Adventure Parc Snowdonia

Hydraulic Modelling Appendix

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Contract

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This report describes work commissioned by Global Shred Ventures UK Ltd, by an instruction dated 29th August 2024. The Client's representative for the contract was Adam Lamond of Global Shred Ventures UK Ltd. Chulani Herath and Kevin Frodsham of JBA Consulting carried out this work.

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1 Introduction

1.1 Background and Purpose

JBA have previously provided up-to-date flood risk information for the Adventure Parc both for the original Surf Snowdonia Flood Consequence Assessment (FCA) in 2013 and a subsequent development update to the Adventure Parc in 2018. In September 2024, JBA were approached to undertake further modelling at the site to inform some further redevelopment at the site (which includes a reduction in size of the main lagoon and new accommodation lodges and commercial buildings). This work subsequently expanded into JBA creating a site-specific FCA to support this latest phase of development.

This Appendix documents the hydraulic modelling work that underpins the flood risk information provided in the FCA. The previous FCA work at the site highlighted that the main risks to the site were fluvial and tidal from the Afon Conwy. Consequently, the new hydraulic modelling work that has been undertaken for the 2024 FCA is focussed on these flood risk sources. New modelling was required to provide an up-to-date risk to the site because the hydraulic model and hydrology of the Afon Conwy were both updated by NRW in 2023 and new extreme tide levels and climate change estimates for sea level rise have also been published since the previous work was undertaken.

The hydraulic modelling work undertaken was aimed at providing as up-to-date assessment of the following risks.

1. The existing fluvial and tidal risk based on current site elevations (as captured in topographic survey undertake in October 2024). This was modelled for 1% and 0.1% AEP fluvial events both with and without climate change plus 0.5% and 0.1% AEP tidal events both with and without climate change.
2. The existing fluvial and tidal risk based on the consented site elevations following the 2013 FCA for any events that caused flooding of the site in scenario 1.
3. The risk from local defence failure (re-using the breaches that were modelled for the 2013 FCA). These were modelled for both fluvial and tidal 0.1% AEP with climate change events.

1.2 Site location and design

The Adventure Parc Snowdonia is located in the village of Dolgarrog on the western edge of the Afon Conwy floodplain in North Wales. The site itself covers an area of approximately 5.5 hectares that is bounded to the east by the Conwy floodplain, to the north by the Dolgarrog Power station and to the west by the B5106 (Conwy Road) as shown in Figure 1-1.

The general pattern of ground level elevations across the site based on the latest available LIDAR DTM are shown in Figure 1-2. This was cross-checked against a site topographic survey collected in 2001 and there was found to be a good correspondence between the two data sources.

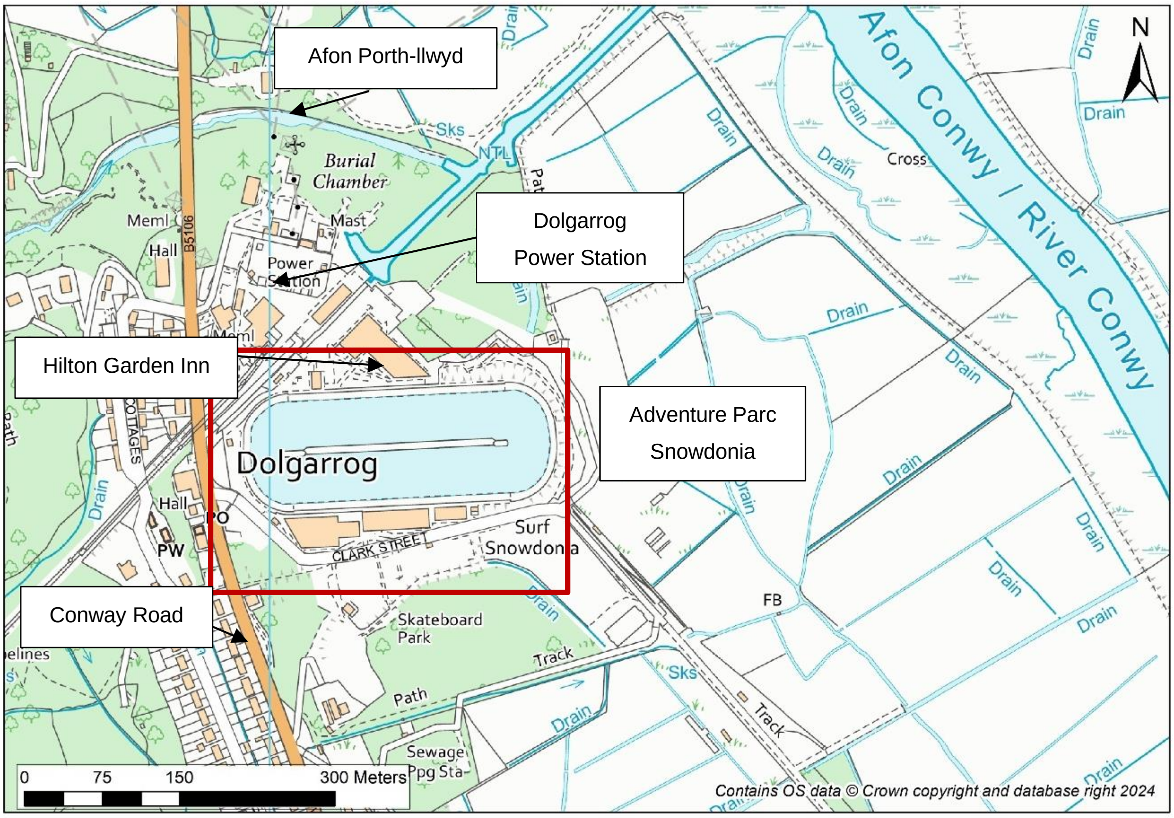

Figure 1-1 Location Map of Adventure Parc Snowdonia

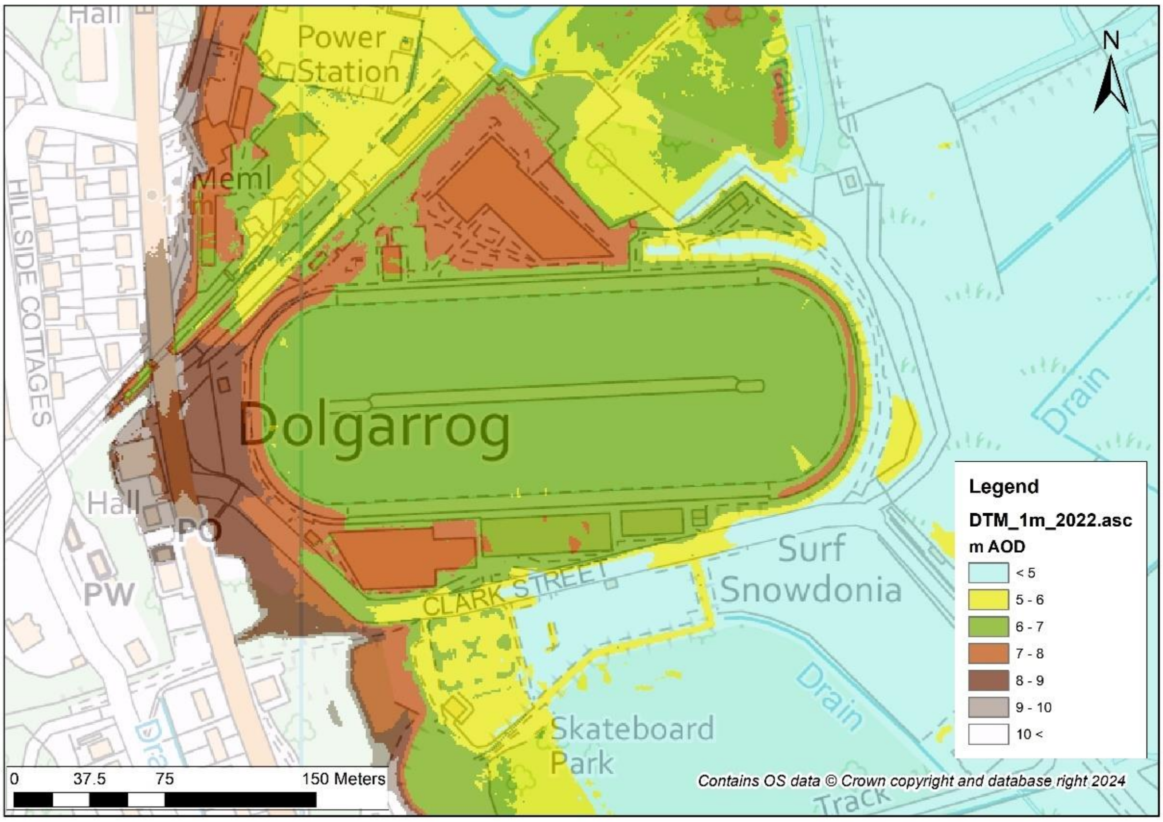

Figure 1-2 LIDAR elevations of the site and its vicinity

Planning permission for the 2013 FCA allowed for development at a consented minimum ground elevations of 6.86m AOD across hardstanding areas with the lagoon having a typical water level in the order of 5.4m AOD. The 6.86m AOD level was based on the previously modelled tidal 0.5% AEP in 2114 level of 6.26m AOD plus a freeboard of 600mm.

The redevelopment plans are illustrated in the main FCA. This will involve resizing of the lagoon into a more circular shape with the infilling of both western and eastern ends of the current lagoon and the placement of bungalows on these raised areas.

1.3 Climate Change Allowances used in FCA

The Welsh Government publishes updates on how climate change should be assessed for flood risk studies in Wales. The latest version was published in August 2022[1] and recommends that climate change allowances should be calculated as follows.

- Fluvial risk - Peak river flow uplifts are still based on an assessment of UKCP09 data that was undertaken by the Environment Agency between 2013 and 2015. Wales is divided into three river basin districts (of which the River Conwy is situated within West Wales) and each district is provided with a series of potential climate change uplifts across two scenarios and three epochs (Table 1-1).

Table 1-1 Current climate change uplift guidance for fluvial flows in West Wales

Scenario	Total potential change anticipated for the 2020s (2015 to 2039)	Total potential change anticipated for the 2050s (2040 to 2069)	Total potential change anticipated for the 2080s (2070 to 2115)
Upper (90th)	24%	40%	75%
Central (50th)	15%	25%	**30%**

Current guidance recommends using the Central (50th percentile) estimate for change for most purposes for the proposed lifetime of the development with the Upper (90th percentile) typically being reserved for sensitivity testing solutions. Therefore, the FCA modelling is based on applying the Central estimate for change for an assumed 100-year lifetime of the development (i.e. a 30% uplift).

- Tidal Risk - The August 2022 'Adapting for Climate Change Wales' guidance note recommends that mean sea level rises due to climate change should be based on the projections published in November 2018 by UK Climate Projections (UKCP18). As with the fluvial uplifts, the guidance provides two confidence bands that arise from the relevant emissions scenario; the 70th percentile, which is recognised as the more likely scenario, and the 95th percentile, which is considered less likely and is typically reserved for sensitivity testing.

[1] Adapting to Climate Change: Guidance for Flood and Coastal Erosion Risk Management Authorities in Wales, August 2022

The sea level rise for this study was obtained directly from the UK Climate Projections (Met Office) user interface, which predicted a 0.95 metre rise for the 70th percentile for a location offshore of the Conwy Estuary between 2024 and 2125. According to the Adapting to Climate Change guidance, the 95th percentile would be in the order of 0.37 metre higher.

1.4 Data Used in Modelling

The following data sources were used to inform the modelling.

- Hydraulic Models - sourced from NRW (under licence)
  - 2022 Conwy Estuary 2D model
  - 2023 Conwy Valley 1D2D (Tan Lan) model.
- LIDAR DTM (flown March 2022) - https://datamap.gov.wales/ (NB Only used for cross-checking the topographic survey as the Conwy Valley model had already been updated to use the 2022 LIDAR).
- Site Topographic Survey supplied by Global Shred Ventures UK Ltd - Greenhatch Group in October 2024 (drawing number 52513_T).
- Existing site plan by HB Architects September 2024 (drawing numbers 03124-HBA-DR-0025).
- Proposed site design by HB Architects July 2024 (drawing numbers 03124-HBA-DR-0012)
- Coastal Flood Boundary Extreme Sea Levels (2018)[2] - used to create up-to-date tidal boundary series.
- Ordnance Survey Mastermap (a small area was purchased to provide the existing risk land-use pattern across the Adventure Parc, given that the existing model still contained pre-development OS Mastermap).

[2] https://www.data.gov.uk/dataset/73834283-7dc4-488a-9583-a920072d9a9d/coastal-design-sea-levels-coastal-flood-boundary-extreme-sea-levels-2018

2 Hydraulic Modelling (Conwy Valley)

2.1 Introduction

The Adventure Parc site lies within the active 2D domain of NRW's Conwy Valley 1D-2D (FM-TUFLOW) model, which extends from Betws-y-Coed to Tal-y-Cafn (Figure 2-1). Therefore, it is necessary to run this model to capture the flood risk to the FCA site from the Afon Conwy. The Conwy Valley model was last updated by ARUP in 2023 following an earlier major flood mapping update that had been undertaken by JBA Consulting in 2017. The main updates that were undertaken in 2023 that are of relevance to this study included:

- The calculation of a new hydrology.
- The collection of some check sections on the 1D (channel) model geometry.
- A reduction of the 2D cell size from six to four metres.
- Updating the floodplain topography to represent the 2022 LIDAR elevations.

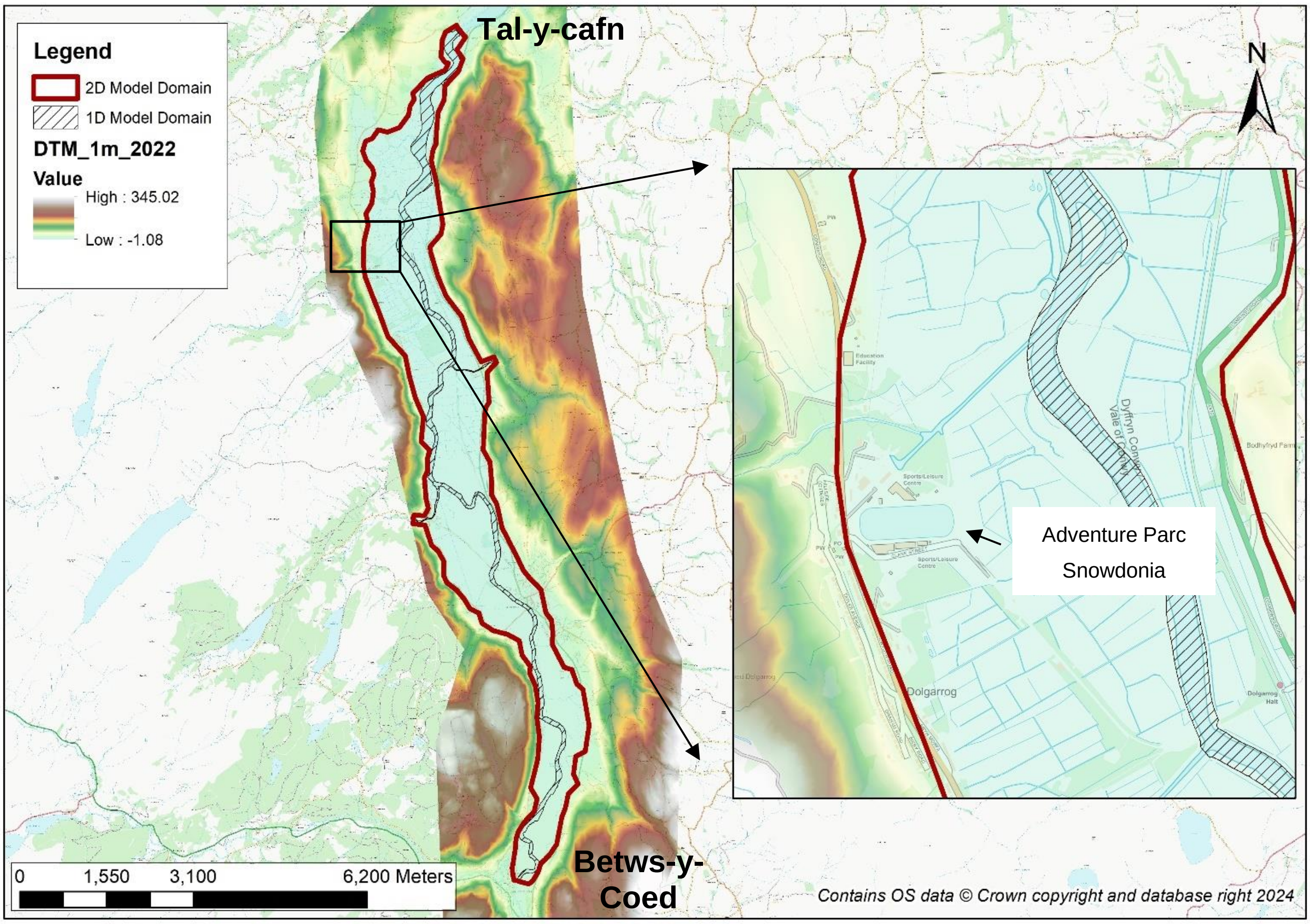

Figure 2-1 Conwy Valley model extent

The Conwy Valley 2023 model was sourced under licence from NRW for this study and, given that the model had only recently been updated by NRW, the model and hydrology were sufficiently up to date to act as the core of the baseline model to inform the Adventure Parc FCA. Only a small number of changes were needed to run the FCA models.

- The representation of the Adventure Parc was improved by removing the proposed Surf Snowdonia elevation polygons that still represented the site in the 2023 model and replacing these with a combination of the 2022 LIDAR and a z-line of the surveyed crest line around the lagoon from the 2024 survey. The roughness across the Adventure Parc was also updated using a purchased patch of OS Mastermap that represented the existing land-usage pattern across the development.
- Additional stability measures were introduced as necessary to stabilise the more extreme events (i.e., 2D roughness patches and altering some spill coefficients on troublesome tributary reaches).
- The model boundaries (inflows and/or tidal level) were updated as necessary to provide up-to-date assessment of the fluvial flows and extreme tide levels both with and without climate change.

The updated Conwy Valley models were run using Flood Modeller (FM) version 7 and TUFLOW Classic 2023-03-AF-iSP-w64.

2.2 FCA updates to supplied Conwy Valley model

Most of the files used by the Conwy Valley Fluvial model (2024) are identical to those supplied with the Conwy Valley (2023) model. However, some adjustments were made to both the 1D and 2D models to ensure compatibility with the latest software versions and improve stability.

Table 2-1 lists the changes that were made to the supplied Flood Modeller DAT file; noting that all these changes were made to maintain model stability in extreme events.

Table 2-1 Adjustments made to the supplied FM Dat file

Model Node	Modification / remark
CON_12042su, CON_05771su, CRAF_0668su, CRAF_0387su, MAEN_0880	Weir coefficient updated to 1.9 (for stabilisation)
MAEN_0424su	Weir coefficient updated to 1.7 (for stabilisation)
CON_05771bu	Added panel markers
MAEN_0581	Culvert was removed (for stabilisation)

Table 2-2 lists any new Flood Modeller input files that were created to run the FCA models.

Table 2-2 New or updated files used in the 1D component of the fluvial model

1D software and Key files used to run the design model	
New DAT Files (.dat)	CNWY_EX_017c
New Event Files (.ief)	**Baseline (with site at existing levels)** *CNWY_Q0100_TMHWS+Q0100_EX_S00_041_FR - Fluvial 1% AEP* *CNWY_Q0100CC_TMHWS_70thCC+Q0100CC_EX_S00_041_FR - Fluvial 1% AEP+CC* *CNWY_Q1000_TMHWS+Q1000_EX_S00_041_FR - Fluvial 0.1% AEP* *CNWY_Q1000CC_TMHWS_70thCC+Q1000CC_EX_S00_041_FR - Fluvial 0.1% AEP+CC* *CNWY_Q0002_T200_MHWS+Q0002_EX_S00_041_TR - Tidal 0.5% AEP* *CNWY_Q0002_T1000_MHWS+Q0002_EX_S00_041_TR - Tidal 0.5% AEP+CC* *CNWY_Q0002CC_T200_MHWS_70thCC+Q0002CC_EX_S00_041_TR - Tidal 0.1% AEP* *CNWY_Q0002CC_T1000_MHWS_70thCC+Q0002CC_EX_S00_041_TR - Tidal 0.1% AEP +CC* **Baseline (with site at consented levels)** *CNWY_Q1000CC_TMHWS_70thCC+Q1000CC_EX_S00_043_FR FR - Fluvial 0.1% AEP+CC* **Breach (with site at existing levels)** *CNWY_Q0002CC_T1000_MHWS_70thCC+Q0002CC_Breach01_S00_041_TR - Breach 1 Fluvial 1% AEP+CC* *CNWY_Q0002CC_T1000_MHWS_70thCC+Q0002CC_Breach02_S00_041_TR - Breach 2 Fluvial 1% AEP+CC* *CNWY_Q1000CC_TMHWS_70thCC+Q1000CC_BREACH01_S00_041_FR - Breach 1 Tidal 0.1% AEP +CC* *CNWY_Q1000CC_TMHWS_70thCC+Q1000CC_BREACH02_S00_041_FR - Breach 2 Tidal 0.1% AEP +CC* **Breach (with site at consented levels)** *CNWY_Q1000CC_TMHWS_70thCC+Q1000CC_Breach01_S00_043_FR - Breach 1 Fluvial 1% AEP+CC* *CNWY_Q1000CC_TMHWS_70thCC+Q1000CC_Breach02_S00_043_FR - Breach 2 Fluvial 1% AEP+CC*
New IED Files	New IED files were created to model the events that had not previously been modelled. Please use the IEF file list above to locate the relevant IED file for any specific event.

Table 2-3 lists new or updated TUFLOW input files that were used to run the FCA models.

Table 2-3 New or updated files used in the 2D component of the fluvial model

2D software and Key files used to run the design model	
TUFLOW Control files (.tcf, ecf, .tef)	Baseline Model at existing levels CNWY_~e1~_~e2~_~s1~_~s2~_~s3~_041.tcf CNWY_~e1~_~e2~_~s1~_~s2~_~s3~_041.ecf Baseline Model at consented levels CNWY_~e1~_~e2~_~s1~_~s2~_~s3~_043.tcf CNWY_~e1~_~e2~_~s1~_~s2~_~s3~_043.ecf
TUFLOW geometry (.tgc) file	Conwy_040.tgc - Baseline Model at existing levels Conwy_041.tgc - Baseline Model at consented levels
TUFLOW Boundary Control files	Conwy_040.tbc - Baseline Model at existing levels Conwy_041.tbc - Baseline Model at consented levels
TUFLOW materials (.tmf) file(s)	Conwy_001.tmf - additional roughness value added for stability
1d node/ network / WLL layer	Minor updates to the following layers were undertaken to overcome local stability issues 1d_nwk_CNWY_016_P.shp 1d_nwk_CNWY_016_L.shp 1d_WLL_CNWY_013_L.shp
Active / Inactive model cells files (s)	2d_code_CNWY_002_R.shp - small change to include the whole site 2d_code_inactive_CNWY_014.shp
Additional Topographic Changes to the basic model grid (i.e. Z-line, z-shape, z-point layers)	2d_zsh_Snowdonia_Lagoon_002_R.shp - Lagoon at existing levels 2d_zln_Snowdonia_TopoSurvey-2024_001_L.shp | 2d_zln_Snowdonia_TopoSurvey-2024_001_P.shp - Site crest at existing levels 2d_zln_Snowdonia_TopoSurvey-2024_002_L.shp | 2d_zln_Snowdonia_TopoSurvey-2024_002_P.shp - Site crest at consented levels
2D roughness layer(s)	*Updated stability patch for all models* 2d_mat_stabilitypatch_Tan_Lan_017a_R.shp *Updated/ additional stability patches for fluvial 1% AEP + CC & tidal 0.5% AEP* 2d_mat_stabilitypatch_Tan_Lan_022b_R.shp 2d_mat_Stability_Patch_024_R.shp *Additional stability patches for fluvial 0.1% AEP (with and without climate change)* 2d_mat_Stability_Patch_023_R.shp *Additional stability patches for tidal 0.5% AEP and 0.1% AEP (with climate change)* 2d_mat_Stability_Patch_026_R.shp

2D software and Key files used to run the design model	
2D Boundary layer(s)	Minor updates to the following layer to overcome local stability issues 2d_bc_HX_CNWY_016_L.SHP
Check files enabled	Yes (for 1% AEP, 1% AEP +CC and 0.5% AEP_MHWS + CC)

Figure 2-2 shows the pattern of roughness patches used in the FCA models. Large patches were needed to stabilise the downstream reaches of the model because the modelled water levels rose significantly above the elevation of the HX lines along the (undefended) bank crests along this reach, particularly when extreme tide levels were being applied at the downstream boundary.

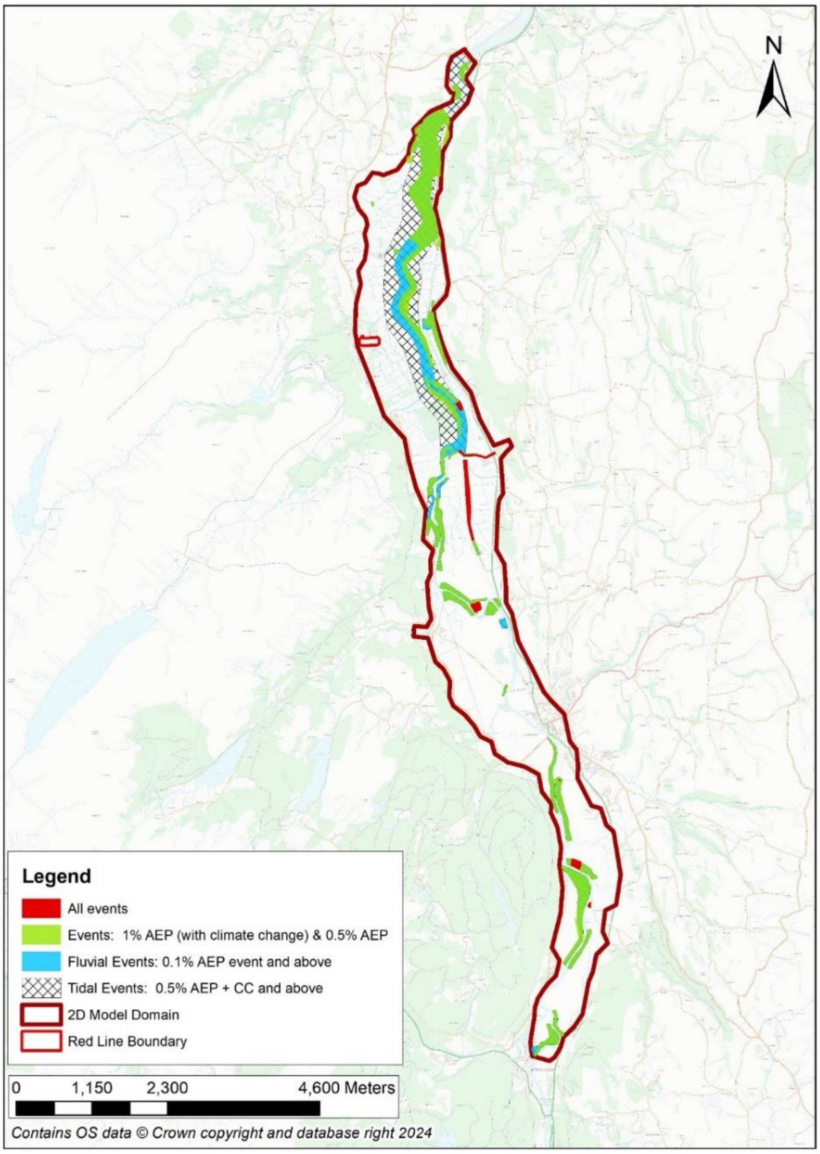

Figure 2-2 Roughness stability patches used by the model.

2.3 Generating boundary conditions

The hydrology of the Conwy Valley model was updated for the 2023 study. Therefore, the supplied 1% AEP (both with and without climate change) and 0.1% AEP (without climate change) fluvial inflows provided with the 2023 study were up to date for the FCA. Therefore, the only update to the flows required for the FCA was to add the +30% climate change uplift to the 0.1% AEP event as this event had not previously been modelled.

Note that to avoid destabilising the 0.1% AEP with climate change simulation, the Nant Maenan inflows were adjusted down to QMED for this event. This is justified by the facts that the site is remote from the Maenan and the flows on the Maenan are negligible relative to those along the Afon Conwy and peak earlier than the Conwy (as shown on Figure 2-3).

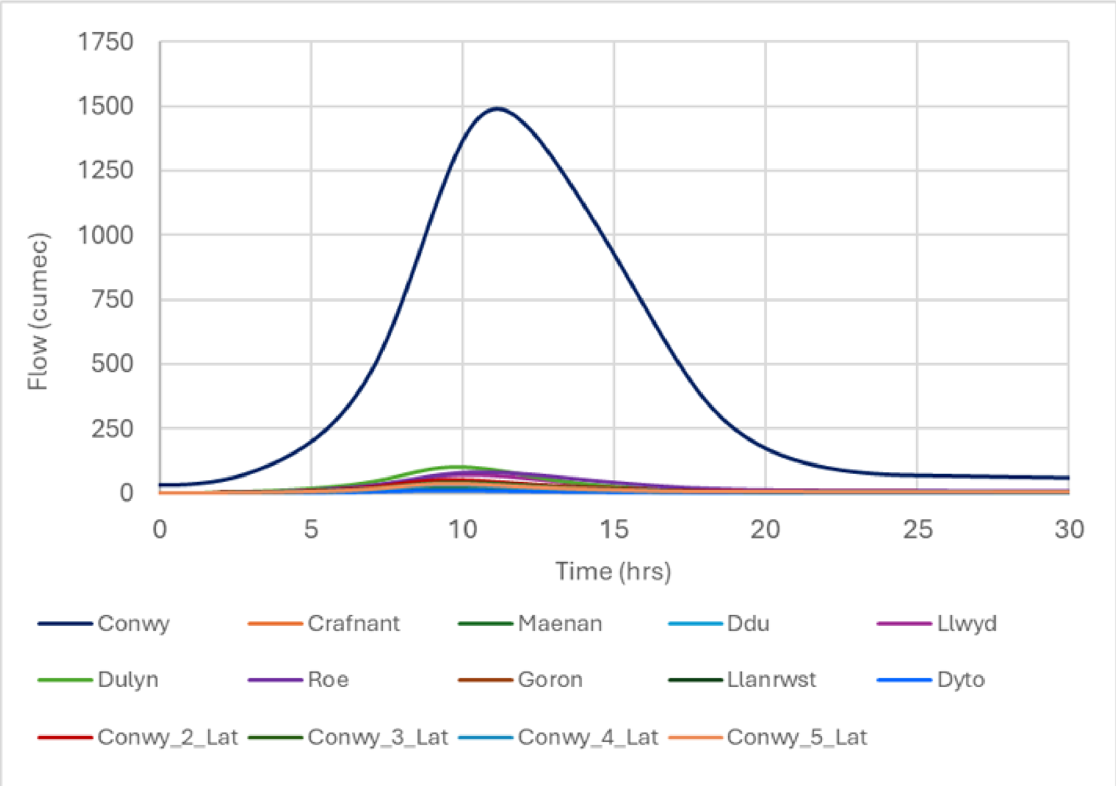

Figure 2-3 0.1% AEP fluvial inflows into Conwy Valley model

The downstream boundary of the Conwy Valley model is a Head-Time Boundary (HTBDY), that represents river level at Tal-y-Cafn. To generate appropriate downstream boundaries for the FCA, it was necessary to run tidal events through the Conwy Estuary (Tidal Prism) Model (see Section 3). The resulting boundary series that were extracted from the Tidal Prism model at Tal-y-Cafn and input into the Conwy Valley model are shown in Figure 2-4 and Figure 2-5 for fluvial and tidal events, respectively.

Note that the downstream boundaries for the fluvial events were generated by running MHWS (with or without climate change) series in conjunction with a high fluvial flow through the Tidal Prism model whereas the downstream boundaries for the tidal events were generated by running extreme tidal events in conjunction with a QMED flow (with or without climate change).

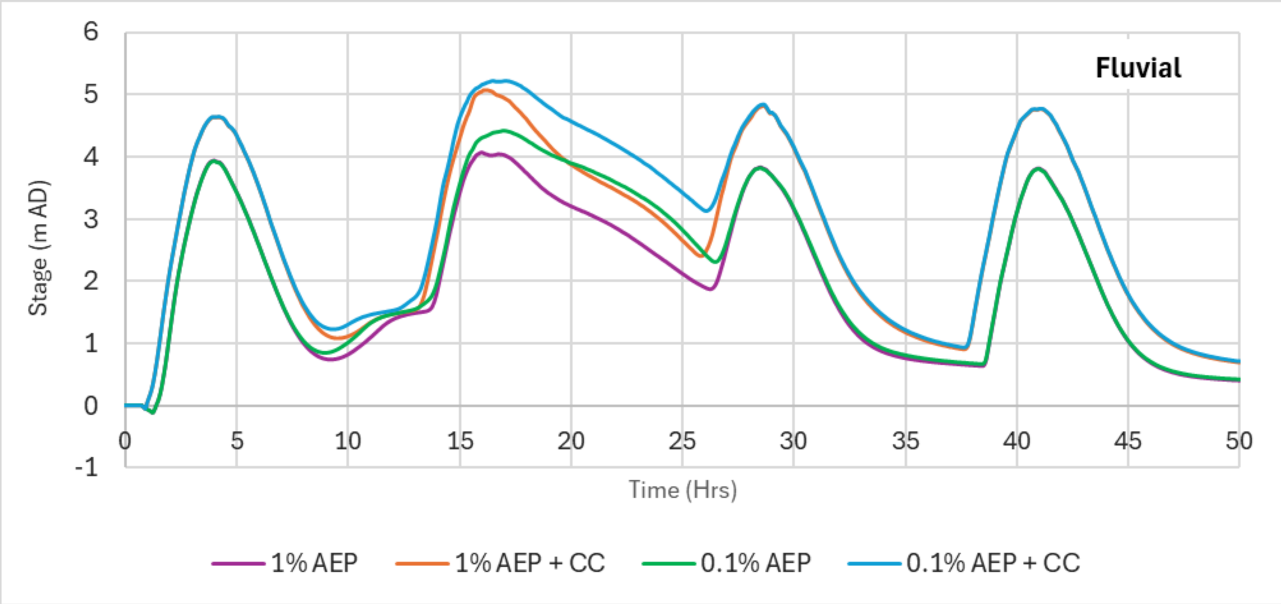

Figure 2-4 Downstream boundary series generated at Tal-y-Cafn for modelling fluvial events

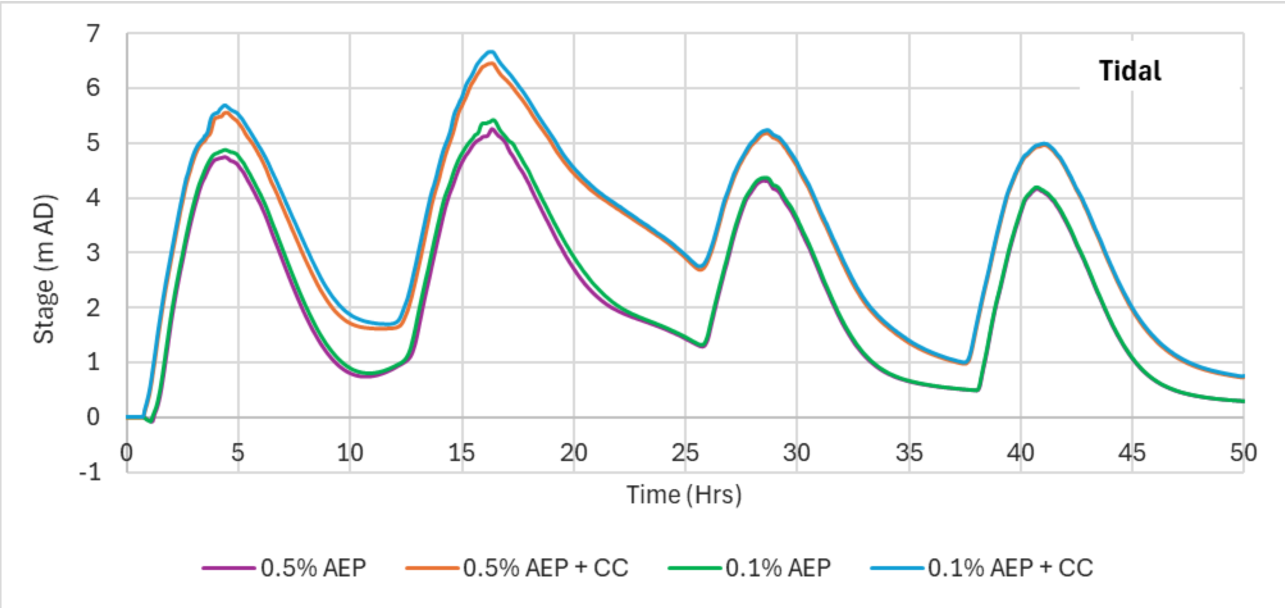

Figure 2-5 Downstream boundary series generated at Tal-y-Cafn for modelling tidal events

2.4 Modelled scenarios and events

The following scenarios and events were run through the Conwy Valley model.

1) Baseline Risk (at existing levels based on site topographic survey)

- Fluvial Events
  - 1% AEP inflow with MHWS downstream boundary
  - 1% AEP event with climate change
    (30% uplift in fluvial flows plus 0.95m sea level rise in MHWS tidal boundary)
  - 0.1% AEP event with MHWS downstream boundary
  - 0.1% AEP event with Climate Change
    (30% uplift in fluvial flows plus 0.95m sea level rise in MHWS tidal boundary)
- Tidal Events
  - 0.5% AEP event with QMED inflow
  - 0.5% AEP event
    (30% uplift in QMED inflows plus 0.95m sea level rise)
  - 0.1% AEP event with QMED inflow
  - 0.1% AEP event with Climate Change
    (30% uplift in QMED inflows plus 0.95m sea level rise)

2) Baseline Risk (adjusted for previously consented levels)

- Fluvial Events
  - 0.1% AEP event with Climate Change (30% uplift in fluvial flows plus 0.95m sea level rise in MHWS tidal boundary)

This was the only event required to be run for Scenario 2) as this was the only event that led to partial inundation of the lagoon when running Scenario 1). For this scenario the crest line around the lagoon was adjusted to have a minimum elevation of 6.86m AOD (as per the previously consented levels).

3) Breach Residual Risk

The following defence failure scenarios were run for each of two breach locations.

- Fluvial Events (with site at both existing and previously consented levels)
  - 0.1% AEP event with Climate Change (30% uplift in fluvial flows plus 0.95m sea level rise in MHWS tidal boundary)
- Tidal Events (with site at existing levels)
  - 0.1% AEP event with Climate Change (30% uplift in QMED inflows plus 0.95m sea level rise)

The breaches were modelled as per the 2013 FCA by simply reading the previously modelled (variable z-shape) breaches into the model. The locations of these breaches are shown in Figure 2-6 and each of the previous breaches had been timed to initiate at T=7 hours into the model runs, which meant that the breaches were fully open by the time peak fluvial or tidal conditions were reached.

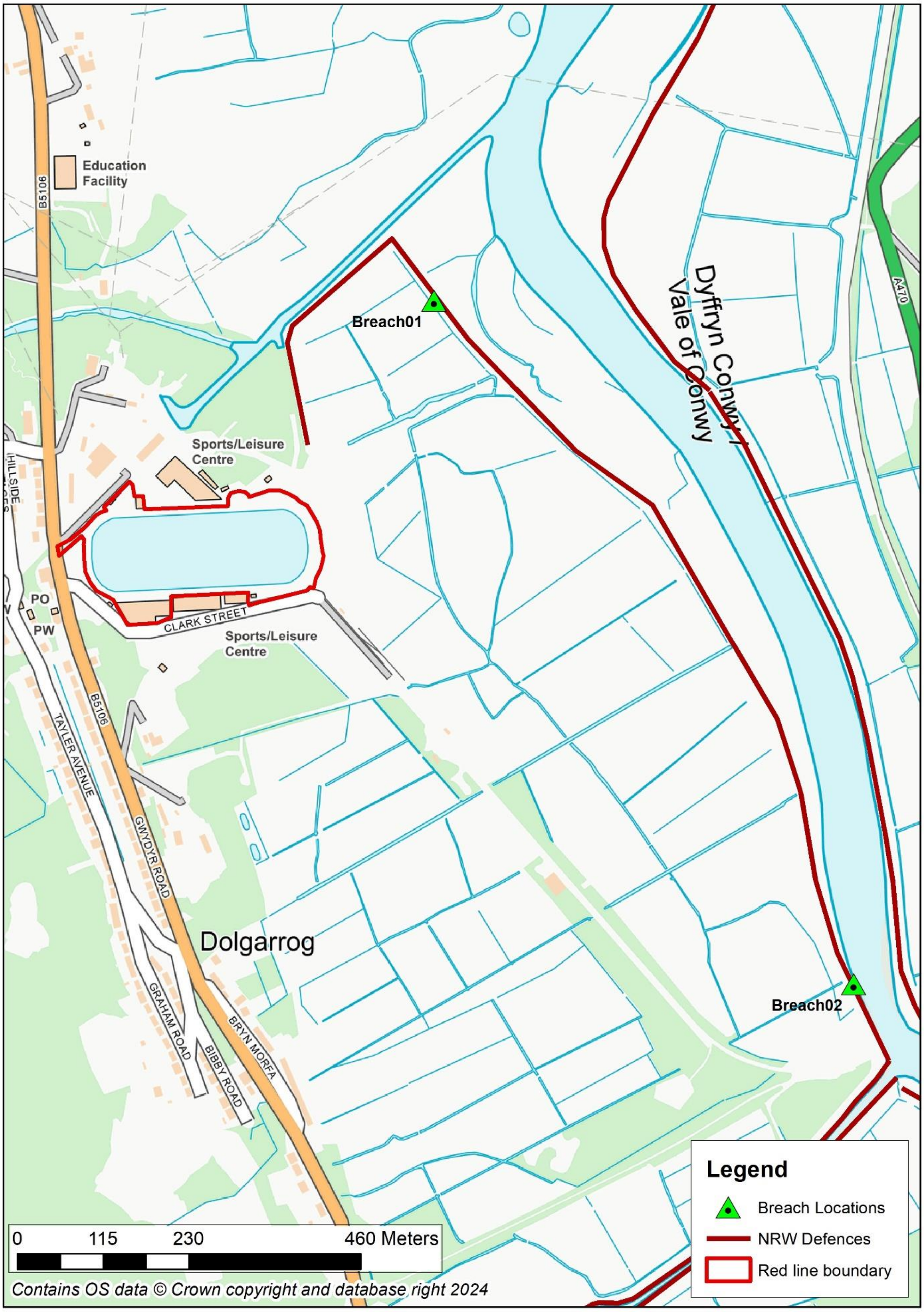

Figure 2-6 Breach locations modelled for FCA

2.5 Model Performance

This section provided a summary of the general performance of the Conwy Valley FCA models.

2.5.1 Run time Parameters

Simulations were run via the following settings:

- The model was run with the following software versions; Flood Modeller Version 7.1 and TUFLOW Classic TUFLOW 2023-03-AF-iSP-w64.
- All models were run with a 1D (FM) timestep of 1 second and a TUFLOW timestep of 2 second[3].
- The initial conditions for all design simulations are contained in a separate (CNWY_Q0030_TMHWS+Q0030_EX_S00_0.5HR_017.IIC.iic) file.
- The maxitr and dflood advanced parameters were adjusted upwards as necessary to suitably stabilise each model run.
- All design event simulations were run for a hydrograph duration of 40 hours, which was sufficient to capture peak conditions.
- Each 4m grid design event simulation took between 12 and 19 hours to run on a standard modelling PC.

2.5.2 Model Stability

Because the FCA modelling for the Adventure Parc involved modelling more extreme events than had previously been run through the Conwy Valley model, initial attempts to run the supplied model to completion and/or obtain suitably stable results were unsuccessful. Therefore, several stability measures (as outlined in Section 2.2) were subsequently required to satisfactorily attain these objectives. This section logs the stability of the final FCA model runs.

Flood Modeller

The Flood Modeller run time plots for the modelled tidal and fluvial with climate change events are provided in Figure 2-7. This shows that these model runs were convergent across the full simulation period. Flood Modeller reports two mass balance errors. The MB[1] value is often significantly outside the normally quoted tolerance for acceptable mass balances but the MB[1] calculation is not the most appropriate measure of mass balance for cyclical (i.e. tidal) models. By contrast, the MB[2] values, which are more appropriate for cyclical models, are within a tolerance of ±1.5% across the modelled events implying that the FM mass balance is not an issue for this model.

[3] Note a 2D timestep of 1 second as tested but more than doubled the model run time and did not lead to a significant improvement in stability.

TUFLOW

The TUFLOW dVol and 2D cumulative mass balance error plots for the modelled with climate change events are shown in Figure 2-8 and Figure 2-9 for fluvial and tidal events, respectively. The dVol plots shows the general pattern of floodwater entering (positive dVol values) and then leaving (negative dVol values) the (2D) floodplain. The key feature re model stability is that the dVol curves are smoothly varying with no sign of widespread flow oscillation between 1D and 2D domains. The TUFLOW 2D mass balance plots both record a period of high mass balance early in the model runs. This is common in 2D models when the number of wet cells is relatively small. More importantly, the cumulative mass balance settles down to be within a tolerance of ±1% for the remainder of the model run time before peak conditions are reached

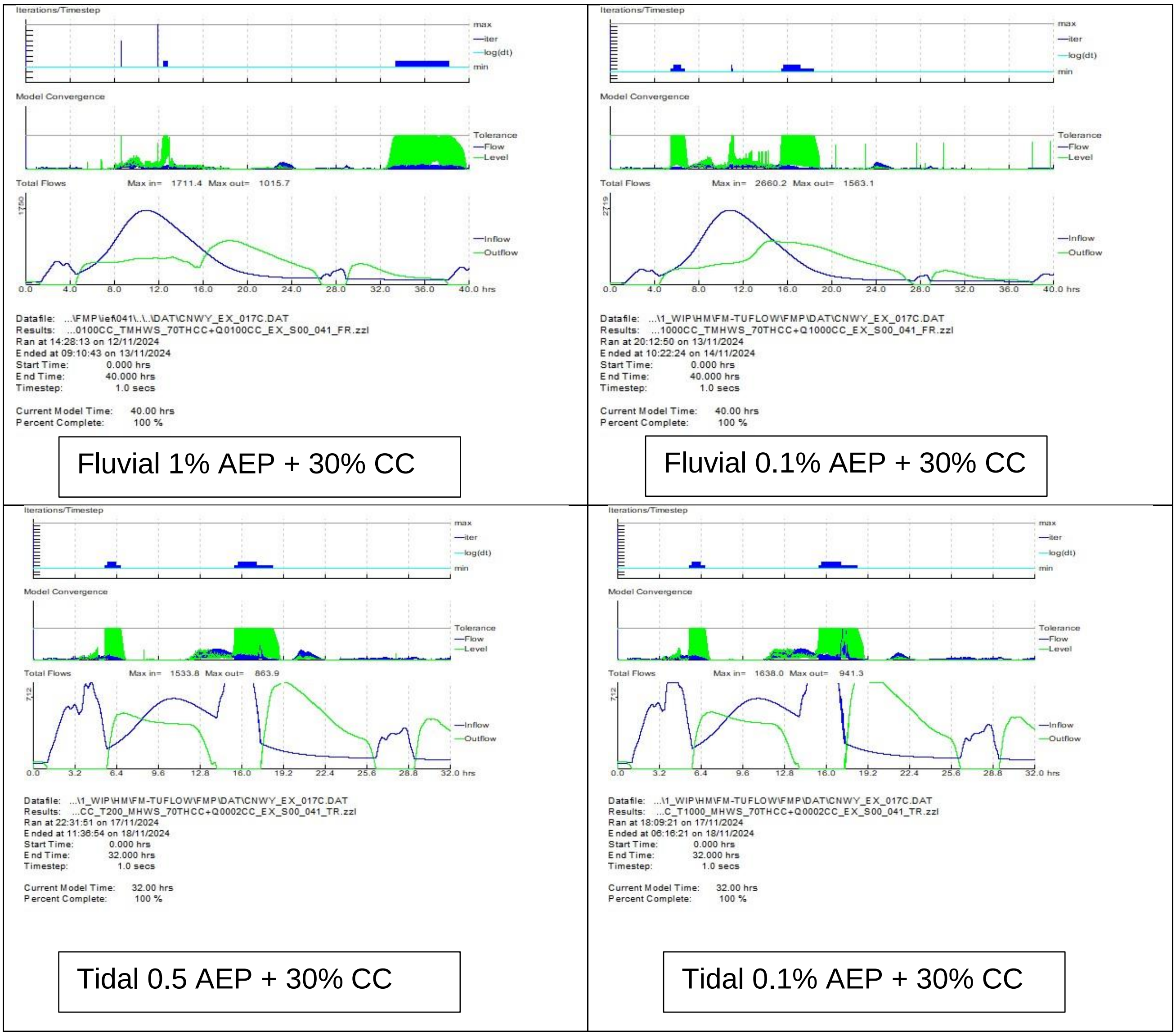

Figure 2-7 Flood Modeller Run Time Plots (existing risk model runs)

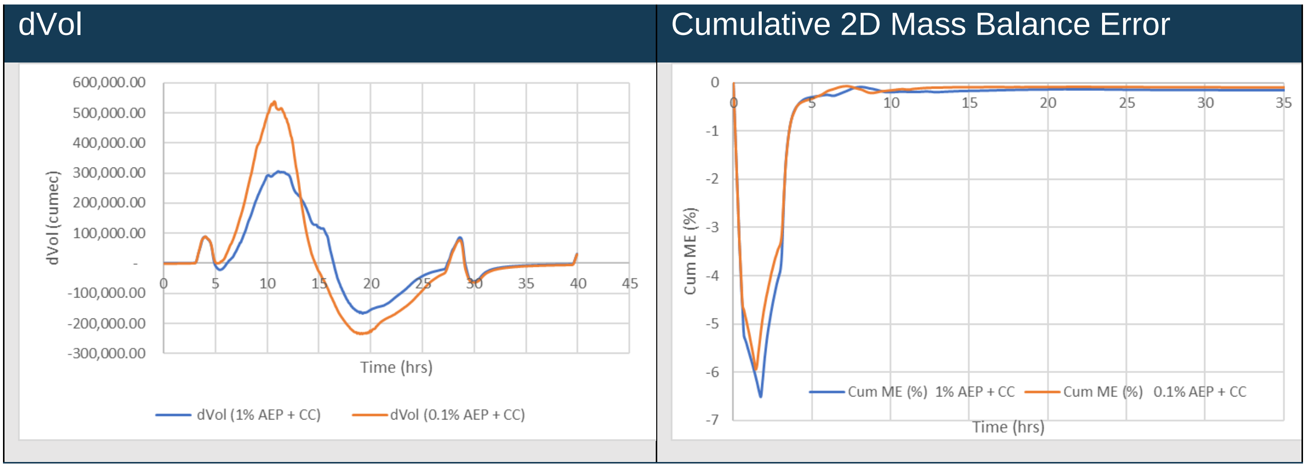

Figure 2-8 TUFLOW dVol and Mass Balance Plots for fluvial (existing risk) events

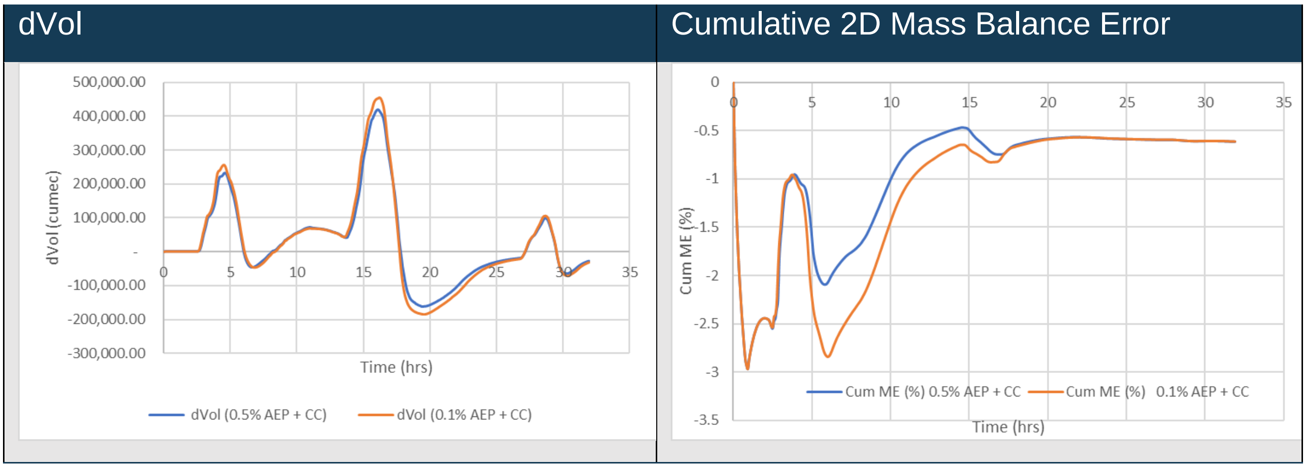

Figure 2-9 TUFLOW dVol and Mass Balance Plots for tidal (existing risk) events

2.6 Modelling Outcomes

The main outcomes of the hydraulic modelling of relevance to the FCA are included in the main FCA report. This section merely provides a little more information on the outcomes.

2.6.1 Fluvial Events

Figure 2-10 shows the modelled flood outlines in the vicinity of the site obtained from the fluvial 1% AEP and 0.1% AEP events both with and without climate change when the model is modelled at existing levels. This illustrates that low points identified in the site topographic survey allow floodwater from the Afon Conwy floodplain to enter the lagoon in a 0.1% AEP with climate change event.

2.7 Sensitivity Testing

No additional sensitivity testing was carried out for the FCA because the sensitivities of both Conwy models have previously been tested. As it was already a struggle to maintain stability for the 0.1% AEP plus climate change events using the standard (central) uplifts, it would been very difficult to obtain meaningful results based on worse case uplift.

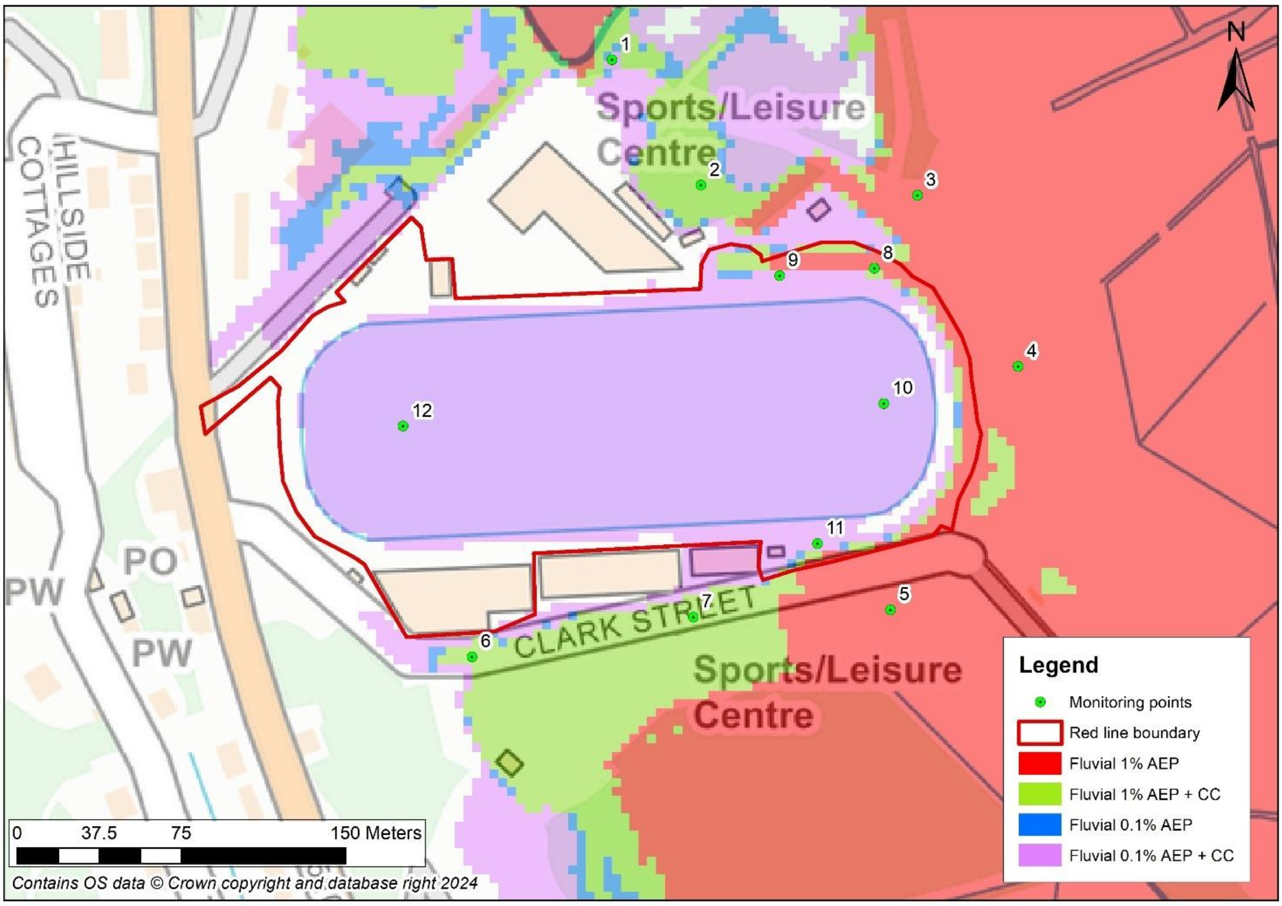

Figure 2-10 Modelled fluvial flood outlines with site at existing levels

Figure 2-10 also contains a series of numbered monitoring points in the vicinity of the site. The modelled peak fluvial flood depths and levels at these monitoring points are shown in Table 2-4. Points 10 to 12 are located on the site so are highlighted in bold in Table 2-4, which demonstrates that the lagoon is modelled to fill to a level of 6.64m AOD in the fluvial 0.1% AEP with climate change event in response to floodplain levels reaching 6.72m AOD to the south of the site and 6.69m AOD to the north of the site.

Table 2-4 Peak fluvial flood depths (metres) and levels (m AOD) at monitoring points

No	1% AEP		1% AEP + CC		0.1% AEP		0.1% AEP + CC	
	Depth	Level	Depth	Level	Depth	Level	Depth	Level
1	DRY	DRY	DRY	DRY	0.02	5.92	0.62	6.66
2	DRY	DRY	0.52	5.81	0.66	5.95	1.40	6.69
3	1.02	5.16	1.67	5.81	1.82	5.95	2.56	6.69
4	0.85	5.16	1.51	5.81	1.65	5.96	2.39	6.70
5	0.89	5.17	1.55	5.82	1.69	5.97	2.44	6.72
6	DRY	DRY	0.32	5.83	0.47	5.98	1.22	6.72
7	DRY	DRY	1.11	5.83	1.26	5.98	2.01	6.72
8	0.46	5.16	1.11	5.81	1.26	5.95	1.99	6.69

No	1% AEP		1% AEP + CC		0.1% AEP		0.1% AEP + CC	
	Depth	Level	Depth	Level	Depth	Level	Depth	Level
1	DRY	DRY	DRY	DRY	0.02	5.92	0.62	6.66
9	DRY	DRY	DRY	DRY	DRY	DRY	0.45	6.69
10	**DRY**	**DRY**	**DRY**	**DRY**	**DRY**	**DRY**	**1.24**	**6.64**
11	**DRY**	**DRY**	**DRY**	**DRY**	**DRY**	**DRY**	**0.38**	**6.72**
12	**DRY**	**DRY**	**DRY**	**DRY**	**DRY**	**DRY**	**1.24**	**6.64**

The currently consented platform level is a minimum of 6.86m AOD based on the previously modelled 0.5% AEP with climate change level of 6.26m AOD plus a 600mm freeboard. The fluvial 0.1% AEP with climate change flood outline obtained when the site periphery is modelled at the consented levels is compared with the outline of the same event modelled with the site at existing levels in Figure 2-11. This shows that the lagoon does not flood in this event with the site at consented levels. A comparison of the modelled flood levels from both scenarios is made in Table 2-6 and Figure 2-12, which show that the impact of adjusting the site to the previously consented levels would be minimal.

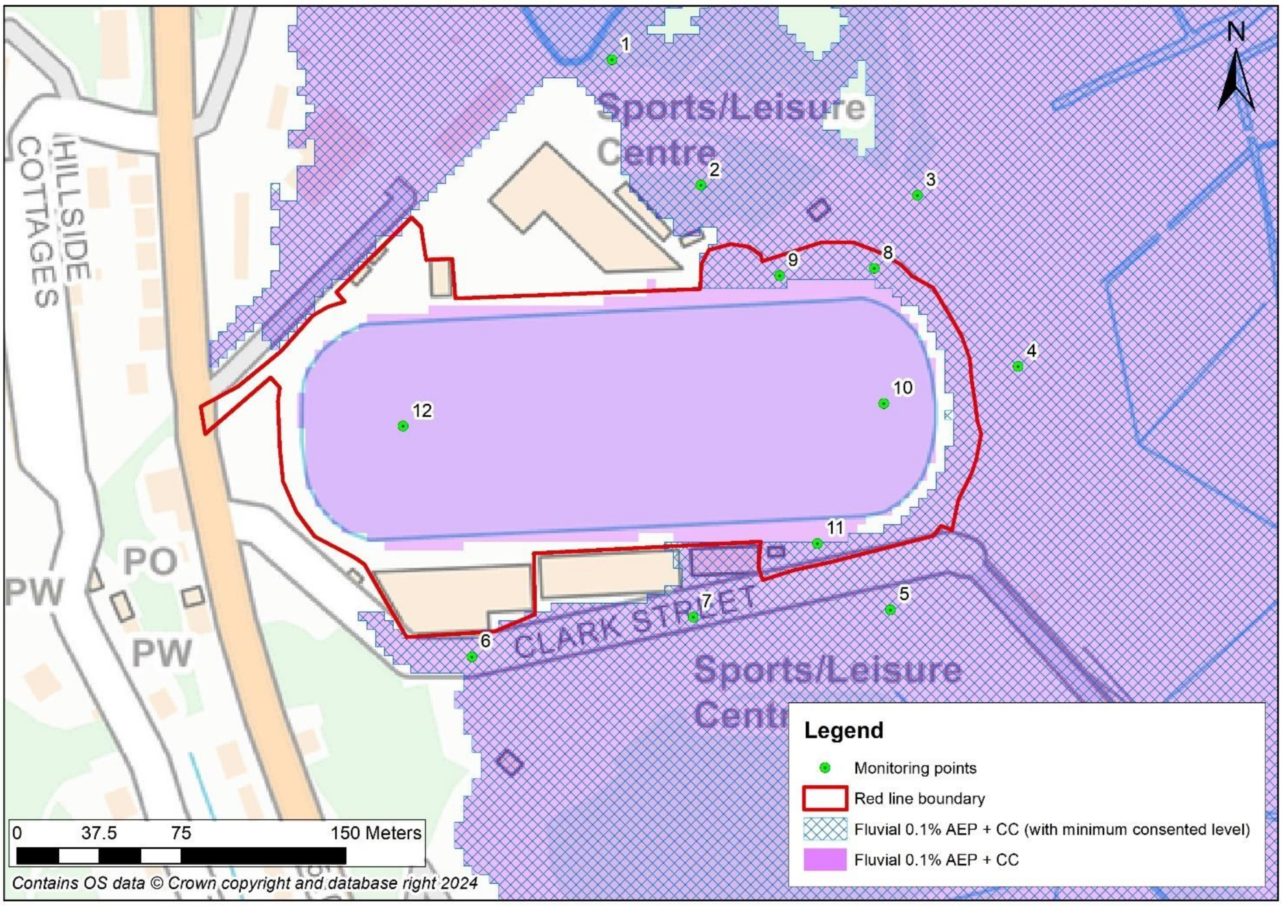

Figure 2-11 0.1% AEP with climate change flood outlines with site at existing vs consented levels

Table 2-5 Comparison of fluvial 0.1% AEP with climate change flood levels (in m AOD)

No	Site at Existing Levels	Site at Consented Levels	Difference
1	6.663	6.665	0.002
2	6.689	6.692	0.003
3	6.693	6.695	0.002
4	6.698	6.700	0.002
5	6.718	6.720	0.002
6	6.723	6.725	0.002
7	6.722	6.724	0.002
8	6.693	6.697	0.004
9	6.693	6.697	0.004
10	6.639	DRY	-
11	6.721	6.722	0.001
12	6.640	DRY	-

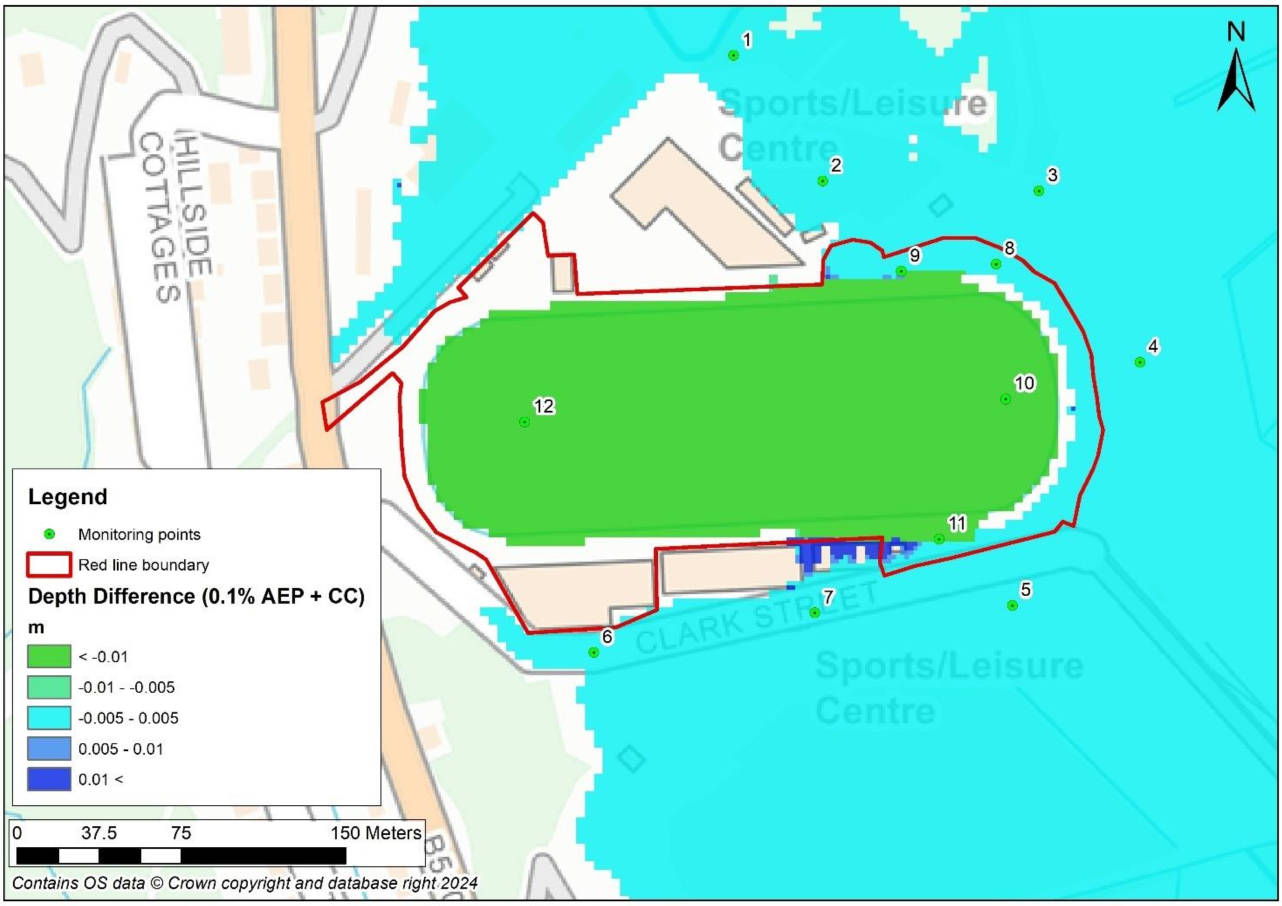

Figure 2-12 Depth difference map of fluvial 0.1% AEP with climate change

2.7.1 Tidal Events

Figure 2-13 shows the modelled flood outlines in the vicinity of the site obtained from the tidal 0.5% AEP and 0.1% AEP events both with and without climate change when the model is modelled at existing levels. These illustrate that the site was modelled to remain above all of these modelled events so there was no tidal inundation of the site.

The modelled peak flood levels and depths at several monitoring points in the vicinity of the site are provided in Table 2-6, from which it is evident that the tidal 0.5% and 0.1% AEP with climate change levels peak at 6.08 and 6.34m AOD, respectively, adjacent to the site. The letter is around 0.1 metres below the current low point on the path in the south-eastern corner of the site but around 0.5 metres below the previously consented level of the development.

Note that as the site was not modelled to flood from tidal events when at existing ground levels, there was no need to model the site, separately, at previously consented ground levels.

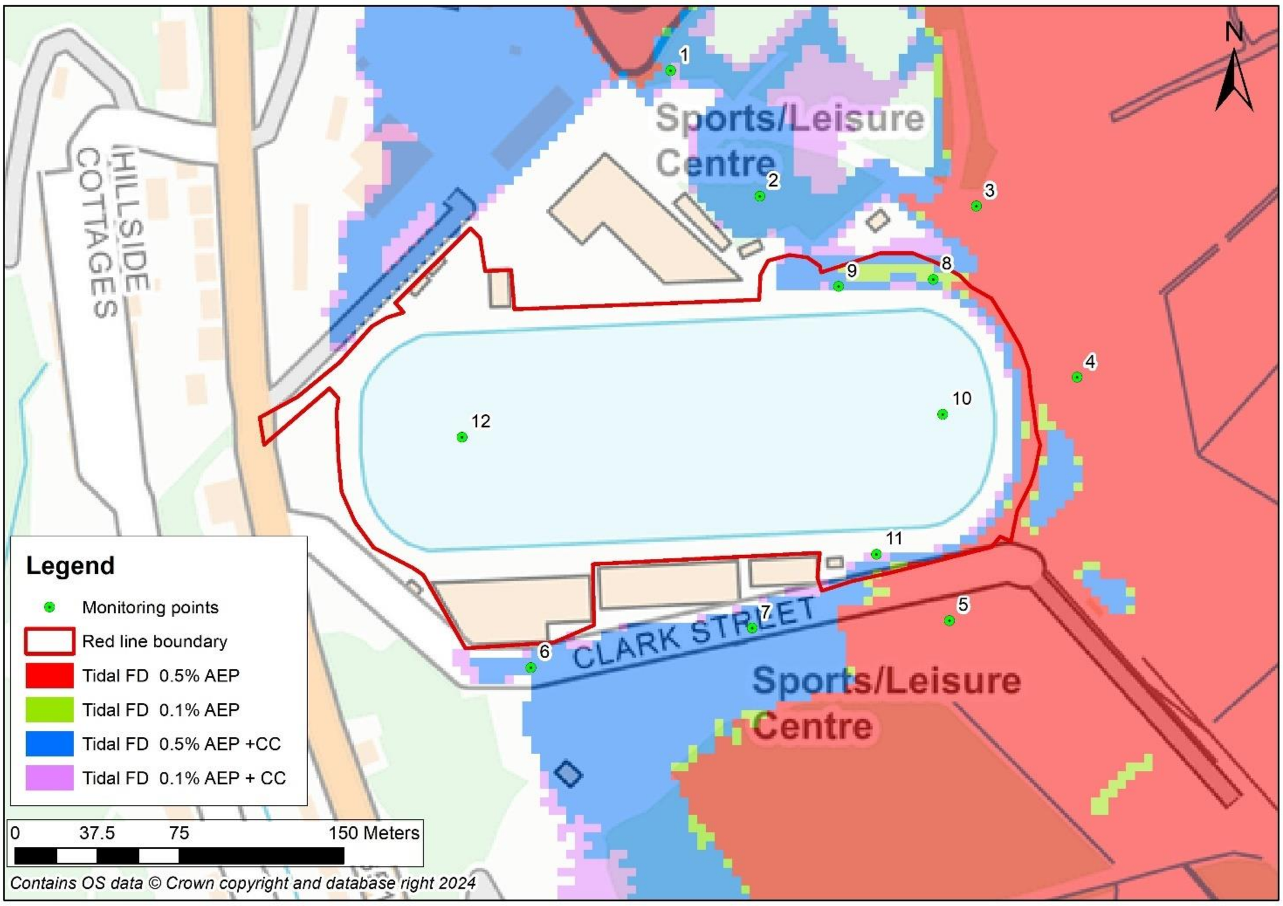

Figure 2-13 Modelled tidal flood outlines

Table 2-6 Peak tidal flood depths (metres) and levels (m AOD) at monitoring points

No	0.5% AEP		0.5% AEP + CC		0.1% AEP		0.1% AEP + CC	
	Depth	Level	Depth	Level	Depth	Level	Depth	Level
1	DRY	DRY	0.09	6.07	DRY	DRY	0.27	6.32
2	DRY	DRY	0.78	6.07	DRY	DRY	1.04	6.33
3	0.56	4.69	1.93	6.07	0.75	4.88	2.20	6.33
4	0.38	4.69	1.76	6.07	0.57	4.88	2.03	6.33
5	0.41	4.69	1.79	6.07	0.60	4.88	2.06	6.34
6	DRY	DRY	0.58	6.08	DRY	DRY	0.84	6.34
7	DRY	DRY	1.36	6.08	DRY	DRY	1.62	6.34
8	DRY	DRY	1.38	6.08	0.18	4.88	1.65	6.34
9	DRY	DRY	0.02	6.08	DRY	DRY	0.15	6.34
10	**DRY**	**DRY**	**DRY**	**DRY**	**DRY**	**DRY**	**DRY**	**DRY**
11	**DRY**	**DRY**	**DRY**	**DRY**	**DRY**	**DRY**	**0.08**	**6.35**
12	**DRY**	**DRY**	**DRY**	**DRY**	**DRY**	**DRY**	**DRY**	**DRY**

2.7.2 Breach Models

As detailed in Section 2.4, a set of breach models were simulated to evaluate the impact of local defence failure of the Conwy embankments in the vicinity of Dolgarrog (see Figure 2-6). Figure 2-14 depicts the modelled flood outlines obtained from modelling the two breaches during a fluvial 0.1% AEP with climate change event with the site at existing levels and Figure 2-15 does likewise for the tidal 0.1% AEP with climate change event. Peak flood depths and flood levels at the various monitoring points shown in these figures are provided in Table 2-7 and Table 2-8 for the fluvial and tidal events, respectively. Finally, Figure 2-16 and Table 2-9 show the outcome of the breaches when a fluvial 0.1% AEP with climate change event was run through the version of the model with the site at existing levels.

The main outcome of the breach modelling is that the risk is not significantly changed from the existing risk situation (i.e., with the defences retained at crest level) from either breach location. The flood levels outside the site due to the breaches were modelled to peak up to 0.02 metres higher than the existing risk situation in the fluvial event but there was no significant difference in peak level in the tidal event. The reason that defence failure has such a small impact on the flood risk at the site is because, in the extreme event being modelled here, the flood level in the Afon Conwy near Dolgarrog peaks at a much higher level than the local defence crests so the defences are already significantly overtopped in the existing risk scenario.

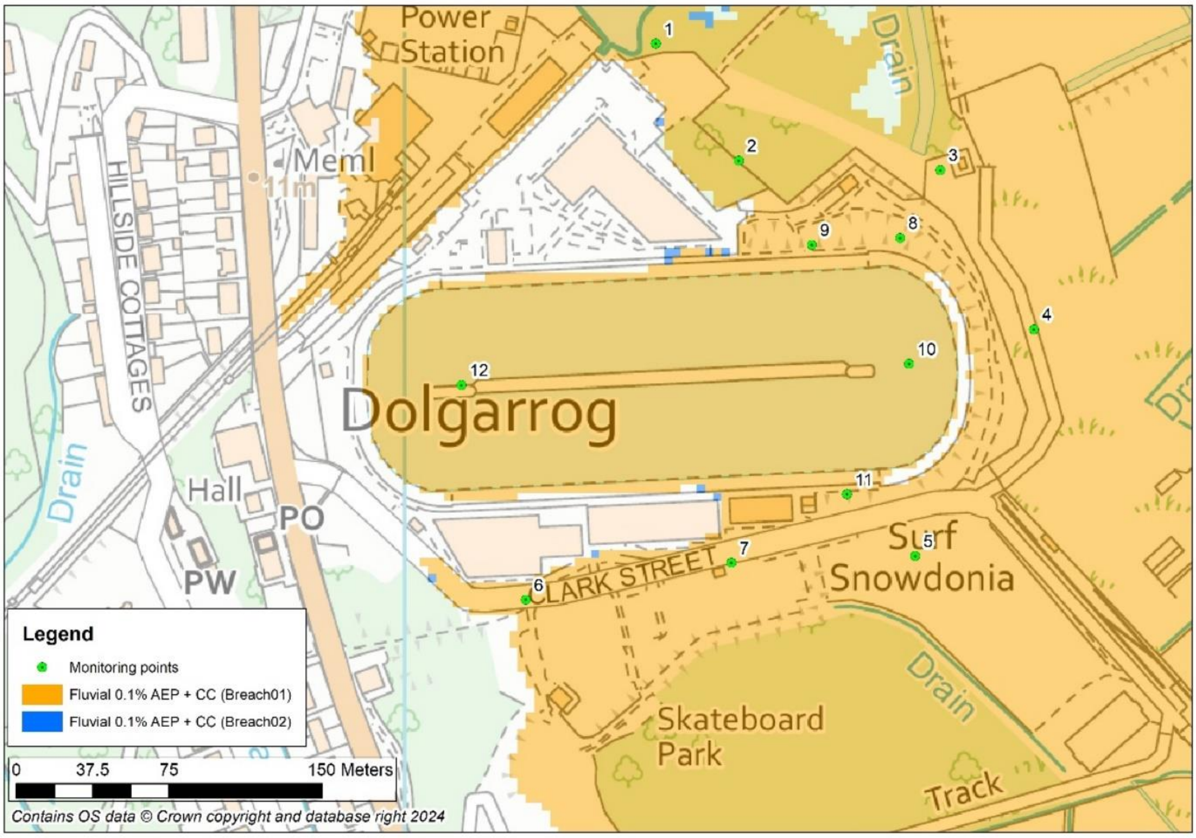

Figure 2-14 Modelled fluvial flood outlines with site at existing levels

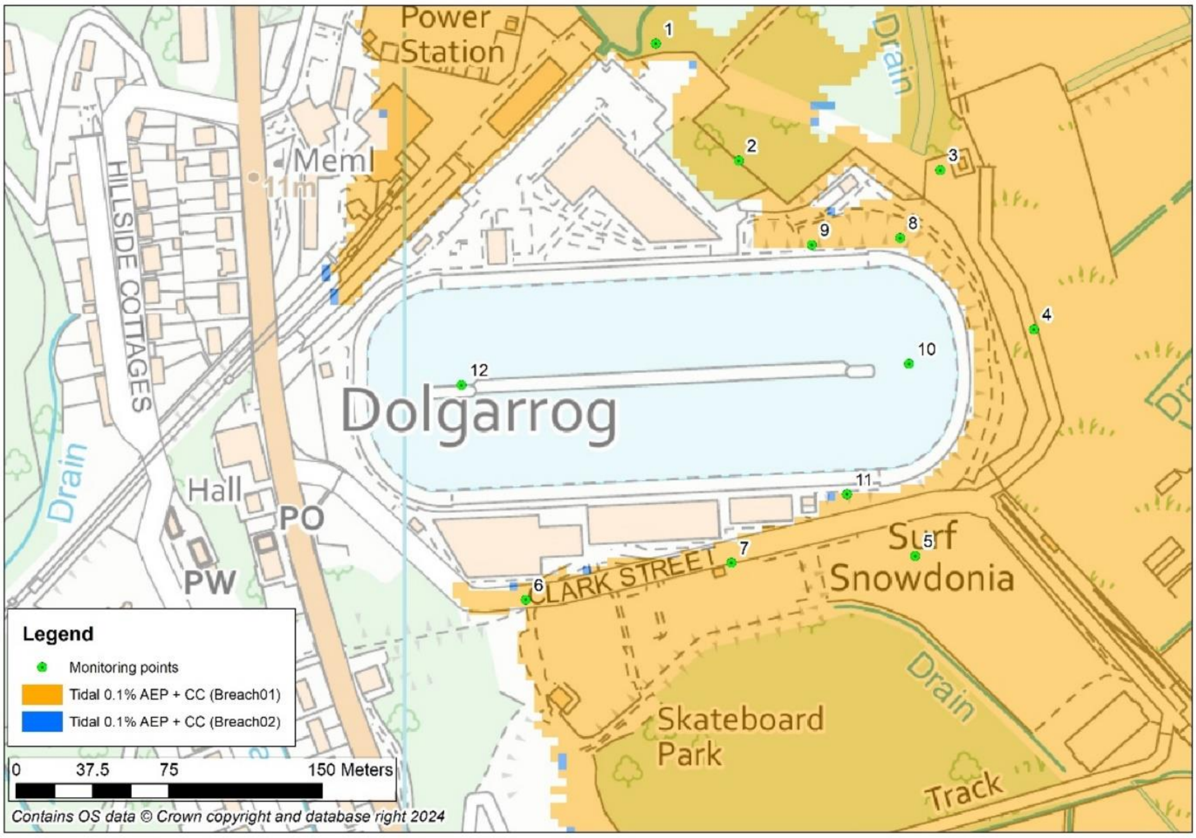

Figure 2-15 Modelled Tidal flood outlines with site at existing levels

Table 2-7 Peak flood depths (metres) and levels (m AOD) at monitoring points from breach models for fluvial event

Monitoring point	Fluvial Flood Depth in m (0.1% AEP + CC)		Fluvial Flood Level in m AOD (0.1% AEP + CC)	
	Breach 01	Breach 02	Breach 01	Breach 02
1	0.62	0.63	6.67	6.67
2	1.40	1.41	6.69	6.70
3	2.56	2.57	6.70	6.70
4	2.39	2.40	6.70	6.71
5	2.44	2.45	6.72	6.73
6	1.22	1.23	6.73	6.73
7	2.01	2.01	6.73	6.73
8	2.00	2.00	6.70	6.70
9	0.45	0.45	6.70	6.70
10	1.26	1.28	6.66	6.68
11	0.39	0.40	6.72	6.74
12	1.26	1.29	6.66	6.69

Table 2-8 Peak flood depths (metres) and levels (m AOD) at monitoring points from breach models for Tidal event

Monitoring point	Tidal Flood Depth in m (0.1% AEP + CC)		Tidal Flood Level in m AOD (0.1% AEP + CC)	
	Breach 01	Breach 02	Breach 01	Breach 02
1	0.27	0.28	6.32	6.32
2	1.04	1.05	6.33	6.34
3	2.20	2.20	6.33	6.34
4	2.03	2.03	6.33	6.34
5	2.06	2.07	6.34	6.34
6	0.84	0.85	6.35	6.35
7	1.63	1.63	6.34	6.35
8	1.64	1.65	6.34	6.35
9	0.15	0.16	6.34	6.34
10	DRY	DRY	DRY	DRY
11	0.08	0.08	6.35	6.35
12	DRY	DRY	DRY	DRY

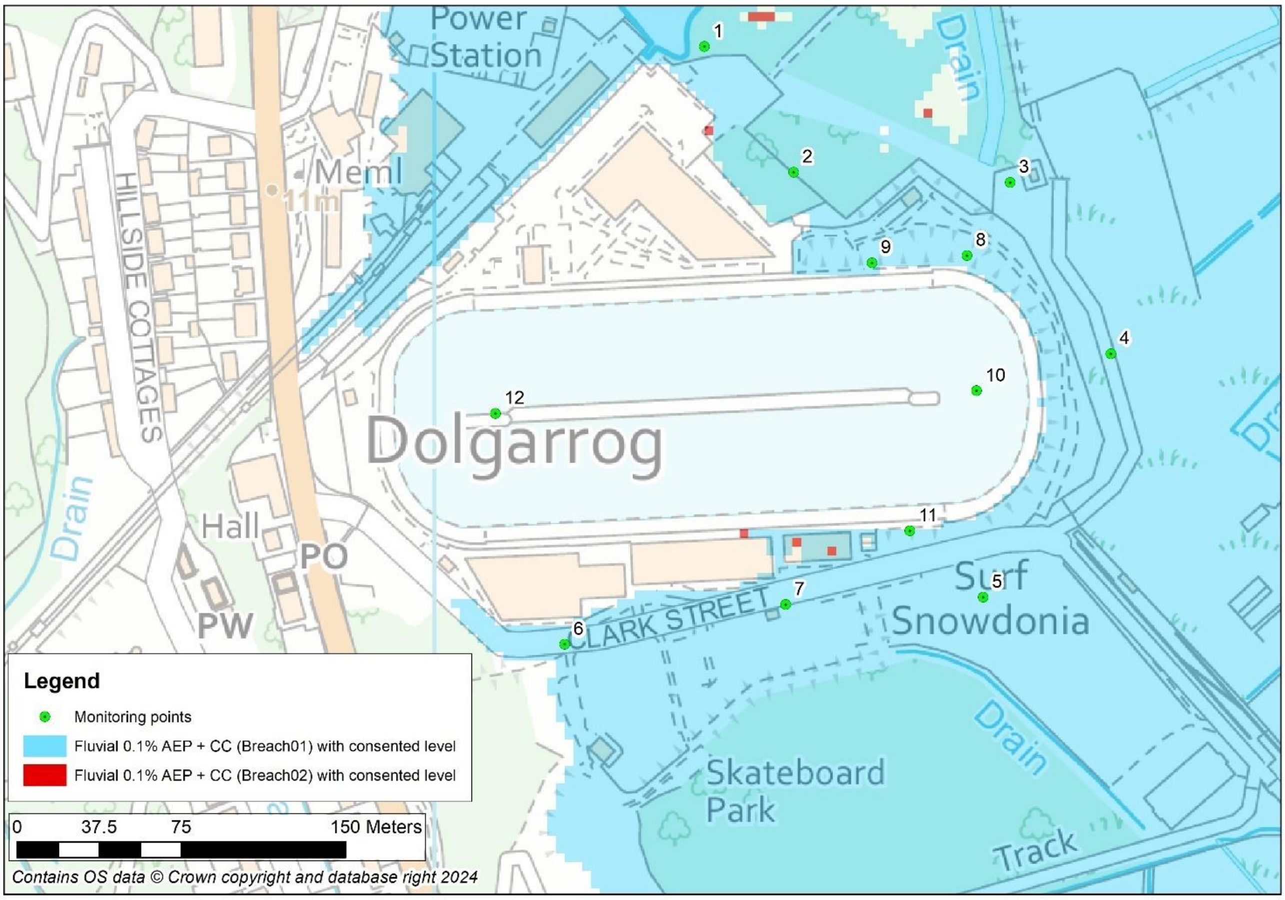

Figure 2-16 Modelled fluvial flood outlines with site at consented levels

Table 2-9 Peak flood depths (metres) and levels (m AOD) at monitoring points from breach models for fluvial event at consented level

Monitoring point	Tidal Flood Depth in m (0.1% AEP + CC)		Tidal Flood Level in m AOD (0.1% AEP + CC)	
	Breach 01	Breach 02	Breach 01	Breach 02
1	0.62	0.63	6.67	6.68
2	1.41	1.41	6.70	6.70
3	2.56	2.57	6.70	6.70
4	2.40	2.40	6.70	6.71
5	2.45	2.45	6.72	6.73
6	1.23	1.23	6.73	6.74
7	2.01	2.02	6.73	6.73
8	2.00	2.01	6.70	6.71
9	0.45	0.46	6.70	6.71
10	DRY	DRY	DRY	DRY
11	0.27	0.27	6.73	6.73
12	DRY	DRY	DRY	DRY

3 Conwy Estuary (Tidal Prism) Model

3.1 Introduction

Because the Adventure Parc location is sensitive to the downstream boundary of the Conwy Valley model, it was necessary to evaluate a suitable downstream boundary series for each of the events being modelled for the FCA. This was achieved by running tidal events through NRW's existing downstream Conwy Estuary (Tidal Prism) model (obtained under licence from NRW) and extracting the resulting level time series at Tal-y-Cafn from this model. The Conwy Estuary model is a 2D (TUFLOW) only model of the Afon Conwy estuary between Tal-y-Cafn and the Irish Sea, which has a cell size of 10 metres and an active 2D domain of 25.7km^2 (Figure 3-1).

3.2 Methodology

The only change made to the supplied model configuration before setting up the required events was a quick conversion from TUFLOW Classic to TUFLOW GPU to speed up the model run times. Hence, the supplied model took around twelve hours to run in TUFLOW Classic[4], but the GPU version ran through in around one and a half hours. A comparison of the results between the two versions showed no observable difference in flood outlines and only a small (<0.05 metre) difference in peak water level at Tal-y-Cafn. Given that TUFLOW GPU utilises the HPC solver, which is volume conservative, these 2D only Conwy Estuary model runs will also be inherently more stable than running TUFLOW Classic, which in turn justifies the use of TUFLOW GPU for the FCA modelling.

To run the required events through the model it was then only necessary to create the appropriate hydraulic boundary series. The Conwy Estuary (Tidal Prism) model required the following two boundaries.

- A QT (flow time) boundary at the upstream extent for fluvial inflows. These were extracted from the Conwy Valley model of the relevant event.
- An HT (head-time) boundary across the mouth of the estuary to represent the offshore tidal series. These were supplied by JBA's coastal team using the guidance provided in the UK coastal extremes database combined with the 'Adaptation to Climate Change Wales' guidance for calculating climate change uplifts (as outlined in Section 1.3).

Eight boundary combinations were run through the Conwy Estuary model to generate boundary conditions at Tal-y-Cafn for use in the Conwy Valley model. These are listed in Table 3-1 and illustrated in Figure 3-2 and Figure 3-3 for the inflow boundaries and calculated offshore tidal series, respectively.

[4] Note that a re-run of the tidal 0.1% AEP event in Classic took 24 hours but this extended run time is likely because multiple Tidal Prism models were being run at the same time.

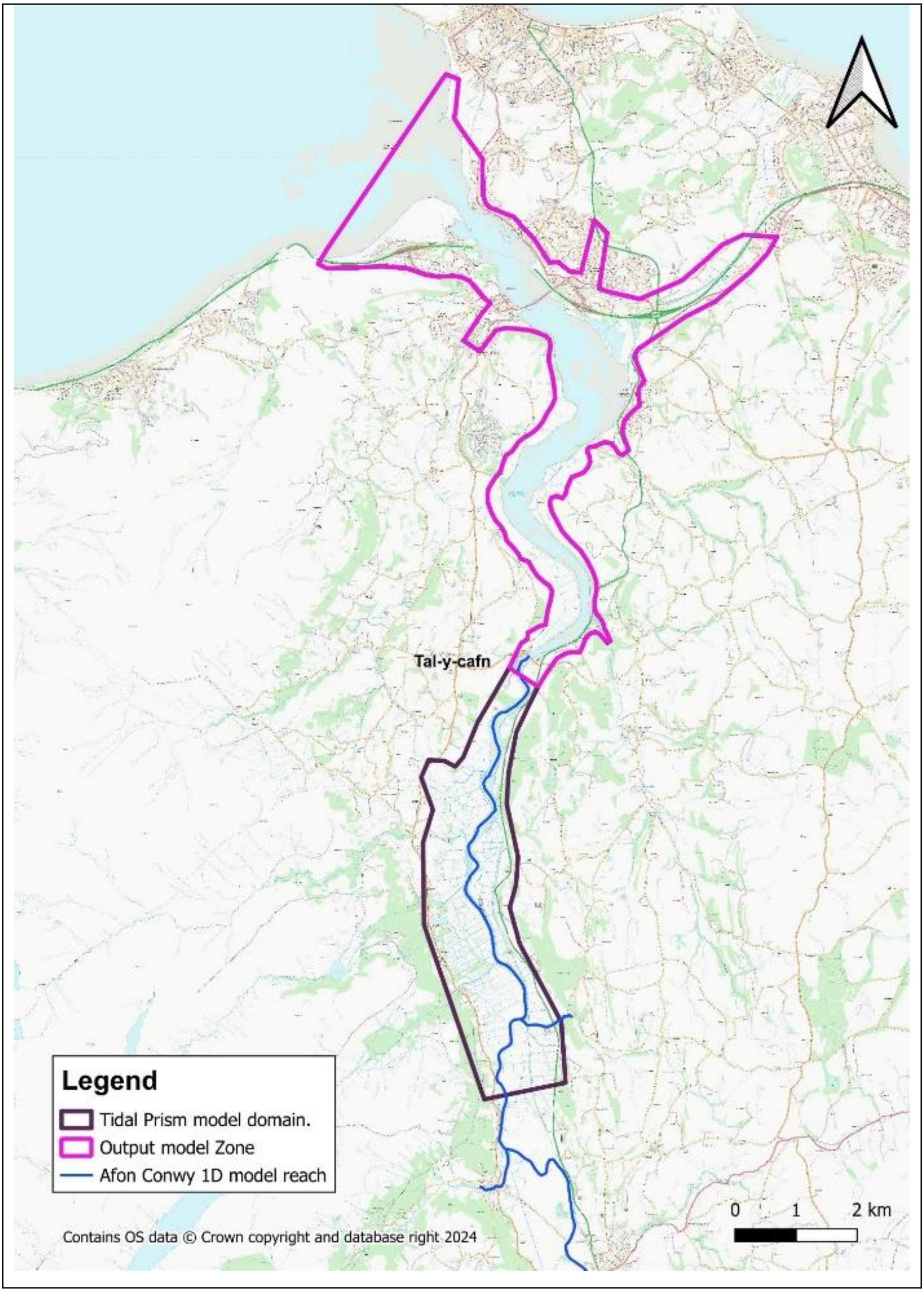

Figure 3-1 Extents of NRW's Conwy Valley and Conwy Estuary (Tidal Prism) models, illustrating the importance of using the Estuary model to obtain downstream boundaries for the Valley model

Table 3-1 Event combinations modelled to generate HT boundaries at Tal-y-Cafn

Upstream Boundary	Downstream Boundary
Fluvial Flood Risk	
1% AEP flow	MHWS series
1% AEP with Climate Change flow	MHWS with sea level rise
0.1% AEP flow	MHWS series
0.1% AEP with Climate Change flow	MHWS with sea level rise
Tidal Flood Risk	
50% AEP flow	1% AEP MHWS series
50% AEP with Climate Change flow	1% AEP MHWS series with Climate change
50% AEP flow	0.1% AEP MHWS series
50% AEP with Climate Change flow	0.1% AEP MHWS series with Climate change

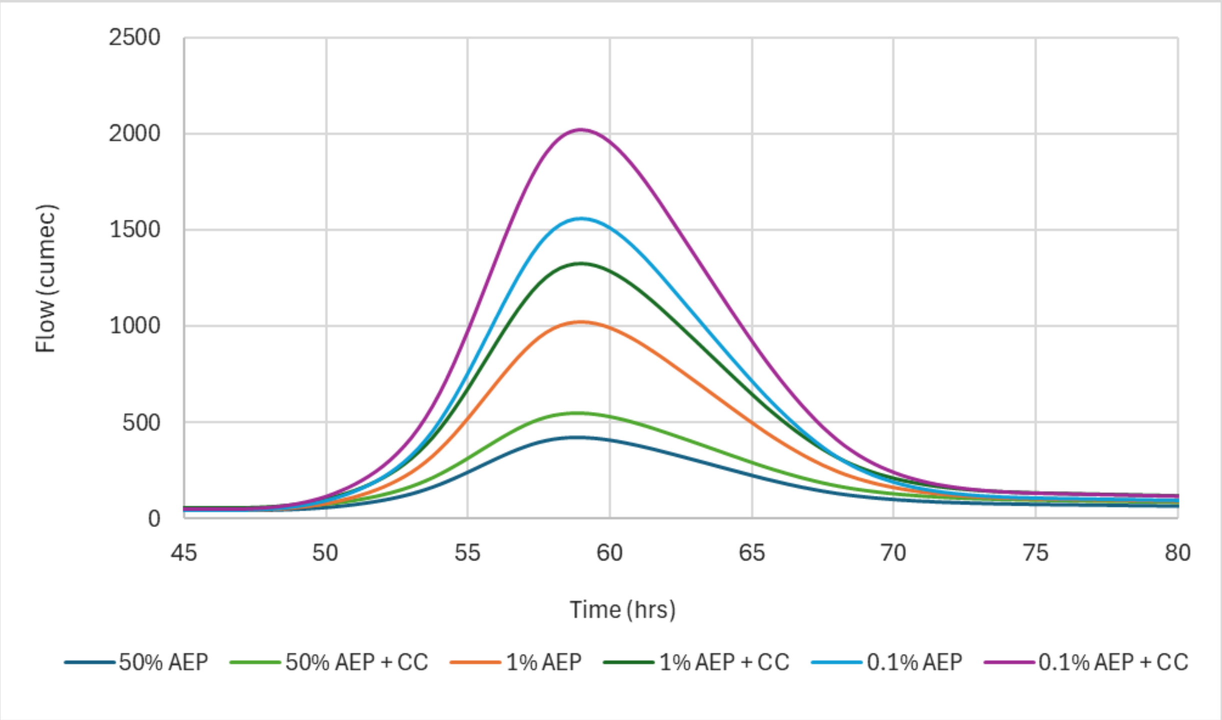

Figure 3-2 Fluvial inflow series used in Conwy Estuary (Tidal Prism) model simulations

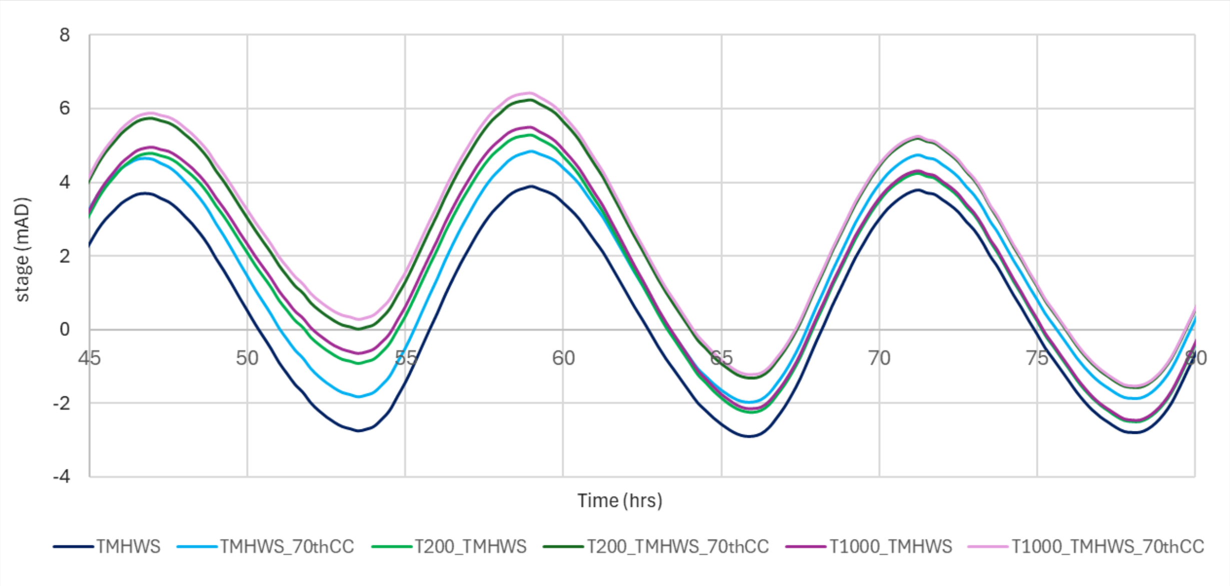

Figure 3-3 Tidal series used in Conwy Estuary (Tidal Prism) model simulations

3.2.1 Outcomes

The 2D flood outlines from the Conwy Estuary model are not discussed here as the only purpose of the using this model was to generate boundaries at Tal-y-Cafn for the Conwy Valley model. The resulting boundary series that were modelled and extracted from the Tidal Prism model at Tal-y-Cafn for use in the Conwy Valley model were illustrated in Figure 2-4 and Figure 2-5 for the modelling of fluvial and tidal events, respectively. Table 3-2 provides a summary of the peak boundary levels that were obtained at Tal-y-Cafn in response to each of the different fluvial/tidal joint probability combinations that were modelled. The peak calculated offshore tide levels are also provided for comparison with the levels obtained at Tal-y-Cafn.

Model stability was not an issue since this is a 2D only model that was run using TUFLOW HPC (GPU) and no stability issues were flagged in the TUFLOW log (tlf) files

Table 3-2 Calculated and modelled peak sea levels (m AOD) for specified events

Tidal	Fluvial	Offshore (Calculated)	Tal-y-Cafn (Modelled)
MHWS (2024)	1% AEP	3.90	4.07
MHWS + CC (2125)	1% AEP + CC	4.85	5.08
MHWS (2024)	0.1% AEP	3.90	4.43
MHWS + CC (2125)	0.1% AEP + CC	4.85	5.21
0.5% AEP (2024)	50% AEP	5.28	5.25
0.5% AEP + CC (2125)	50% AEP + CC	6.23	6.45
0.1% AEP (2024)	50% AEP	5.48	5.41
0.1% AEP + CC (2125)	50% AEP + CC	6.43	6.66

4 Summary and Limitations

4.1 Limitations of hydraulic model results

All studies involved in the prediction of flood risk, especially involving extreme and future (with climate change) risks, are subject to a set of assumptions and limitations, given the nature of trying to represent real-world scenarios with the use of equations and computer software. The following limitations and assumptions have been recognised in this FCA modelling.

- The fluvial flows used in this study were signed off by NRW in 2023 and the tidal extreme boundaries were obtained by following best practice, which should provide a measure of confidence in the model boundaries. However, it is recognised that these model boundaries are based on idealised design event profiles (rainfall hyetograph, fluvial inflow hydrograph or tidal boundary series) that have been scaled up to extreme events. Idealised (single peaked) events cannot be guaranteed in future and the interpolations involved in these scaling processes will become progressively more uncertain as the event magnitude increases.
- The climate change allowances applied in this study follow current best practice as documented in the latest Welsh Government guidance. However, it should be recognised that there is still a high degree of uncertainty over the impacts of climate change on fluvial flows and extreme sea levels over the modelled 100-year lifetime of the development.
- Both the Conwy Valley and Conwy Estuary models supplied by NRW have been updated by NRW in recent years and were considered fit for informing the Adventure Parc FCA (subject to the minor updates discusses in the main text). Furthermore, NRW has calibrated the Conwy Valley model against several high flow events in recent years, which has provided some confidence that the model can broadly match the observations made during these historic events. However, these events will have been of lower magnitude than the extreme events required for the FCA.
- The FCA has modelled the Conwy Valley on the assumption that existing (or previously consented) ground levels and land-uses are maintained across the catchment for the lifetime of the proposed development. However, these conditions and flood modelling guidance will likely change over the next 100 years.
- The FCA presents the results of flood events during which either a fluvial or tidal source is dominant because this is the way that design flood events are typically modelled. In reality, different magnitudes of fluvial and tidal event could combine to cause flooding. A detailed joint probability exercise was not undertaken for the FCA so the FCA assumes that no joint probability combination would lead to a worse outcome for the site than those that have been modelled.

- Because the FCA required the modelling of some extreme future events, several stability measures were needed to ensure that the models ran to completion and did not lead to obviously unstable results. These stability measures have the potential to impact on the model results but without these measures there would be much less confidence in the outcomes.

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