockage scenario has been provided with the model, undertaken on the footbridge downstream of Mainetti Ltd (CLYW2865). Blockage should follow our guidance document (GN43: Modelling blockage and breach scenarios) which identifies the blockage proportion as 5%/25%/80%.	<i>25% Blockage run now done for causeway bridge (March 2021)</i>

Appendix D Supplementary description of the derivation of inflow boundaries

D.1 Methodology

In the revised model, there are three inflow boundaries:

- The River Clywedog at the upstream end of the model,
- The Redwither brook
- The Bedwell Brook included for completeness; it is not part of the hydraulic model but does contribute to the Bowling Brook catchment.

Following discussion with NRW, it was agreed that the inflow hydrographs could be scaled from the peak flows for Bowling Bank given in Section 2.3 in the Baseline Flood Model Report. The methodology used to do this is as follows:

1. Obtain the 1% (1 in 100) design flood hydrograph for the River Clywedog upstream of the Redwither Brook using the ReFH2 methodology – this will be used as the basis for the inflow boundary at the upstream end of the model;
2. Extract the storm parameters (duration, time step, areal reduction factor, seasonal correction factor) for this storm at this location.
3. Use ReFH2 to obtain the hydrographs **using the storm extracted for the Clywedog catchment** for both the Redwither and Bedwell Brooks.
4. Sum the hydrograph ordinates for each time step for the three hydrographs
5. Produce three dimensionless flow hydrographs, one for each inflow boundary, by dividing each ordinate by the peak of the summed hydrograph.
6. Multiply by the appropriate instantaneous peak for Bowling Bank to obtain three inflow hydrographs for each return period.

The key step here is that the hydrographs for the two tributaries are not for their respective 1% case; they are for the 1 (1 in 100) critical duration storm from the main catchment applied to the tributaries.

D.2 Results

The catchment descriptors for the three catchments are shown in Table D-1 and the catchment areas in Figure D-1 to Figure D-3. It is interesting to note that the QMED(URBAN) values for the Redwither and Bedwell Brooks are similar; the larger and more urban nature of the Redwither catchment being balanced by the increase in SPRHOST.

The peak runoff ordinate from the three catchments is shown in Table D-2 (column 3). The peak of the hydrograph occurs at different times in each of the three catchments. The combined peak is obtained by summing the hydrograph ordinates for each time step and then extracting the maximum value; this is lower than the sum of the peaks from the three sub-catchments. The Table also shows the peak of the 1% and 0.1% AEP hydrographs used for the modelling (columns 5 & 6).

The relevant hydrographs are shown in Figure D-4 (in dimensioned of m^3/s) and in Figure D-5 (dimensionless). Standard reports from the software are provided in Table D-3 to Table D-5; these confirm the use of a 9-hour duration storm for each catchment, this being the critical duration for the Clywedog at the Site.

Table D-1: Catchment descriptors

	Location:	Redwither confl.	Clywedog confl.	Clywedog confl.
	River:	Clywedog	Redwither	Bedwell
	Reference:			
	NGR:	SJ 38700 48950	SJ 38800 49050	SJ 39300 48350
AREA	Catchment area (km ²)	86.29	10.8175	5.55
ALTBAR	Mean elevation (m)	186	58	53
ASPBAR	Mean aspect	93	108	103
ASPVAR	Variance of aspect	0.46	0.44	0.42
BFIHOST	Base flow index	0.524	0.645	0.414
DPLBAR	Mean drainage path length (km)	14.61	3.84	4.17
DPSBAR	Mean drainage path slope	68.3	32.4	25
FARL	Index of lakes	0.988	0.99	1
FPEXT	Prop. of catchment in 1% FP	0.0624	0.0689	0.0972
FPDBAR	Mean flood depth (catchment)	0.533	0.479	0.715
FPLOC	Avg dist of FP to outlet	0.844	0.883	0.964
LDP	Longest drainage path (km)	25.84	7.93	7.41
PROPWET	Proportion of time soil is wet	0.51	0.51	0.51
RMED-1H	Median 1 hour rainfall (mm)	10	9.6	9.2
RMED-1D	Median 1 day rainfall (mm)	34.7	29.7	29.1
RMED-2D	Median 2 day rainfall (mm)	43.4	36.9	36.9
SAAR	Average annual rainfall (mm)	879	717	709
SAAR4170	Ditto for 1941-1970 (mm)	886	729	744
SPRHOST	Percentage runoff	36.03	27.44	38.8
URBCONC1990	Urban concentration 1990	0.751	0.701	-999999
URBEXT1990	Urban extent 1990	0.0696	0.0931	0.0043
URBLOC1990	Urban location 1990	0.832	1.085	-999999
URBCONC2000	Urban concentration 2000	0.851	0.849	0.786
URBEXT2000	Urban extent 2000	0.0986	0.1491	0.0056
URBLOC2000	Urban location 2000	0.842	0.989	1.051
QMEDcds	(m ³ /s)	18.033	1.24	1.500
	l/s/ha	2.09	1.15	2.70
QMEDurban	(m ³ /s)	20.272	1.553	1.508
	l/s/ha	2.35	1.44	2.72

Table D-2: Comparison of peak flows for sub-catchments

(1)	(2)	(3)	(4)	(5)	(6)
Watercourse	Location	1% ReFH Peak (m³/s)	As % of combined	1% stat pk (m³/s)	0.1% stat pk (m³/s)
Clywedog	Bowling Bank	61.95	n/a	41.59	64.98
Clywedog	Redwither confluence	55.79	84.3%	35.05	54.76
Redwither	Clywedog confluence	6.014	9.1%	3.78	5.90
Bedwell	Clywedog confluence	5.702	8.6%	3.58	5.60

Figure D-1: Catchment Area for Clywedog upstream of confluence with Bedwell Brook

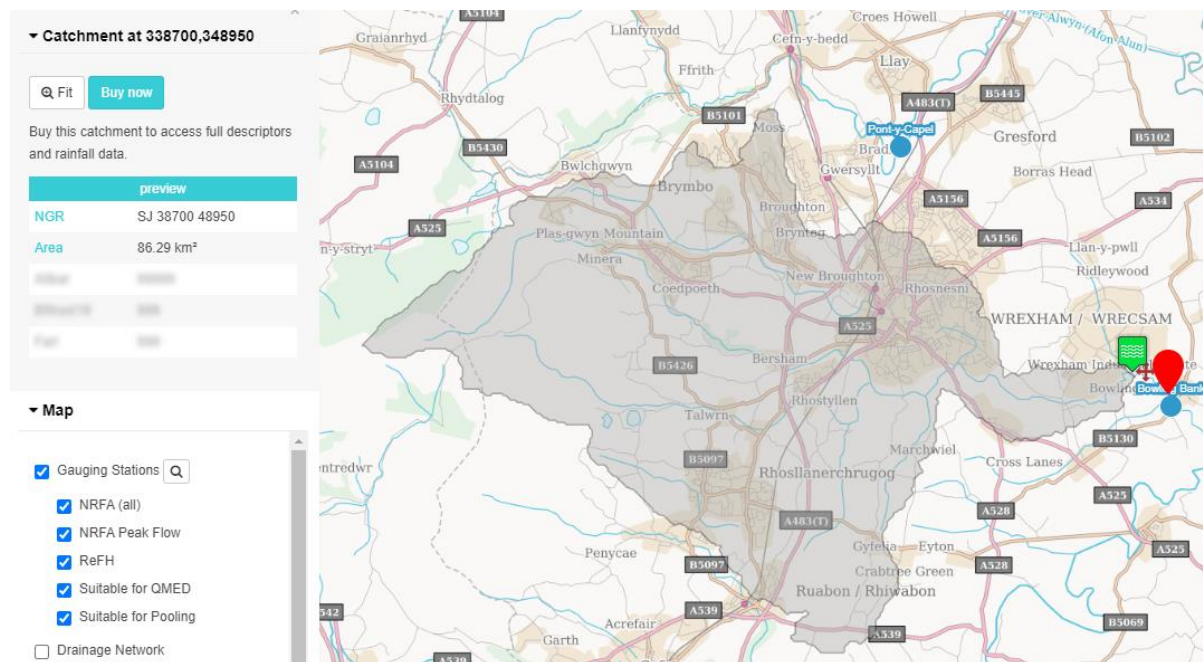


Figure D-2: Catchment Area for Redwither Brook

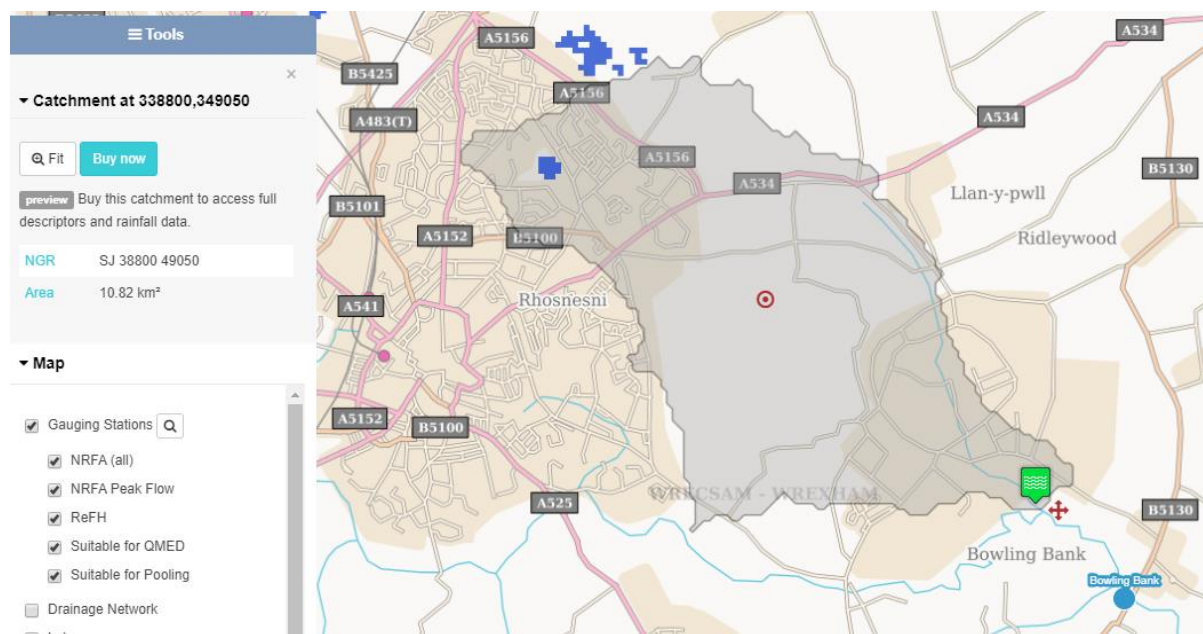


Figure D-3: Catchment Area for Bedwell Brook

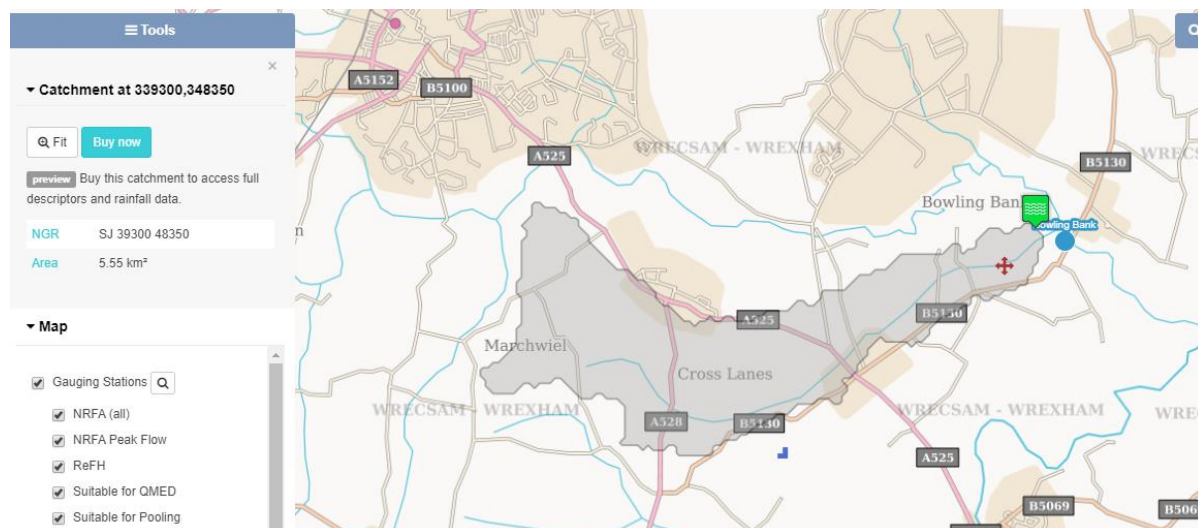


Figure D-4: Hydrographs obtained using ReFH2

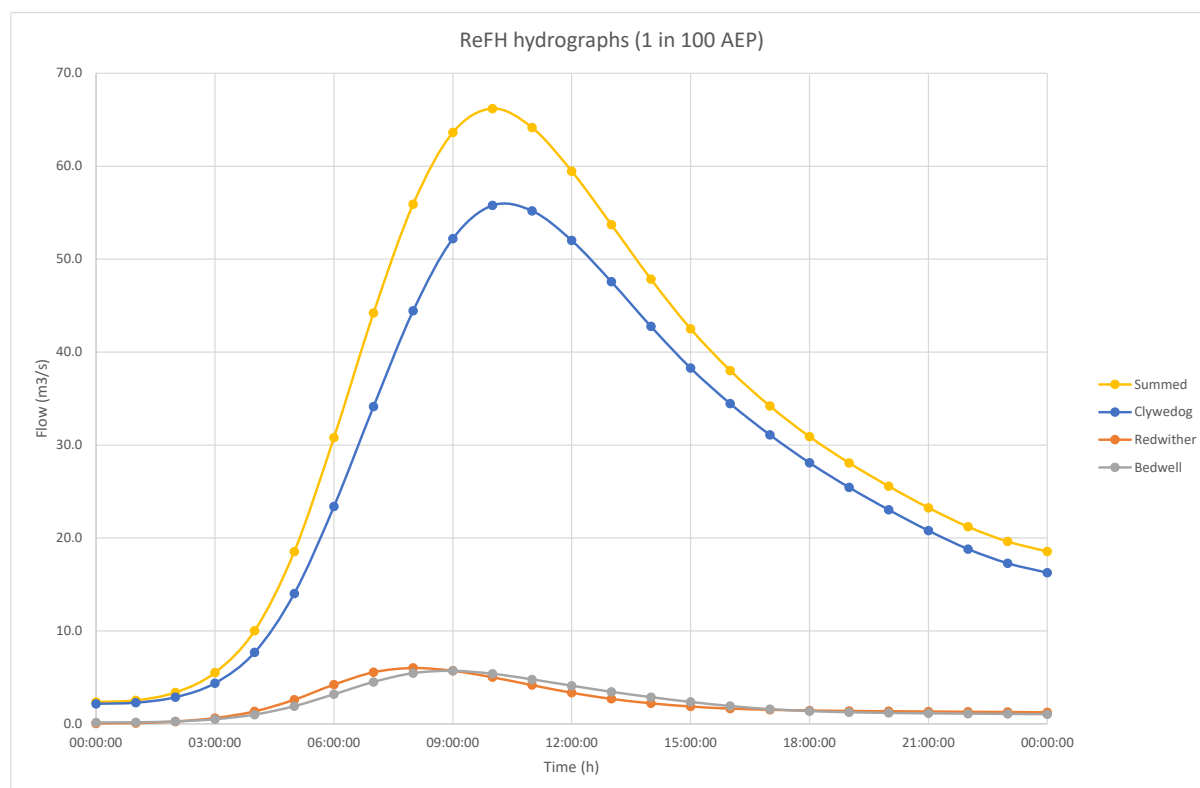


Figure D-5: Dimensionless hydrographs obtained using ReFH2

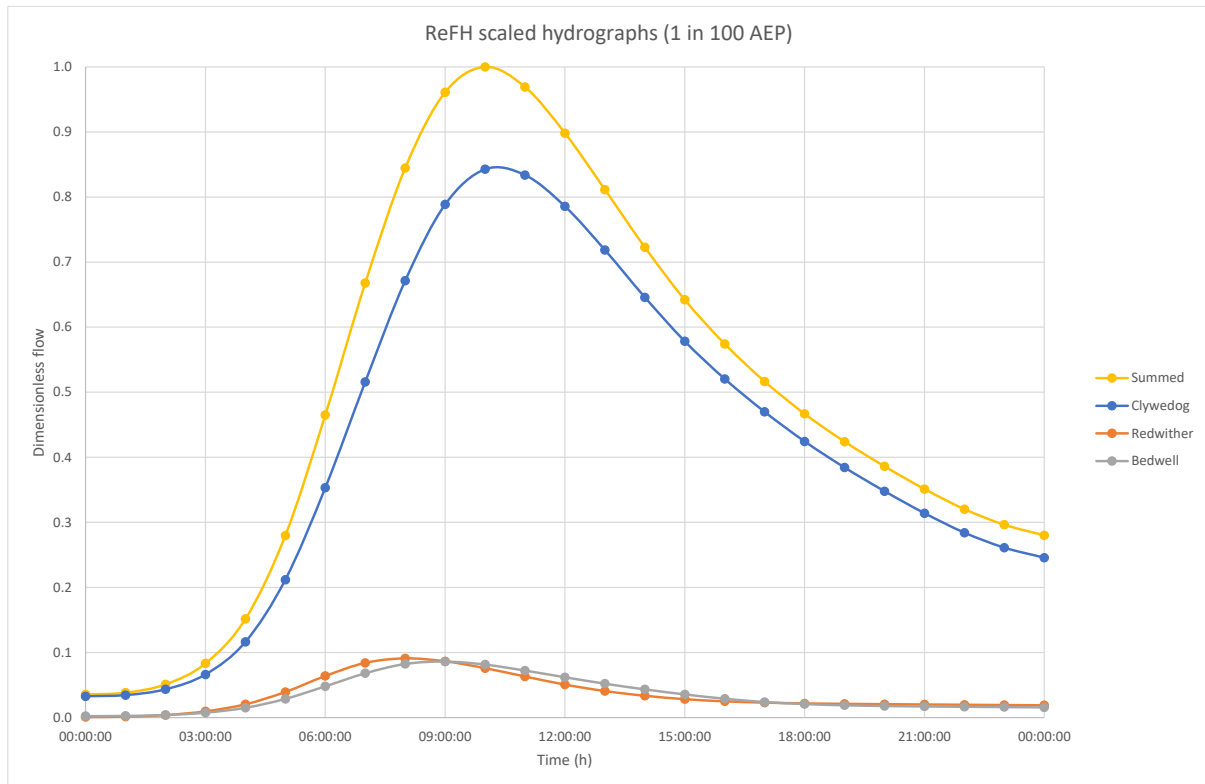


Table D-3: ReFH2 report – Clywedog at Redwither confluence

UK Design Flood Estimation

Generated on Thursday, August 20, 2020 2:43:31 PM by Chris
Printed from the ReFH2 Flood Modelling software package, version 3.0.7363.25782

Summary of estimate using the Flood Estimation Handbook revitalised flood hydrograph method (ReFH2)

Site details Checksum: 4ED3-2B96
Site name: FEH_Catchment_Descriptors_338700_348950
Easting: 338700
Northing: 348950
Country: England, Wales or Northern Ireland
Catchment Area (km²): 86.29
Using plot scale calculations: No
Model: ReFH2.3
Site description: None

Model run: 100 year

Summary of results

Rainfall - FEH 2013 model (mm):	83.41	Total runoff (ML):	1622.56
Total Rainfall (mm):	58.19	Total flow (ML):	4951.78
Peak Rainfall (mm):	15.83	Peak flow (m ³ /s):	55.79

Parameters

*Where the user has overridden a system-generated value, this original value is shown in square brackets after the value used.
* Indicates that the user locked the duration/timestep*

Rainfall parameters (Rainfall - FEH 2013 model)

Name	Value	User-defined?
Duration (hh:mm:ss)	09:00:00	No
Timestep (hh:mm:ss)	01:00:00	No
SCF (Seasonal correction factor)	0.76	No
ARF (Areal reduction factor)	0.92	No
Seasonality	Winter	No

Loss model parameters

Name	Value	User-defined?
Cini (mm)	86.18	No
Cmax (mm)	393.98	No
Use alpha correction factor	No	No
Alpha correction factor	n/a	No

Routing model parameters

Name	Value	User-defined?
Tp (hr)	5.01	No
Up	0.65	No
Uk	0.8	No

Baseflow model parameters

Name	Value	User-defined?
BFO (m ³ /s)	2.3	No
BL (hr)	50.93	No
BR	2.37	No

Urbanisation parameters

Name	Value	User-defined?
Urban area (km ²)	13.33	No
Urbext 2000	0.1	No
Impervious runoff factor	0.7	No
Imperviousness factor	0.4	No
Tp scaling factor	0.75	No
Depression storage depth (mm)	0.5	No
Exporting drained area (km ²)	0.00	Yes
Sewer capacity (m ³ /s)	0.00	Yes

Table D-4: ReFH2 report – Redwither Brook at Clywedog confluence

UK Design Flood Estimation

Generated on Thursday, August 20, 2020 3:24:04 PM by Chris
Printed from the ReFH2 Flood Modelling software package, version 3.0.7363.25782

Summary of estimate using the Flood Estimation Handbook revitalised flood hydrograph method (ReFH2)

Site details Checksum: FE4E-AC28
Site name: FEH_Catchment_Descriptors_338800_349050
Easting: 338800
Northing: 349050
Country: England, Wales or Northern Ireland
Catchment Area (km²): 10.82
Using plot scale calculations: No
Model: ReFH2.3
Site description: None

Model run: 100 year

Summary of results

Rainfall - FEH 2013 model (mm):	81.49	Total runoff (ML):	127.07
Total Rainfall (mm):	56.89	Total flow (ML):	374.17
Peak Rainfall (mm):	15.47	Peak flow (m ³ /s):	6.01

Parameters

Where the user has overridden a system-generated value, this original value is shown in square brackets after the value used.
* Indicates that the user locked the duration/timestep

Rainfall parameters (Rainfall - FEH 2013 model)

Name	Value	User-defined?
Duration (hh:mm:ss)	09:00:00 [05:30:00]	Yes
Timestep (hh:mm:ss)	01:00:00 [00:30:00]	Yes
SCF (Seasonal correction factor)	0.76 [0.71]	Yes
ARF (Areal reduction factor)	0.92 [0.96]	Yes
Seasonality	Winter	No

Loss model parameters

Name	Value	User-defined?
Cini (mm)	65.54	No
Cmax (mm)	622.33	No
Use alpha correction factor	No	No
Alpha correction factor	n/a	No

Routing model parameters

Name	Value	User-defined?
Tp (hr)	2.96	No
Up	0.65	No
Uk	0.8	No

Baseflow model parameters

Name	Value	User-defined?
BF0 (m ³ /s)	0.05	No
BL (hr)	45.43	No
BR	3.19	No

Urbanisation parameters

Name	Value	User-defined?
Urban area (km ²)	2.53	No
Urbext 2000	0.15	No
Impervious runoff factor	0.7	No
Imperviousness factor	0.4	No
Tp scaling factor	0.75	No
Depression storage depth (mm)	0.5	No
Exporting drained area (km ²)	0.00	Yes
Sewer capacity (m ³ /s)	0.00	Yes

Table D-5: ReFH2 report – Bedwell Brook at Clywedog confluence

UK Design Flood Estimation

Generated on Thursday, August 20, 2020 3:49:35 PM by Chris
Printed from the ReFH2 Flood Modelling software package, version 3.0.7363.25782

Summary of estimate using the Flood Estimation Handbook revitalised flood hydrograph method (ReFH2)

Site details
Site name: FEH_Catchment_Descriptors_339300_348350
Easting: 339300
Northing: 348350
Country: England, Wales or Northern Ireland
Catchment Area (km²): 5.55
Using plot scale calculations: No
Model: ReFH2.3
Site description: None

Checksum: ABC1-FA2B

Model run: 100 year

Summary of results

Rainfall - FEH 2013 model (mm):	80.95	Total runoff (ML):	132.20
Total Rainfall (mm):	56.51	Total flow (ML):	313.63
Peak Rainfall (mm):	15.37	Peak flow (m ³ /s):	5.70

Parameters

Where the user has overridden a system-generated value, this original value is shown in square brackets after the value used.
* Indicates that the user locked the duration/timestep

Rainfall parameters (Rainfall - FEH 2013 model)

Name	Value	User-defined?
Duration (hh:mm:ss)	09:00:00 [05:30:00]	Yes
Timestep (hh:mm:ss)	01:00:00 [00:30:00]	Yes
SCF (Seasonal correction factor)	0.76 [0.71]	Yes
ARF (Areal reduction factor)	0.92 [0.97]	Yes
Seasonality	Winter	No

Loss model parameters

Name	Value	User-defined?
Cini (mm)	100.37	No
Cmax (mm)	305.43	No
Use alpha correction factor	No	No
Alpha correction factor	n/a	No

Routing model parameters

Name	Value	User-defined?
Tp (hr)	3.37	No
Up	0.65	No
Uk	0.8	No

Baseflow model parameters

Name	Value	User-defined?
BF0 (m ³ /s)	0.15	No
BL (hr)	34.13	No
BR	1.37	No

Urbanisation parameters

Name	Value	User-defined?
Urban area (km ²)	0.05	No
Urbext 2000	0.01	No
Impervious runoff factor	0.7	No
Imperviousness factor	0.4	No
Tp scaling factor	0.75	No
Depression storage depth (mm)	0.5	No
Exporting drained area (km ²)	0.00	Yes
Sewer capacity (m ³ /s)	0.00	Yes



Planning

Landscape

Architecture

Hydrology

Ecology