Llywodraeth Cymru / Welsh Government

A487 New Dyfi Bridge

Environmental Statement – Volume 3: Appendix 15.8

Flood Consequences Assessment

900237-WHS-ZZ-ZZ-RP-ZX-00001

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1 The Project

1.1 Context

The A487 forms an important part of the Welsh north-south and east-west trunk road network. The existing bridge, Pont-ar-Ddyfi, is a pinch point on the network. The structure was not designed to carry the volume and type of traffic that it experiences today. The bridge is Grade II* listed which restricts the options for altering the bridge.

In addition, the floodplain of the River Dyfi frequently floods, causing the A487 trunk road to be closed and severing the local communities either side of the river.

1.2 Background

The bridge is regularly closed through the winter months as a result of flooding, structural damage caused by flood waters, and traffic accidents. During closures, trunk road traffic is required to take a diversion of approximately 30 miles, approximately 10 miles for non-trunked road traffic. Figure 1 illustrates flood waters flowing over the A487, looking northwards towards Pont-ar-Ddyfi.

Figure 1: Flooding across the A470, looking north towards Pont-ar-Ddyfi from Machynlleth; Source: http://www.ukweatherworld.co.uk/forum/index.php?/topic/82834-postcard-from-machynlleth-13th-jan-2011-floods/

1.3 The Scheme

It is proposed to build a new single carriageway road joining the existing A487 south east of Pont-ar-Ddyfi. The new road will cross the River Dyfi approximately 480m upstream of the existing bridge. This new stretch of road will become the A487, with the existing road north of the bridge becoming the A493. The bridge will be elevated above ground levels on piers, which will be spaced at typically 34m intervals. No piers will be constructed within the existing River Dyfi channel. The majority of the structure will be launched off a temporary platform/embankment north of the Dyfi Eco Park, with the main river spans and curved southern section traditional crane lifted. The existing road will form a junction at the Dyfi Eco Park, and will be raised up to the new road levels on embankment. The proposed scheme layout is detailed in the design drawings which are included in Appendix B herewith.

The existing bridge structure will remain in-situ due to its listed status. The function of the bridge and associated access road will remain as a Non-Motorised User (NMU) crossing of the River Dyfi, with restricted vehicular access.

As part of the scheme, a new flood embankment will be constructed along the northern edge of the Dyfi Eco Park to provide a flood defence with a standard level of protection up to the 1 in 100 year plus climate change flood event.

1.4 The Project Objectives

The following Transport Planning Objectives (TPOs) for the scheme were developed during the WelTAG Planning Stage and reported in the WelTAG Planning Stage Report (April 2012).

- TPO1 - To improve the reliability of crossing the Afon Dyfi for people, freight and emergency vehicles on A487 strategic corridor.
- TPO2 - To improve efficient and reliable accessibility to key services including employment opportunities, healthcare and education.
- TPO3 - To maintain the role of Machynlleth as a vibrant and sustainable local centre.
- TPO4 - To preserve the long-term integrity of Pont-ar-Ddyfi.
- TPO5 - To reduce the number and severity of collisions and casualties on the A487 in the study area.
- TPO6 - To ensure that flood risk to third parties is not increased.
- TPO7 - To minimise the impact of transport improvements on the landscape, biodiversity, water resources and heritage.
- TPO8 - To increase the opportunity for efficient, safe and reliable travel by walking and cycling on the A487 corridor within the study area.

2 Purpose of the Report

This Flood Consequences Assessment (FCA) will address the key flood risk issues associated with the proposed scheme. The FCA is informed by detailed hydraulic modelling of the River Dyfi, and is carried out in accordance with the requirements set out in the most up-to-date and relevant guidance. Specifically, this FCA refers to the Design Manual for Roads and Bridges, and Planning Policy Wales (with particular regard to TAN15).

2.1 Design Manual for Roads and Bridges

The Design Manual for Roads and Bridges (DMRB) sets out the design constraints for new road infrastructure. With regard to the management of flood risk, transport infrastructure in the functional floodplain must be designed and constructed to:

i) Remain operational and safe for users in times of flood;

ii) Result in no net loss of floodplain storage;

iii) Not impede water flows; and

iv) Not increase flood risk elsewhere.

The DMRB outlines the possible flooding risks and impacts to local drainage. Where construction is proposed within the floodplain, it is recommended that the relevant environmental agency should be consulted as early as possible where proposed projects may have an impact on a floodplain or local drainage and the parameters for the assessment established.

The general procedure for assessing impacts on the water environment as part of any environmental assessment process, including an FCA, should follow the principles as set out in DMRB Volume 11, Sections 1 and 2.

This FCA is primarily concerned with assessing the flood impacts, which follows Methods E (Hydrological Assessment of Design Floods) and F (Hydraulic Assessment), as set out in Annex I of the DMRB.

2.2 Planning Policy Wales

Planning Policy Wales (PPW) sets out the land use planning policies of the Welsh Government. PPW promotes a sustainable approach and sets out a precautionary framework for development. It is supplemented by a series of Technical Advice Notes (TANs). TAN15 addresses development and flood risk.

Chapter 13 of PPW states that in areas of flood plain currently unobstructed, where water flows in times of flood, built development should be wholly exceptional and limited to essential transport and utilities infrastructure. Such infrastructure should be designed and constructed so as to remain operational even at times of flood, to result in no net loss of floodplain storage, to not impede water flows and to not increase flood risk elsewhere.

The overarching aim of the precautionary framework is, in order of preference, to:-

- Direct new development away from those areas which are at high risk of flooding.
- Where development has to be considered in high risk areas (Zone C) only those developments which can be justified on the basis of the tests outlined in Section 6 and Section 7 of PPW Chapter 13 are located within such areas.

The precautionary framework identifies the vulnerability of different land uses to flooding and, for this purpose, development has been subdivided into three categories: Emergency Services; Highly Vulnerable Development; and Less Vulnerable Development. Transport infrastructure is classified as Less Vulnerable Development according to TAN 15.

Development, including transport infrastructure, will only be justified if it can be demonstrated that:-

i. Its location in Zone C is necessary to assist, or be part of, a local authority regeneration initiative or a local authority strategy required to sustain an existing settlement; or,

ii Its location in Zone C is necessary to contribute to key employment objectives supported by the local authority, and other key partners, to sustain an existing settlement or region;

and,

iii It concurs with the aims of PPW and meets the definition of previously developed land (PPW fig 2.1); and,

iv The potential consequences of a flooding event for the particular type of development have been considered, and in terms of the criteria contained in Sections 5 and 7 and Appendix 1 of TAN15 found to be acceptable.

This FCA will seek to demonstrate that the proposed bridge development has considered the potential consequences of a flooding event, and that the development is acceptable with regard to Sections 5 and 7 and Appendix 1 of TAN15.

2.3 Assessment Approach

In order to inform this FCA, detailed hydraulic modelling of the River Dyfi was carried out. An existing model of the River Dyfi and Garsiwn tributaries around Machynlleth, developed by Natural Resources Wales (NRW) as part of the North Wales Work Package B in June 2011[1], was made available for use by NRW. This existing ISIS TUFLOW model did not extend as far as the proposed bridge location and was not considered sufficient for assessment of flood risk associated with the proposed bridge. Therefore, WHS has extended the model, using additional river channel and topographic survey data. Liaison with NRW established the required scope and extent of the additional survey, which is included in Appendix C

[1] Environment Agency Wales; Commission reference: WA029; North Wales Work Package B Machynlleth Study- Final; June 2011

herewith. Further details relating to the modelling approach can be found in the hydraulic modelling report, which is included in Appendix D.

The calculation methodology of hydrological inputs was discussed with NRW hydrology at the inception phase. Estimated peak flow inputs, as detailed within the *WHS1345_A487 Dyfi Bridge Hydrology_Finalv3* document', were agreed with NRW prior to the commencement of modelling. This is included as Appendix E herewith.

In order to establish a baseline model and provide a level of confidence in the model outputs, the extended model was submitted to NRW for a pre-application technical review. Following some initial comments from the Flood Risk Analysis team, further amendments were made to the model, and this was subsequently re-submitted to and accepted by NRW as appropriate for use to inform the design phase of the bridge.

The design phase has used an iterative approach to derive a scheme that ensures that the new crossing can remain compliant with the guidance detailed in Sections 2.1 and 2.2 of this report. This has involved consultation with NRW throughout to seek agreement on the appropriate type and scope of the assessment of the hydraulic regime, and the parameters to apply in judging the acceptability of the results for the investigations undertaken.

3 Existing Information

3.1 Site Context

The existing Pont-ar-Ddyfi is located approximately 1km to the north of Machynlleth town centre. The bridge approach road from Machynlleth travels across the River Dyfi floodplain, which primarily comprises of agricultural grazing land. The River Dyfi is well established at this location being some 3.5km upstream from the normal tidal limit, as indicated by OS mapping. It subsequently flows into the Dyfi Estuary and discharges into Cardigan Bay at Aberdovey. The River Dyfi is characterised by large meanders across the valley bottom, and LiDAR data indicate depressions and channel remnants within the floodplain. Furthermore, a network of field drainage ditches serve to drain the wide, flat floodplain. The existing A487 is elevated on embankment above the floodplain by 0.3-0.6m. A highway and land drainage ditch runs along the eastern edge of the existing A487 road, and flows in a southerly direction towards the Dyfi Eco Park. A number of culverts along the ditch allow access over this ditch off the A487 and into the agricultural fields. The ditch crosses underneath the highway via culvert to a short length of ditch to west of A487 before discharging into a culvert under the Cambrian railway line, where it subsequently flows into the Garsiwn Ditch.

Ground levels on the northern bank of the River Dyfi at Pont-ar-Ddyfi crossing rise steeply by some 30m, so that the A493 effectively defines the edge of the floodplain. Survey data indicate that the A487/A493 junction is set at approx. 10.2m AOD. The road rises steeply from 9.26m AOD to more than 14m AOD. There are a number of residential properties at the road junction, with 2 no. properties to the south of the A493 set lower than the road levels (Nos. 7 and 8). Survey data indicate that the threshold level of the basement of these two buildings is as low as 9.10m AOD.

Along the northern edge of the A493, there is a row of 6 no. terraced residential cottages. These buildings are also set slightly lower than the road levels, which is between the river and cottages. Survey data records that the threshold levels of these properties range between 9.09-9.61m AOD.

Figure 2 illustrates the existing Pont-ar-Ddyfi structure with the row of terraced cottages evident to the left. The rooftops of Nos. 7 & 8 can also be seen to the fore, with ‘Ysgoldy’ positioned on slightly higher ground on the far side of the A493.

Figure 3 illustrates floodwaters encroaching into the rear gardens of Nos. 7 & 8 during a flood event on the River Dyfi in November 2015, as viewed from Pont-ar-Ddyfi.

Figure 2: Existing A487 River Dyfi Bridge and residential properties at the northern junction; Image taken from http://www.russellgeorge.com/news/russell-george-am-welcomes-progress-new-dyfi-bridge

Figure 3: Flooding at properties (Nos 7 & 8) immediately upstream of the A487 River Dyfi Bridge; Credit: Love Tywyn; http://www.itv.com/news/wales/2015-11-15/150-homes-without-power-as-rain-and-winds-batter-wales/

3.2 TAN15 Development Advice Map

As set out in TAN15: 'Development and Flood Risk', the Development Advice Maps are used to provide advice on the development control process. These maps classify land according to the zone of risk (A, B, C, C1 and C2), and the acceptability of development within the zones is dependent on the development type, planning requirements and acceptability criteria. Transport is considered to be a less vulnerable development. It can be seen in Figure 4 that the existing Pont-ar-Ddyfi crossing is located within the River Dyfi floodplain and is land classified as Zone C2.

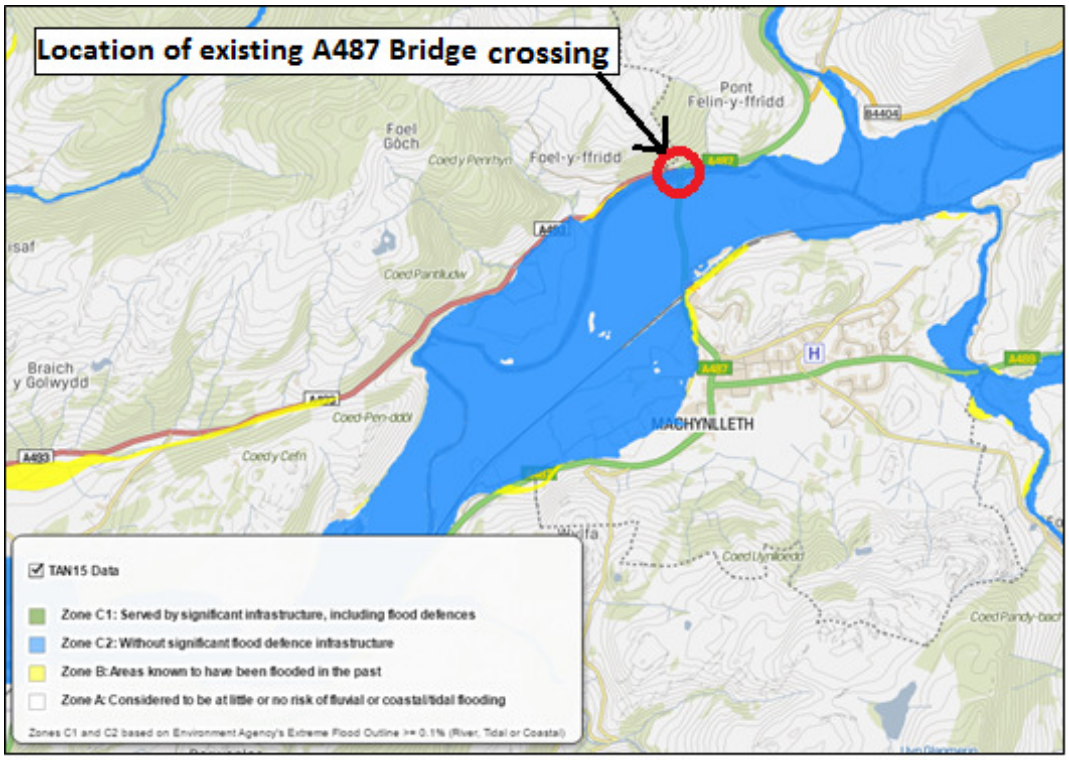


Figure 4: Welsh Government Development Advice Map for Pont-ar-Ddyfi

3.3 NRW Flood Map and Modelling

The NRW Flood Map is based on hydraulic modelling of the River Dyfi, which was undertaken as part of the Flood Risk Mapping Study for Machynlleth during the North Wales Work Package B. The conclusions of this study reported that in all model scenarios, the River Dyfi overtops its banks and floods the entire valley floor, with the exception of several small, isolated areas of high ground. The mapped flood extent is very similar for the 1 in 100 year and 1 in 1000 year flood events, which confirms the fact that the River Dyfi floodplain is well defined. The NRW Flood Map is shown in Figure 5 below.

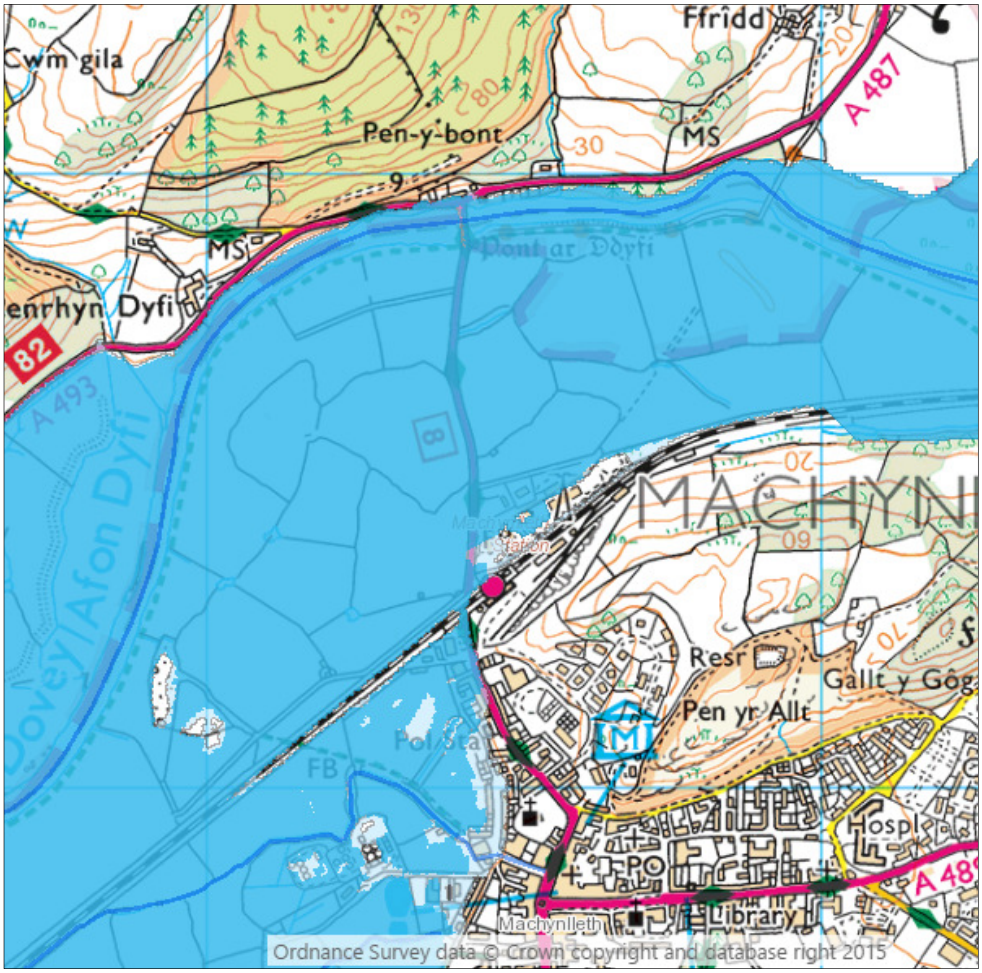


Figure 5: Natural Resources Wales Flood Map

3.4 Surface Water Flood Map

NRW has published its flood map for surface water, which provides the risk of flooding from surface water ranging from Low, Medium and High. It can be seen in Figure 6 below that there is a relatively low risk of surface water flooding across the Dyfi floodplain at the area of interest. Areas of medium to high risk are associated with the main River Dyfi channel and the network of drainage channels within the floodplain.

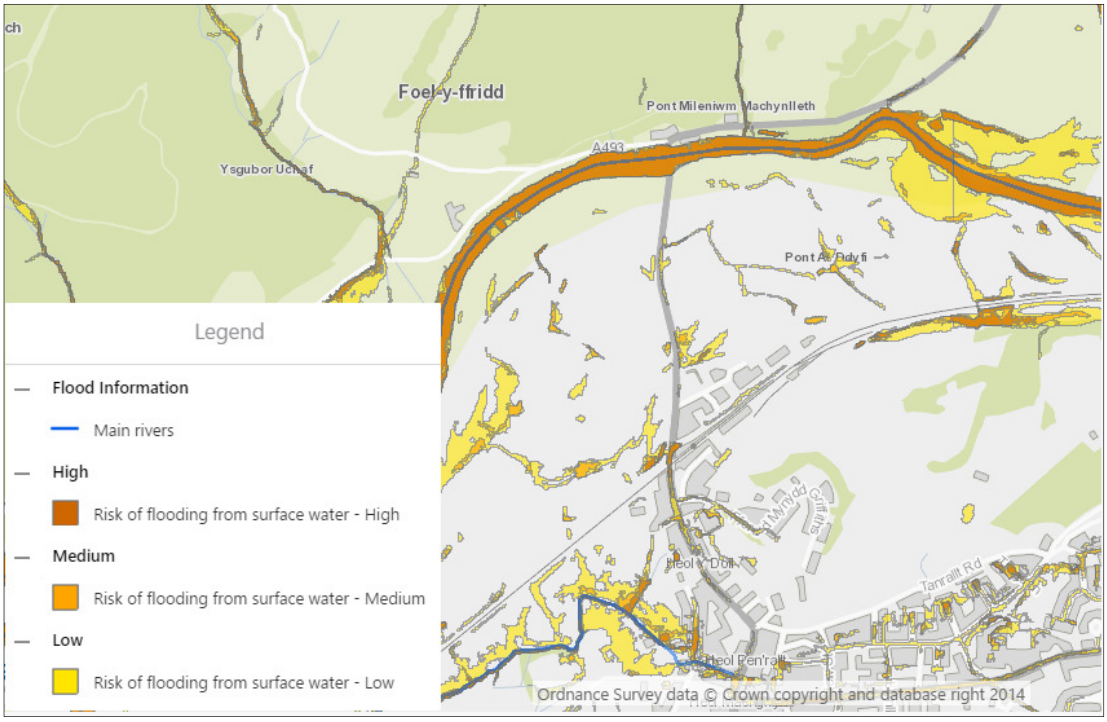


Figure 6: NRW Flood Map for Surface Water Flooding

3.5 Other Sources of Flooding

3.5.1 Groundwater Flooding

There are no known groundwater flooding issues within the immediate vicinity of the site of interest. Data available from the Soilscapes Map[2] indicate that the Dyfi floodplain generally comprises of freely draining acid loamy soils over rock, which drain to local groundwater and the river network. For the narrow river corridor associated with the River Dyfi, soils are classified as loamy and clayey floodplain soils with naturally high groundwater. These drain to local groundwater feeding into the river network.

3.6 Flood History

3.6.1 Historic Flooding at Pont-ar-Ddyfi

There are numerous accounts of flooding at Pont-ar-Ddyfi crossing and subsequent closure of the bridge, which is one of the principal reasons for the proposed works. Frequent flooding throughout the winter months is expected, with recent events causing delays to motorists with a significant traffic diversion. Notable events in recent history are detailed in Table 1.

[2] http://www.landis.org.uk/soilscapes/; Soils Data © Cranfield University (NSRI)

Date	Description	Source
Feb 1946	Extensive and severe flooding across numerous sections of Wales following 6.2in of rainfall in 24 hours (Llyn Llydaw intake, Snowdon).	North West Wales Catchment Flood Management Plan
Mar 1947	Abnormal flooding due to extensive winter snowmelt. Damaged approach embankment to railway bridge close-by to Machynlleth.	North West Wales Catchment Flood Management Plan
Feb 1952	Submergence of railway bridge due to flooding at Machynlleth.	North West Wales Catchment Flood Management Plan
Feb 2004	In the Wnion, Mawddach and Dyfi catchments, many roads and sections of agricultural land were flooded. The A478 across Dyfi in Machynlleth was damaged. Properties were unaffected.	North West Wales Catchment Flood Management Plan
Oct 2005	Heavy rainfall over a number of days caused extensive amounts of water to flow down the mountainsides which resulted in flooding along the major river valleys; causing sections of the Dyfi and Mawddach/Wnion to flood. Some A-roads were disrupted.	North West Wales Catchment Flood Management Plan
13 January 2011	Delivery van driver stranded in his vehicle in floods near Machynlleth on the A487 at Derwenlas. Flood waters estimated to be 3 feet (0.9m) deep.	BBC News website http://www.bbc.co.uk/news/uk-wales-12179323
13 January 2011	A487 in both directions and Pont-ar-Ddyfi Bridge closed due to flooding.	Traffic News Archive

Table 1: Records of Historic Flood Events at Machynlleth; extracted from the NRW report (Ref: WA029): ***North Wales Work Package B Machynlleth Study-Final (June 2011)***

In addition, recorded road closure dates have been recorded by the North Wales Trunk Road Agency (NMWTRA) and have been provided to inform this FCA and are summarised in Table 2.

Date of initial closure	Closure Length	Flood Level (mAOD)
5 December 2006	1 day	9.330
11 December 2006	3 days	9.602
18 January 2007	1 day	9.393
7 December 2007	2 days	9.559
20 January 2008	1 day	9.640
6 September 2008	1 day	9.348
5 October 2008	1 day	9.691
26 October 2008	1 day	9.618
6 December 2008	2 days	9.691 *NRW gauge data does not record any high flows on this date
18 November 2009	2 days	9.462 *NRW gauge data shows highest recorded level on this date
14 September 2010	2 days	9.538
15 January 2011	3 days	Unknown
5 February 2011	36 hours	Unknown

Table 2: Records listing Pont ar Dyfi Flood Severance Periods due to Flooding, as provided by NMWTRA; NB. This record of closures is based on information provided by NMWTRA and may not record all historic closures. The information is provided for context.

During the winter of 2015/16, there were 6-7 further dates when the road was closed due to flooding.

3.6.2 Historic Flooding at Pen-y-Bont Cottages

Along the northern edge of the A493, there is a row of 6 no. terraced residential cottages. These buildings are set slightly lower than the road, which is located in between the river and cottages.

Gwynedd Council, as Lead Local Flood Authority, produced a report in December 2015 investigating flooding at the residential properties, Cottages Numbers 1 to 4. The report notes that these properties were flooded in December 2015, and that the area has a history of flooding. No details of the extent of flooding, or on the history was included.

From speaking with locals, and through observation on site, when river water levels rise above the A493 carriageway level, river water can currently flow through existing ‘letterbox’ drains in the stone parapet retaining wall, flooding the A493 and encroaching on Pen-y-Bont Cottages. River water is also reported to flow back through the piped highway drainage system indicating that existing flapped outfalls are not present or not functioning correctly.

4 Baseline Flood Risk

An assessment of the existing hydrological regime has been carried out in order to inform this FCA. For a detailed methodology and approach, this FCA should be read in conjunction with the Hydraulic Modelling Report (Ref: *A487 New Dyfi Bridge - Modelling Report v2.3*), which is included as Appendix D herewith.

4.1 Hydrology

In accordance with the guidance set out in the DMRB and TAN15, industry standard techniques have been used to derive the peak flow estimates. The principles of the modelling methodology were agreed with NRW prior to the commencement of any modelling and the outcomes have been reviewed by NRW. Further details can be found in the hydrology report, which is included in Appendix E. The peak estimates for the full suite of flows are summarised below in Table 3.

Return Period	Peak Flow (m³/s)				
	River Dyfi	Dulas North	Dulas South	Gershiwn Tributaries	
				GSWN101	GSWN201
2	228.45	63.63	40.14		
5	292.43	81.45	51.39		
10	331.68	92.38	58.28		
30	386.88	107.76	67.98		
50	410.74	114.40	72.17		
75	429.08	119.51	75.40	1.77	4.13
100	441.83	123.06	77.64	1.87	4.40
100CC	530.20	147.67	93.17	2.25	5.28
1000	781.85	217.76	137.39	5.19	8.30

Table 3 – Peak flow estimates for the modelled watercourses.

4.2 Hydraulic Assessments

The hydraulic assessment was carried out using a detailed ISIS TUFLOW model of the River Dyfi, relevant tributaries and the associated floodplain. As part of the modelling study, the existing NRW River Dyfi model was extended to ensure that the model extent was appropriate for the assessment of flood risk at the location of the proposed New Dyfi Bridge. This model has been submitted to NRW for their technical review and comment as part of a pre-FCA application. The final revised baseline model was deemed fit for purpose, and the outputs are subsequently used to establish the baseline flood risk for this FCA. Modelling of the baseline scenario was carried out for the lower order events in order to provide an indication of the current standard of protection afforded to the Dyfi Eco Park and residential properties at Railway Terrace.

In accordance with the requirements of TAN15, the 1 in 100 year and 1 in 1000 year probability flood events have been assessed. An additional 30% has also been applied to the 1 in 100 year flood event to account for future climate change, as required by the latest guidance (Welsh Government: Guidance on Climate Change Allowances for Planning Purposes, 23 August 2016) on adjusting peak flows for

climate change for West Wales river basin to year 2080. The model outputs are explained in further detail below. A review of the Digital Terrain Model (DTM) used to model the Dyfi floodplain is shown in Figure 7 below. An informal arched bund is clearly visible within the topography, which does not provide a designated flood defence purpose. However, it is likely to provide a controlling influence on floodwaters upstream of this once water spills into the floodplain. This feature is retained in the baseline model; however, sensitivity testing is also carried out to indicate the significance of the bund in relation to the proposed development.

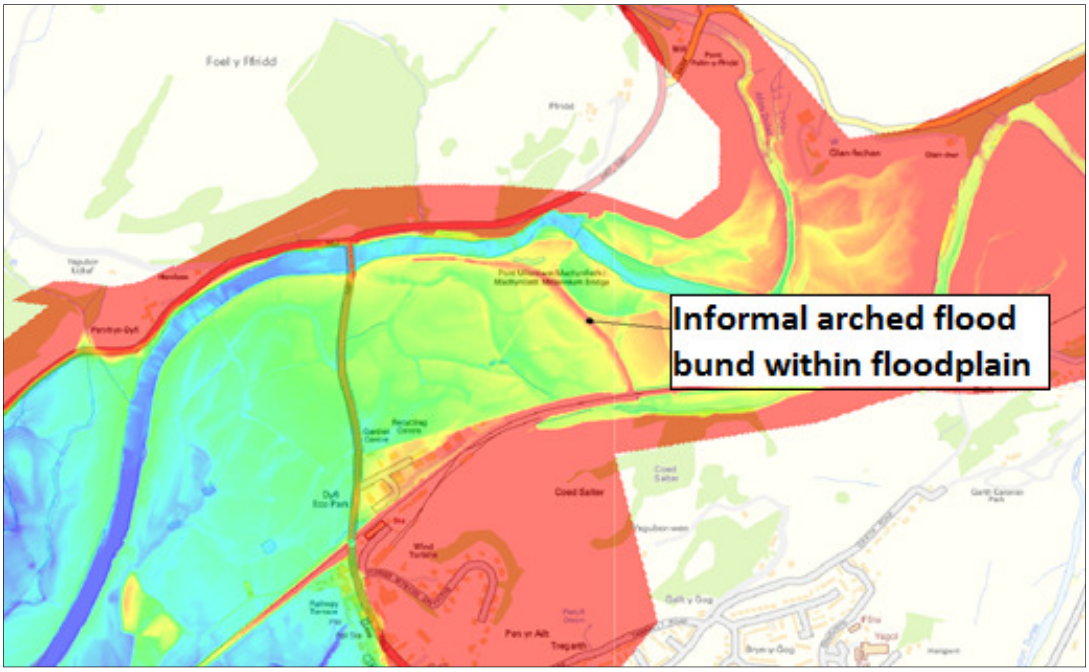


Figure 7: Digital Terrain Model of the Dyfi floodplain, with the informal arched bund clearly visible.

4.2.1 1 in 2 year event

The model outputs for the 1 in 2 year event are shown in Appendix F herewith. It can be seen that during this event, the existing A487 roadway is inundated by floodwaters of up to 0.4m deep. Furthermore, floodwaters encroach into the Dyfi Eco Park site and also affect the residential property at the A487/A493 junction immediately upstream of the existing Pont-ar-Ddyfi, where flood depths of up to 270mm are predicted at the property threshold.

4.2.2 1 in 100 year event

The model outputs for the 1 in 100 year event are shown in Appendix F herewith During the 1 in 100 year event, it can be seen that the maximum flood extent is very similar to that shown by the NRW flood map. Floodwaters spill over the left bank of the River Dyfi channel upstream of Machynlleth, where they are initially retained by the informal earth bund structure which is evident within the agricultural land. Floodwaters also spill into the floodplain downstream of the existing Pont-ar-Ddyfi, and overland flows subsequently gravitate towards the A487 roadway and the railway embankment. At the peak of the flood event, the informal earth bund is overtopped, and floodwaters flow over the A487 roadway. A flow path through the

Dyfi Eco Park develops, and floodwaters also flow along the A487/Heol y Doll underneath the railway bridge and into residential properties at Railway Terrace. The road at the A487/A493 junction effectively forms the northern boundary of the maximum flood extent. Floodwaters encroach into the back garden of the residential properties at Numbers 7 and 8, with inundation of the un-inhabited basement level of Number 7. A small volume of floodwater spills onto the A493 immediately downstream of Pont-ar-Ddyfi, and the model outputs indicate that floodwaters encroach as far as Numbers 1 and 2 along the terraced properties. This corresponds with anecdotal evidence from local residents that when water levels rise above the A493 carriageway level, river water can currently flow through existing 'letterbox' drains in the stone parapet retaining wall, flooding the A493 and encroaching on Pen-y-Bont Cottages.

4.2.3 1 in 100 year event plus climate change

To account for the impact of climate change, an additional 30% was added to the peak flows. The model outputs for the 1 in 100 year plus climate change event are shown in Appendix F herewith. During the 1 in 100 year event with climate change, it can be seen that the flood extent is very similar to that shown by the 1 in 100 year event. The evolution of flooding follows a very similar pattern; however the greater volume of floodwaters creates more extensive flooding at the Dyfi Eco Park and on the southern side of the railway embankment. Furthermore, a flow route along the railway develops to the east of the Dyfi Eco Park, although volumes are not sufficient to enter the site from the eastern boundary. A greater volume of floodwater ponds on the A493 road way in front of the terraced properties along the northern extent.

4.2.4 1 in 1000 year event

The model outputs for the 1 in 1000 year event are shown in Appendix F herewith During the 1 in 1000 year probability event, it can be seen that the flood extent is very similar to that shown by the NRW flood map. Peak flood levels within the River Dyfi floodplain are sufficient to flow into the Dyfi Eco Park and onto Heol y Doll and subsequently through properties at Railway Terrace.

Properties at the A493/A487 junction are inundated by floodwaters spilling over the right bank of the River Dyfi. Although the mapped flood extent does not show the terraced properties as being wholly inundated by floodwaters, it should be noted that they are situated below road levels. It is unlikely that the drainage infrastructure would be unable to accommodate the flows along the roadway during this extreme event and boundary/garden walls would allow the ingress of water into the ground floor levels.

5 Initial Proposed Scheme

Initial discussions with NRW during the early stages of scheme development led to the decision to construct the New Dyfi Bridge crossing on piers rather than embankment in order to reduce the impacts of the crossing on existing flood risk. No piers will be constructed within the existing River Dyfi channel. This will help to reduce the impact of the structure on flood mechanisms within the floodplain. A new flood embankment will also be constructed around the existing Dyfi Eco Park in order to provide flood defence with a standard of protection (SoP) of the 1 in 100 year plus climate change event. The proposed flood embankment will extend along the western boundary of the existing A487, tying in to the existing railway embankment, in order to protect the remainder of the A487 from flooding. The key elements of the initially proposed scheme are illustrated in Figure 8 below.

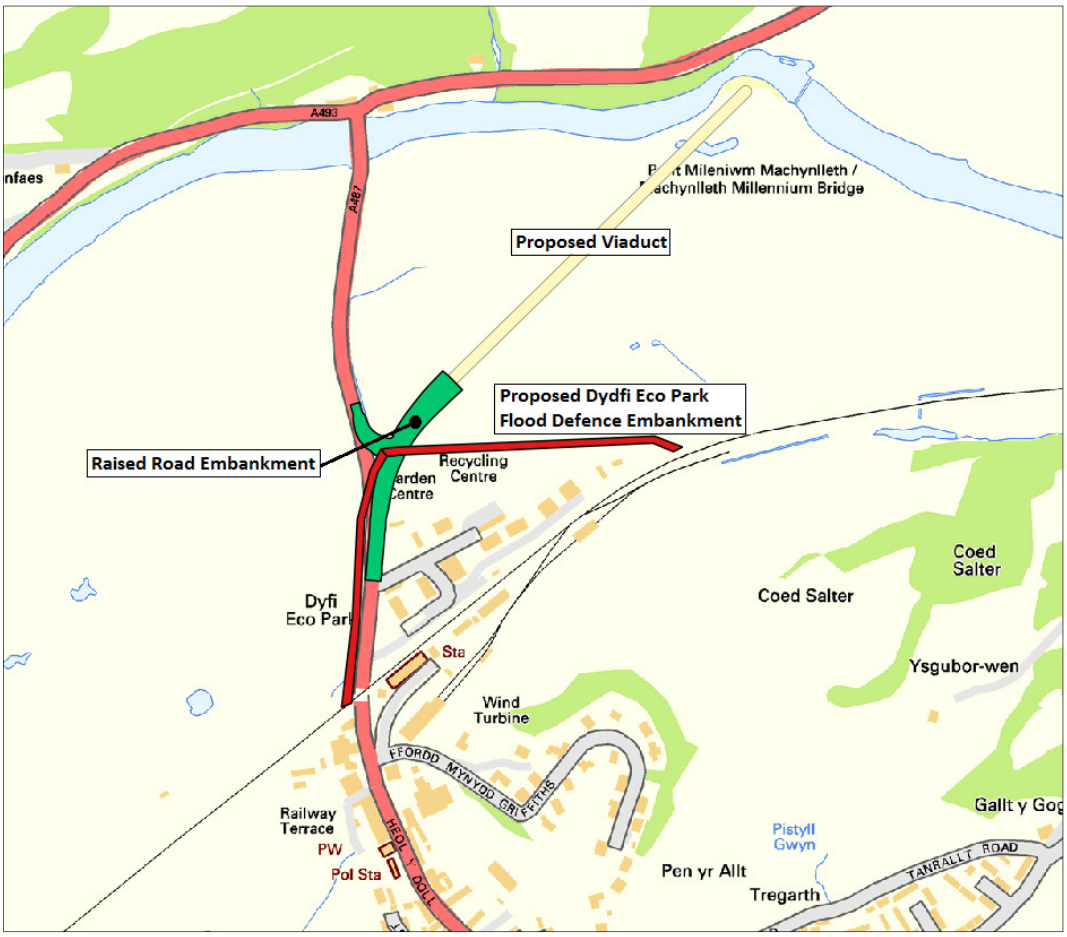


Figure 8: Schematic of the initially proposed scheme.

5.1 Main Sources of Flood Risk

The baseline modelling has confirmed that the River Dyfi floodplain is extensive. However, the flood extents are relatively similar for all extreme flood events, suggesting that the flood extent is well constrained by the topography and floodplain features. The main source of flood risk to the proposed scheme is that emanating from the left bank of the River Dyfi.

The new road will be significantly elevated above the floodplain, therefore ensuring that the route is not at risk of fluvial flooding during an extreme event. The new embankment constructed around the Dyfi Eco Park will serve to protect the lower section of the A487/Heol y Doll from flooding, as well as the residential properties at Railway Terrace. The hydraulic modelling study has been used to inform the design levels of the Eco Park defence embankment and minimum viaduct soffit levels.

In order to quantify the impact of the proposed scheme on the flood risk in the area, hydraulic modelling was carried out for the 1 in 100 year plus climate change (20%) event. This was to provide an initial indication as to whether the proposed scheme was able to remain compliant with PPW and TAN15. The model outputs were subsequently used to provide a comparison of the 'before' and 'after' scenario, and therefore indicate if any property/third party land is adversely affected by the scheme in terms of flood risk. It should be noted that at the time of undertaking this initial assessment of the proposed development, the relevant climate change guidance specified that 20% be applied to peak flow estimates to account for climate change.

The final scheme design has been checked against the latest climate change guidance (Welsh Government: Guidance on Climate Change Allowances for Planning Purposes, 23 August 2016) on adjusting peak flows for climate change for West Wales river basin to year 2080 of 30% increase in peak flows.

5.2 Climate Change

The development of a final scheme design for the proposed Dyfi Bride has been subject to an extensive period of modelling and testing since early 2015. During this period, various schemes were tested for the required design event, the 1 in 100 year + climate change, as set out in TAN15, which assumed a 20% allowance for climate change as per guidance at the time. The modelling work was primarily focussed on deriving a scheme which remained compliant with TAN15 and the quantification of any third party impacts of development within the modelled floodplain. This work confirmed that the initially proposed scheme would need to be revised to reduce impacts. By Autumn 2016, a final scheme design had been determined using model outputs for the 1.0%, 1.0% +CC (20%) and 0.1% Annual Exceedance Probabilities (AEP). When the climate change guidance (Flood Consequences Assessments: Climate change allowances) was implemented in December 2016, a 30% increase in flow through the River Dyfi for the baseline and post development scenarios were run to ensure that the scheme could still remain compliant with TAN15. It was considered that the change in climate change guidance did not invalidate the modelling for the 'optioneering' phase, and the final scheme design has been checked against the latest climate change guidance of 30% increase in peak flows. Therefore, the latest climate change allowance of 30% was not retrospectively applied to the numerous 'optioneering' model runs.

In addition, the hydraulic model report explains that the sensitivity testing of the model was undertaken using the 1.0% AEP + 20% CC scenario prior to the new climate change guidance being implemented. As the focus of this was element of the study was to determine the model sensitivity to various model parameters only, it was considered that the results and the subsequent conclusions were still valid using the 20% climate change values. Therefore, the latest climate change allowance of 30% was not retrospectively applied to the sensitivity model runs.

In subsequent correspondence, NRW advised that the "upper end" estimates provided in the climate change guidance should be considered to inform mitigation measures and help ensure the long term resilience of the development. In this case an increase of 75% should be considered for the 1% AEP flows to assess the impacts of the "upper end" climate change scenario. However, on reviewing the peak flow estimates provided in the hydraulic model report, the 0.1% AEP peak flow is 84% greater than the 0.1% AEP peak flow and it has been agreed with NRW that the 1% AEP impact assessment is a suitable worst case proxy for the "upper end" climate change scenario.

The new A487 trunk road viaduct and approaches will be elevated above existing ground levels and will be above the 0.1% AEP and 1% plus upper end climate change scenarios, complying with TAN15 A1.14 and A1.15 and providing betterment over the existing frequency of road flooding.

5.3 Hydraulic Assessments

The design drawings for the initial proposed scheme are shown in Figure 8 above, and also included in Appendix G herewith. The drawings were used to digitise polygons and points to represent the proposed amendments to the topography within the baseline model. This ensured that the raised road embankment was explicitly modelled within the floodplain. Furthermore, flow constriction cells were used to represent the reduced floodplain conveyance resulting from the construction of the bridge piers. Further details relating to the modelling approach can be found in the associated hydraulic modelling report. The model outputs for the initial proposed scheme during the 1 in 100 year plus climate change (20% as per guidance at time of initial modelling) event are shown in Figure 9 below. It can be seen that the raised roadway for the new section of the A487 remains flood-free due to the elevation. Furthermore, the defence embankment around the Dyfi Eco Park and along the western side of Heol y Doll prevents floodwaters affecting the properties and the lower section of the A487. The initial proposed route is therefore demonstrated to remain flood-free and operational during the 1 in 100 year plus climate change (20%) event. Furthermore, the scheme provides additional flood defences to the properties at the Dyfi Eco Park and Railway Terrace, reducing current flood risk in these areas.

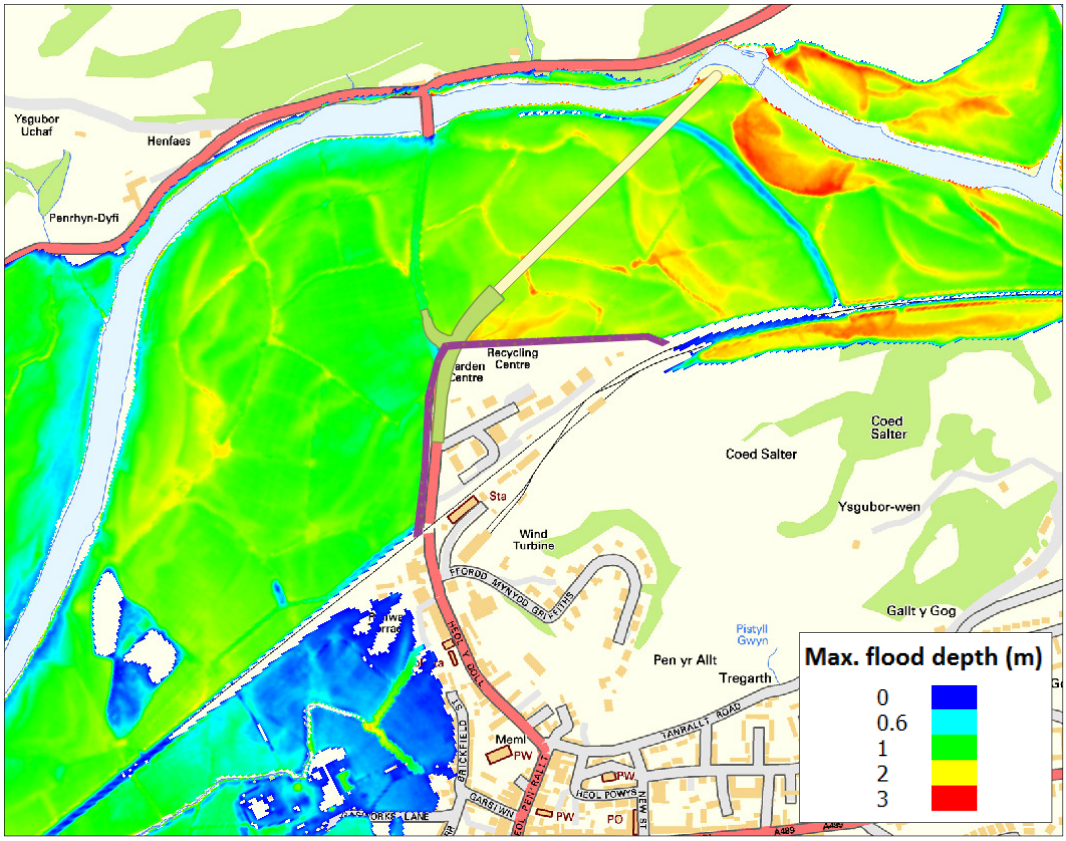


Figure 9: Modelled Peak Flood Depths during the 1 in 100 year plus climate change (20%) event for the initially proposed scheme.

Notwithstanding the above, a comparison between the baseline scenario and the proposed scenario during the 1 in 100 year plus climate change (20%) event indicates that the proposed works cause a detrimental impact on third party property. Figure 10 illustrates the predicted impact, which ranges from betterment of up to 150mm immediately downstream of the scheme, to detriment of up to 580mm immediately upstream. The majority of these impacts are located in the agricultural fields surrounding the proposed viaduct structure, which during the baseline scenario are predicted to already flood to depths exceeding 1m. However, of particular note is the predicted impact at Nos. 7 & 8 immediately upstream of the existing Pont-ar-Ddyfi, where flood levels are predicted to increase by approximately 220mm.

This is initial proposed scheme was deemed to be incompliant with TAN15 Section 6.2, which specifies that flooding consequences as a result of critical transport infrastructure development should be considered and found to be acceptable.

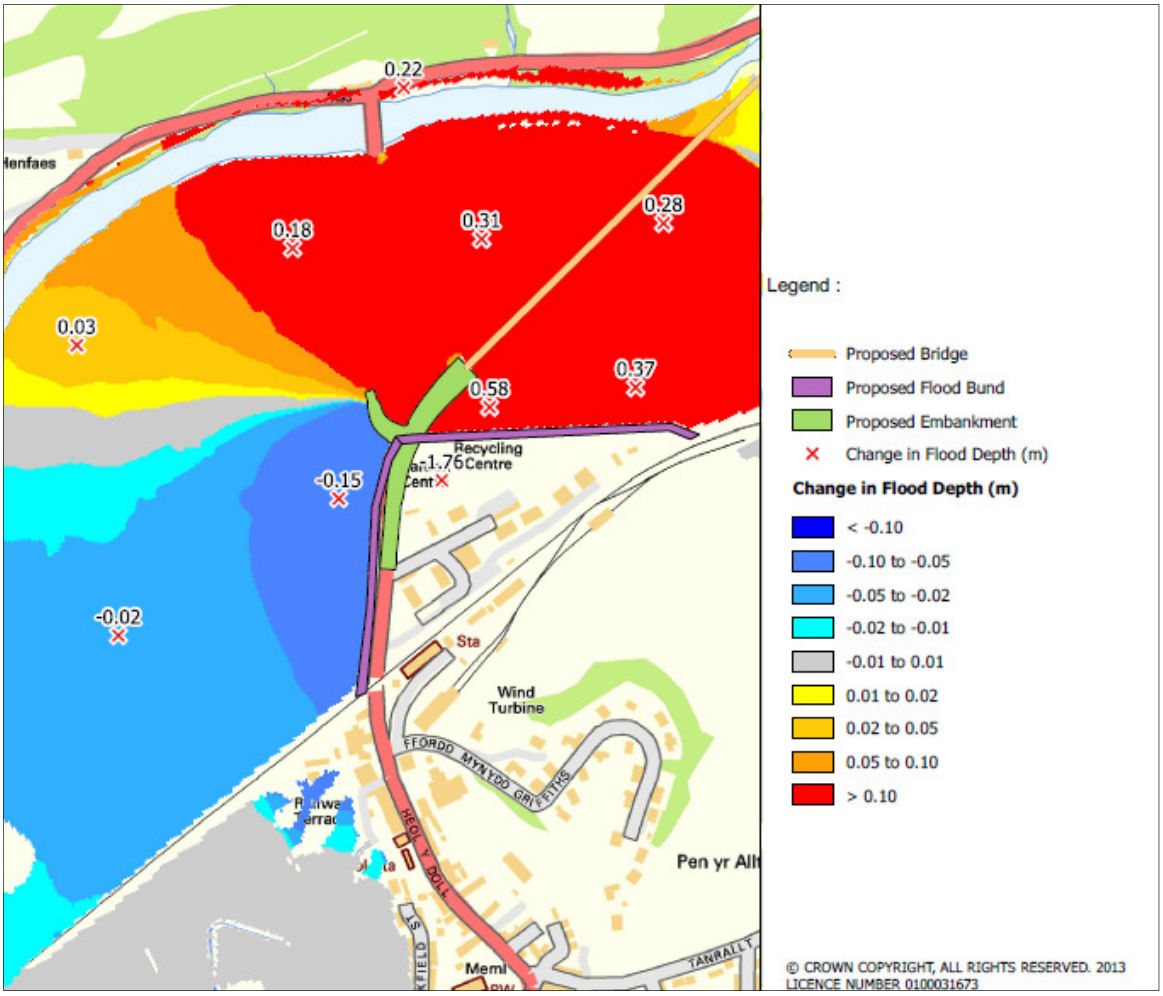


Figure 10: Modelled impacts of the initially proposed scheme compared to the baseline scenario during the 1 in 100 year plus climate change (20%) event.

6 Mitigation Measures

The initially proposed scheme is shown to protect the trunk road infrastructure and properties at the Dyfi Eco Park and Railway Terrace up to the 1 in 100 year plus CC (20%) event. However, a comparison of peak flood levels between the baseline and proposed scenario indicates that there are localised areas of detrimental impact, as shown in Figure 10. Therefore, additional measures were explored to ensure that the proposed scheme can remain compliant with the requirements of TAN15.

6.1 Mitigation Options

A long-list of possible mitigation measures is presented in Table 4, which is colour coded to indicate feasible options. During the early stages of baseline modelling it was identified that, due to the relatively high peak flow, the potential impact of the scheme on flow conveyance in the flood plain would be key issue. Hence the focus of the options long list was on options that could improve conveyance capacity within the floodplain, rather than on storage provision.

Table 4 – Long-list of possible mitigation measures

Option unlikely to be actioned
Option likely to be considered

	Option	Key Works	Main Issues
1	Add additional flood relief to the southern approach embankment	Provide large flood relief culverts/flexi arch in the proposed highway embankment at southern end of proposed bridge, to increase flood conveyance and relieve the flood 'pinch point' created by the highway and Eco Park flood embankments.	Space is limited within the embankment and getting the required cover to the culverts may be difficult.
2	Move the Eco Park flood embankment south, within the Eco Park itself	Adjust horizontal alignment of the proposed Eco Park flood embankment by moving further south adjacent to the Eco Park access road. This will relieve the current 'pinch point' created by the proposed highway embankment and flood embankment. There is a wide surfaced verge adjacent to the access road that may be used to accommodate a flood embankment or wall.	This may impact on the existing garage to the east and disused refuse recycling centre. Anecdotal information suggests that the garage compound suffers flooding and so the owners may be amenable to accommodating a flood wall. The revised flood embankment/wall alignment will not provide protection to the existing garden centre or disused recycling centre to the north.
3	Lowering the disused section of the A487 to adjacent ground levels	Lowering the disused section of the A487 between the tie-in point and the existing bridge. Lower this section of road to match adjacent ground levels (by up to 300mm), increasing flood conveyance in the floodplain and potentially reducing flood flows through the existing Pont-ar-Ddyfi Bridge.	It is understood that access to the old bridge is to be maintained for pedestrians etc. There may be environmental issues which will need considering.

4	Remove conveyance restrictions on the disused section of the A487	Remove/modify kerbs/coping and parapet on the disused section of the A487 to remove blockage risk and increase flood conveyance.	Access path and kerbs may be required for the above reasons.
5	Remove conveyance restrictions - hedgerows.	Remove hedgerows immediately adjacent to the disused section of the A487 to reduce blockage and head loss across the road.	Environmental constraints me be present that could prevent the hedgerows from being removed.
6	Add flood relief culverts to the disused section of the A487.	Flood relief culvert(s) under the disused section of the A487 to increase flood conveyance.	The culverts would need to be relatively large, excavated below floodplain level and would require an associated large flood relief channel excavated within the floodplain that would be prone to blockage. This system would effectively act as a syphon, forming both a significant maintenance & a health and safety liability with an area of deeper and faster flowing flood water running through the flood plain. Modelling of other similar culvert options in the proposed approach embankment have confirmed limited benefit of culvert provision, as described in Appendix H, Section 3.3. Due to the limited flood benefit, and associated H&S hazards, this option was not progressed.
7	Add Property Level Protection to properties at risk of flooding	Provision of property level protection at the Eco Park and other locations where residual flood risk impacts remain.	Considered as a last resort option if increases in flood level cannot be avoided. Requires residents/commercial organisations properties to implement with suitable flood warning.
8	Profiling the flood plain.	Re-profiling the flood plain to remove the raised embankment running north to south near the cycle bridge, that causes flood waters to weir over and back up, potentially leading to flooding of the adjacent railway and through to the Eco Park.	Impact on flood levels as a result of this option would need modelling to confirm its viability. Would impact a relatively large area of floodplain and require consent from land owners. May increase flooding for low order flood events.
9	Clear span bridge across the flood plain.	Provision of clear span bridge deck, eg a cable stayed section. This will reduce the impacts associated with the bridge piers by reducing the number of bridge piers and associated scour risk. May be preferable for landowners.	The main impact of the works is caused by the approach road embankment, with the proposed viaduct piers causing very little impact on flooding. As a clear span option would still require the approach embankment, only little benefit would be obtained and hence would not address the scheme impacts. A single span bridge would introduce significant increase in cost and technical

			complexity, and would fundamentally change the nature of the bridge construction, aesthetics and visual impact. Due to the minimal flooding benefit of a single span bridge, and the associated large cost increases and change of visual impact, this option was not progressed

Options 1-5, and 7 & 8 were carried forward for testing using the baseline hydraulic model in order to identify the most appropriate design. Options 6 and 9 were not progressed further for the reasons stated in the table.

The final design which forms the basis for this FCA was developed following a large number of iterative design scenarios. Further details pertaining to the selection of approaches to take forward are surmised in the Flood Options Report, which is included in Appendix H herewith. It should be noted that all climate change scenarios during the optioneering stage specified an additional 20% for peak flows in accordance with the guidance at the time. The final design of the scheme has been checked against the latest climate change requirement of 30% increase in peak flow.

6.1.1 Impact of initially proposed mitigation measures

The green highlighted mitigation measures in the table above were modelled using an iterative process to assess their viability and effectiveness in reducing the impacts of the bridge on flooding. A summary of the results from each modelled option is provided below:

- Option 1: This option modelled a range of culvert sizes and arrangements through the proposed approach embankment. Model outputs indicated a relatively small reduction in flood levels upstream of the bridge, and slightly elevated levels adjacent to the culvert outlets. The results highlighted that these likely relatively costly mitigation measures would only marginally mitigate the impacts of the proposed bridge and bund structures;
- Option 2: Using an iterative process, the proposed flood embankment protecting the Dyfi Eco Park was moved southwards to increase the conveyance of floodwaters within the floodplain. However this option causes flooding of the existing A487 and very large flow velocities. As a result, the final alignment of this embankment is along the boundary of the existing Park, incorporating the garden centre;
- Option 3: Lowering the existing A487 within the baseline model had negligible effect on the modelled detrimental impacts;
- Option 4: Removal of kerb levels within the baseline model had negligible effect on the modelled detrimental impacts;
- Option 5: Removal of the hedgerow within the baseline model had negligible effect on the modelled detrimental impacts;

- Option 8: Profiling the flood plain with removal of the informal arched bund did not significantly reduce the modelled detrimental impact, and confirmed that land immediately downstream of this feature would experience an increased frequency of flooding;

The options listed above did not significantly improve the detrimental impact predicted for the Dyfi floodplain, which primarily comprises of agricultural grazing land. It is considered that despite the increased flood levels on the agricultural land, the impact on the productivity of this land is negligible due to the pre-development flood depths which exceed 1m during the 1 in 100 year plus climate change (20%) event. Furthermore, scrutiny of the model outputs confirms that the frequency of inundation and principal flood mechanisms are not significantly affected by the proposals during the 1 in 100 year plus climate change (20%) event. However, detriment is also predicted for the properties located at the existing Pont-ar-Ddyfi, specifically No. 7. In accordance with TAN15, this more vulnerable land use should not be affected by increased flooding. Therefore, further options testing was required to minimise this impact.

6.2 Final Proposed Scheme

The initial option testing listed above established that conveyance capacity within the floodplain needed to be significantly increased in combination with the proposed embankment works to reduce the modelled detrimental impact to an acceptable level.

6.2.1 Mitigation Measures

A scheme was developed which primarily involved extending the initial length of the viaduct by approximately 175m, with a tie-in to the proposed defence embankment. During the evolution of the final design a number of options were tested in order to reduce the modelled impact at residential properties located north of the river along the A493. These options considered various by-pass channels of the existing Pont-ar-Ddyfi to increase conveyance through the bridge. During the comprehensive optioneering stage, it was found that increased conveyance through the existing Pont-ar-Ddyfi impacted on flows and velocities through this listed structure, with implications for its future integrity. Furthermore, construction of a by-pass channel would have impacts on the river geomorphology, existing biodiversity, landscape within Snowdonia National Park, agricultural operations, the existing Pont-ar-Ddyfi southern abutment and existing utilities (BT). Refer to the Flood Options Report in Appendix H for more information. Therefore, this option was discounted and not progressed further.

The extended viaduct option is therefore developed in the subsequent section. The existing A487 road will continue to serve as an NMU route and private access road and will tie into the raised embankment at Heol y Doll. The extended scheme layout is shown in Figure 11.

6.2.2 Assessment

The proposals were incorporated into the baseline model in order to assess the impact of the proposed layout. Model outputs indicate that the layout serves to reduce the impact predicted to residential properties north of River Dyfi along the A493 compared to the initial proposed options.

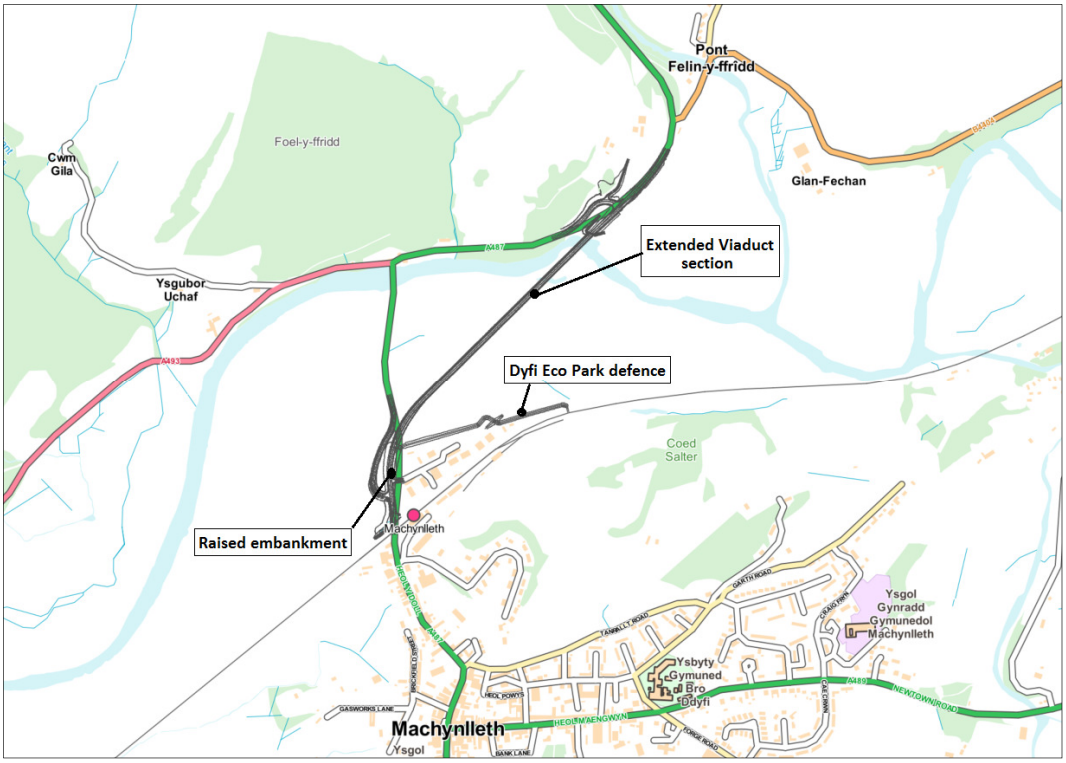


Figure 11: Schematic diagram of the final design layout

The impacts of the final proposed scheme, which incorporates the extended viaduct design detailed above, are presented in Appendix I for a range of events, from the 1 in 2 year to the 1 in 1000 year event. During the progression of the FCA, climate change guidance has been updated and requires that climate change allowances are applied using a River Basin District approach. The River Dyfi is located within the Western Wales River Basin District; therefore, the final proposed scheme incorporates an additional 30% on peak flows to provide the climate change event outputs.

It can be seen that the properties at the Dyfi Eco Park benefit from a standard of protection (SoP) up to the 1 in 100 year event, compared to the baseline scenario, where floodwaters encroach into the site during the 1 in 2 year event. Furthermore, in the baseline scenario, floodwaters flow along Heol y Doll and into Railway Terrace during the 1 in 100 year event. This flow route does not develop during the proposed scenario, thereby providing an improved SoP for the properties along Railway Terrace. It should be noted that there is some instability within the model at this location associated with flows from the Garsiwn Ditch. The hydraulic model is constructed to assess the principal mechanism of floodplain flow and flood risk from the River Dyfi, and the minor contribution from the Garsiwn Ditch is not considered to affect the predicted flood levels and depths at the location of the proposed development. Therefore, a certain amount of caution should be taken with the model outputs at Railway Terrace.

It can be seen that the proposed design causes a small detrimental impact at the properties located at the A487/A493 junction. Immediately upstream of the existing bridge, a detriment of some 50-100mm is predicted during the 1 in 100 year event plus climate change (30%) event. Immediately downstream of Pont-ar-

Ddyfi, the road fronting the row of terraced houses is predicted to be affected by increased flood depths of approximately 45mm during the 1 in 100 year plus climate change (30%) event

A review of the wider floodplain, as shown by the drawings in Appendix H, confirms no predicted impacts at the property next to the B4404 road crossing of the Dulas North, previously highlighted as a known flood risk area by NRW.

Within the wider floodplain and the agricultural fields, a greater degree of detrimental impact is predicted. However, as previously noted, there is no vulnerable development within this area and it is classified as active floodplain, with flood depths of over 1m predicted for the baseline scenario during the 1 in 100 year event plus climate change. In order to assess the relative impact on grazing use of the agricultural fields, a comprehensive review of the modelled outputs has been undertaken at various points across the floodplain. Figure 12 illustrates the locations of the points used for this assessment.

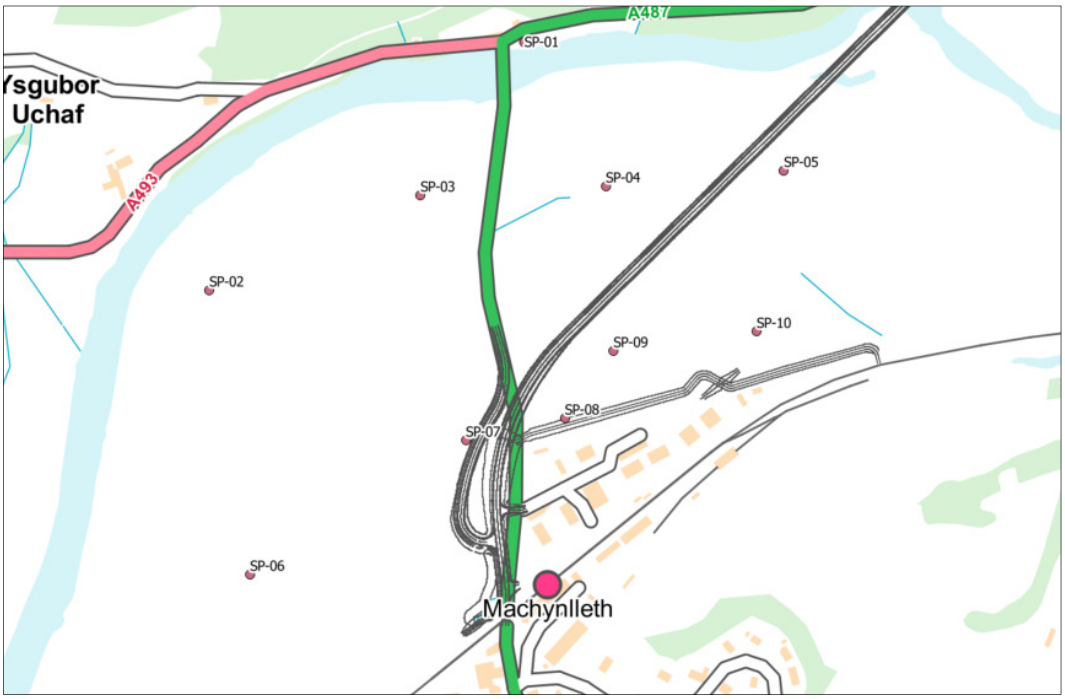


Figure 12: Point IDs used to inform Tables 18-20, and their relative location in the Dyfi Floodplain.

The modelled maximum depth outputs at various locations are detailed in Table 4 and 5 below, with the predicted differences detailed in Table 6.

Sample Point	2 year	5 year	10 year	30 year	50 year	75 year	100 year	100 year +30%CC	1,000 year
SP-01	9.16	9.22	9.27	9.35	9.40	9.44	9.47	9.78	10.06
SP-02	8.26	8.42	8.50	8.59	8.63	8.66	8.68	8.86	9.12
SP-03	8.43	8.64	8.74	8.87	8.92	8.96	8.98	9.21	9.48
SP-04	8.73	8.95	9.07	9.22	9.28	9.32	9.35	9.65	10.01
SP-05	8.89	9.14	9.26	9.43	9.49	9.54	9.58	9.90	10.31
SP-06	8.05	8.21	8.28	8.38	8.42	8.44	8.46	8.65	8.89

SP-07	8.19	8.41	8.52	8.65	8.70	8.73	8.76	8.98	9.27
SP-08	8.66	8.83	8.91	9.02	9.07	9.10	9.13	9.37	9.67
SP-09	8.67	8.87	8.97	9.10	9.16	9.20	9.23	9.51	9.85
SP-10	8.74	9.02	9.15	9.31	9.37	9.42	9.45	9.77	10.14

Table 5 - Baseline Flood Levels

Sample Point	2 year	5 year	10 year	30 year	50 year	75 year	100 year	100 year +30%CC	1,000 year
SP-01	9.15	9.22	9.27	9.36	9.42	9.46	9.50	9.83	10.12
SP-02	8.26	8.43	8.51	8.61	8.65	8.68	8.70	8.89	9.15
SP-03	8.42	8.65	8.76	8.90	8.96	9.00	9.03	9.27	9.56
SP-04	8.73	8.97	9.09	9.25	9.32	9.37	9.40	9.73	10.10
SP-05	8.89	9.15	9.28	9.46	9.53	9.58	9.62	9.97	10.39
SP-06	8.05	8.20	8.28	8.37	8.41	8.43	8.45	8.63	8.88
SP-07	8.23	8.44	8.54	8.66	8.70	8.73	8.76	8.94	9.21
SP-08	8.64	8.84	8.93	9.08	9.14	9.18	9.21	9.50	9.84
SP-09	8.66	8.88	8.99	9.15	9.22	9.26	9.30	9.61	9.98
SP-10	8.74	9.05	9.18	9.36	9.43	9.48	9.52	9.87	10.26

Table 6 – Post Development Flood Levels

Sample Point	2 year	5 year	10 year	30 year	50 year	75 year	100 year	100 year +30%CC	1,000 year
SP-01	0.00	0.00	0.00	0.01	0.02	0.03	0.03	0.05	0.06
SP-02	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.03
SP-03	-0.01	0.02	0.02	0.04	0.04	0.04	0.04	0.06	0.07
SP-04	-0.01	0.01	0.02	0.04	0.04	0.05	0.05	0.08	0.09
SP-05	0.00	0.01	0.02	0.03	0.04	0.04	0.04	0.07	0.08
SP-06	0.00	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.02	-0.01
SP-07	0.04	0.03	0.02	0.01	0.00	0.00	0.00	-0.04	-0.06
SP-08	-0.02	0.01	0.02	0.06	0.07	0.08	0.08	0.13	0.17
SP-09	-0.02	0.01	0.02	0.05	0.06	0.06	0.07	0.10	0.13
SP-10	0.00	0.02	0.03	0.05	0.06	0.06	0.06	0.10	0.12

Table 7 – Change in Flood Levels

It is clear that the impacts on the wider floodplain are not significant. The model outputs for the 'baseline' and 'existing' scenarios have been processed to provide 'difference' maps showing changes in the peak flood levels for all modelled events. These are presented in Appendix I.

It is also concluded that the frequency of inundation is not significantly altered. To confirm this assertion, Drawing Nos. WHS-1345-F01-012-r01, WHS-1345-F01-013-r01, and WHS-1345-F01-014-r01 illustrate the flood extent changes for the 1 in 2 year, 1 in 10 year, and 1 in 100 year events respectively. These are included in Appendix I herewith. It can be seen that there are no significant changes to the modelled flood extent for these events.

The model outputs have also been interrogated to confirm that there is no change to the onset of flooding. In order to quantify the impact of the proposed works on the existing flood risk mechanisms across the Dyfi floodplain, and the subsequent depth and durations of flooding, the model outputs for the 1 in 1000 year event were interrogated at key timesteps. The evolution of the extreme flood event captures the full suite of modelled flows, and provides a quantitative assessment of any potential impact on the surrounding agricultural land, specifically during the onset of flooding. Peak flood depths within the floodplain are reached after approximately 15 hours into the design hydrograph. Appendix J presents the modelled flood outlines at hourly intervals during the onset of flooding. The maximum flood extents for both the baseline and the final scenarios are plotted on the same map in order to allow a comparison at each timestep and the identification of any change (increase/decrease) in flood outline. A depth-time series graph has also been extracted for each sample point used in Table 5 to describe the evolution of flooding at that point throughout the model simulation. The outputs for both the baseline and the proposed scenarios are plotted on the same graph to enable a direct comparison between the two. For all graphs, the baseline model outputs are shown by the orange line, and the proposed model outputs are shown in green, as shown in Table 8. The graphs of flood depth against time demonstrate that the onset and duration of flooding are similar for all sample points

Referring to Appendix J and Table 8, flooding is initiated downstream at SP-02 at circa 08:15:00 hrs into the model run, with floodwaters spilling over the left bank of the River Dyfi into the floodplain. This mechanism is retained within the proposed scenario, with the timing of the initial spill modelled at 08:15:00 hrs.

At 08:45:00 hrs, model outputs show that floodwaters continue to spill into the River Dyfi floodplain, with floodwaters backing up behind the raised informal arch bund upstream of the site. Floodwaters also propogate in an easterly direction towards the existing A487 road downstream of the site. This flood mechanism is identical for both the existing and proposed scenarios as floodwaters propagate towards the location of the A487 works.

By 09:45:00 hrs, the modelled extents are broadly similar for both the existing and the proposed scenarios. The influence of the raised embankment works at the Dyfi Eco Park is evident on the western side of the existing A487 road. Upstream of the road, the extent of flooding within the agricultural fields is identical with no additional flooding or early onset of flooding as a result of the proposed works.

At 10:00:00 hrs, it can be seen that the new embankment at the Dyfi Eco Park serves to prevent floodwaters entering the area, with the purple colours in Appendix J showing the areas ‘protected’ at this stage.

At 13:00:00 hrs, the model shows that floodwaters overtop the embankment and the properties within the Eco Park are inundated. A very small area of additional flood extent is predicted at the properties along the A493 immediately downstream of the existing Pont-ar-Ddyfi. However, this area of flooding is inundated during the subsequent 60 minutes, and so does not constitute ‘additional flooding’.

The model outputs confirm that the modelled flood extent is not increased elsewhere as a result of the proposed development, and the flooding mechanism remains the same for the existing and proposed scenarios.

The proposed scenario shows less extensive flooding at the Dyfi Eco Park, which reflects the reduced floodplain extent as a result of the proposed defence embankment. No additional flooding on the floodplain is predicted, and the mechanisms of flooding are broadly identical for both scenarios, with no marked increase in floodplain extent or change in onset of flooding as a result of the proposed works.

Table 8 – Flood depths in metres during the modelled 1 in 1000 year flood event for the baseline and proposed scenarios; X-axis shows time (hours); Y-axis shows depth (m)

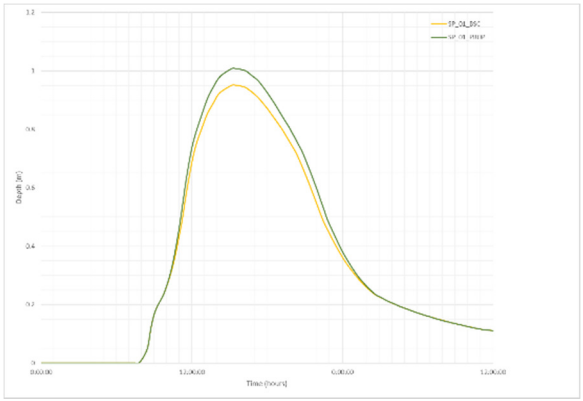
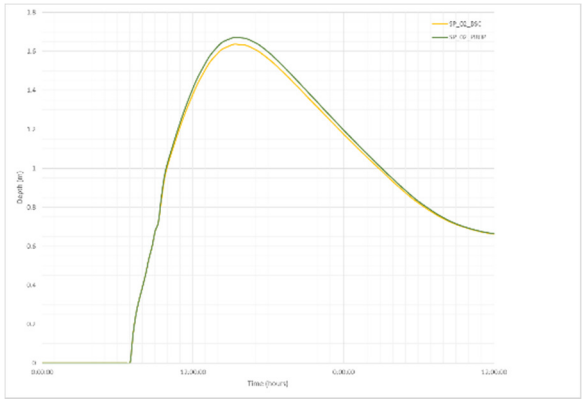
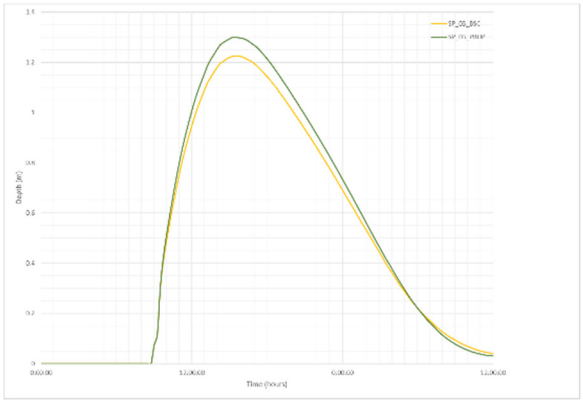
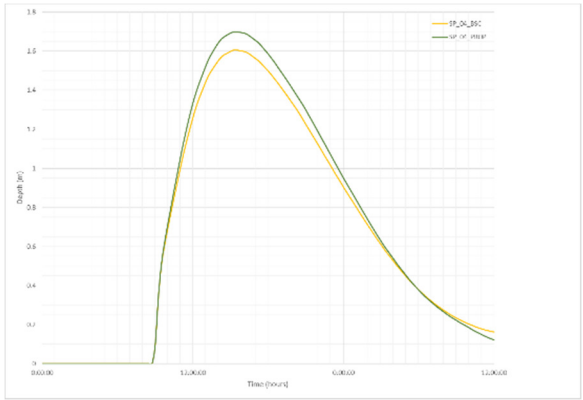
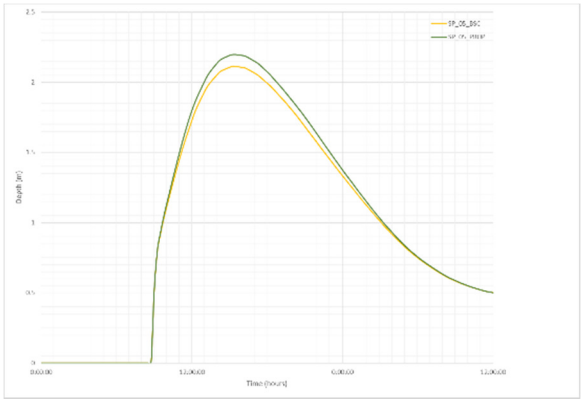
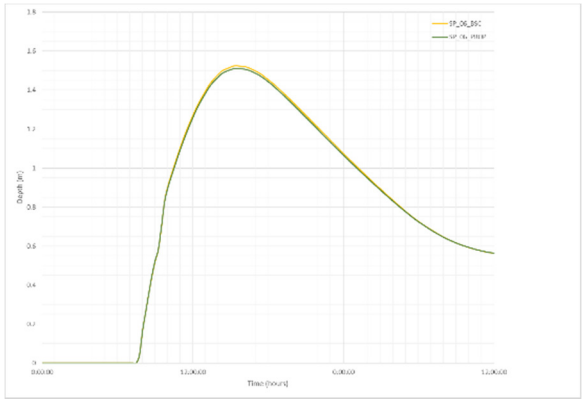
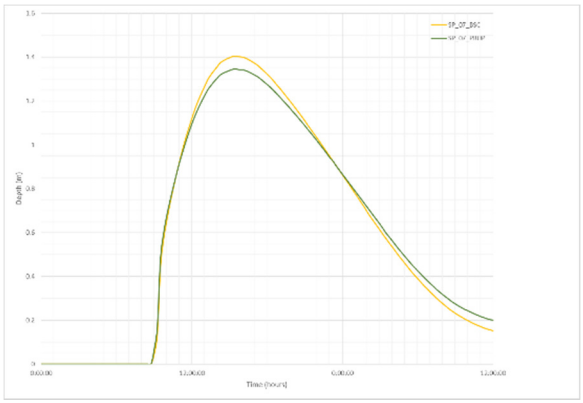
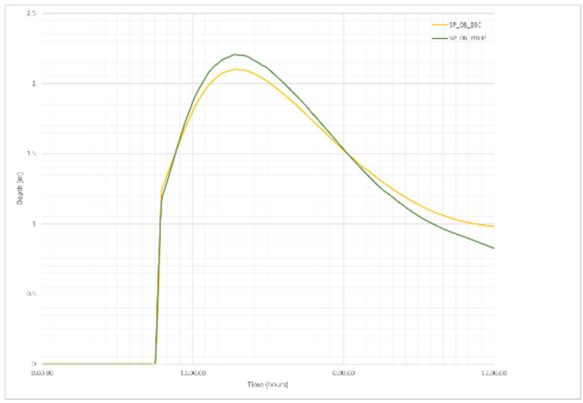
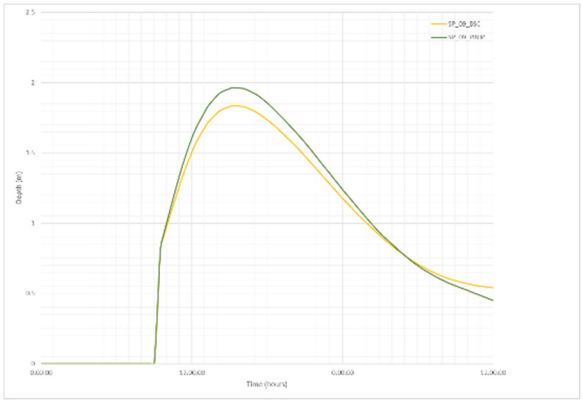
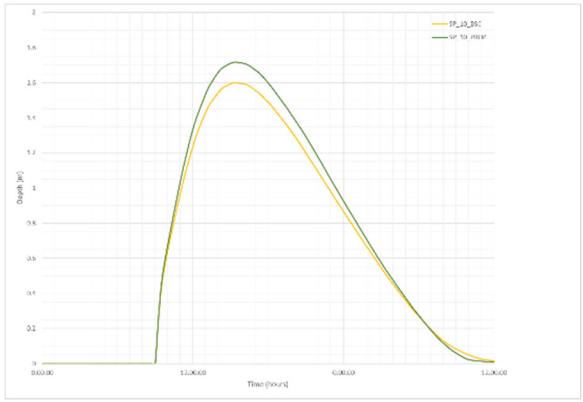
 SP-01	 SP-02
 SP-03	 SP-04

Table 9 continued

 SP-05	 SP-06
 SP-07	 SP-08
 SP-09	 SP-10

During the 1 in 1000 year event the majority of the Dyfi Eco Park benefits from reduced flood levels, as shown in blue in Figure 13. The green colours indicate areas which are no longer within the floodplain, with a total of four buildings being no longer in the floodplain during the 1 in 1000 year event. Some detriment is predicted for a small area within the Dyfi Eco Park, shown in orange and red. It

can be seen that a total of 2 properties are affected by increased flood depths of 60-100mm during this extreme flood event. Notwithstanding this, it is noted that these properties are inundated during the baseline scenario by up to 400mm. Furthermore, the proposed development provides protection to these properties during the 1 in 100 year event, which are shown to flood during the baseline scenario for the same event. Therefore, this localised detriment during the 1 in 1000 year event is not considered to be significant and is outweighed by the overall benefits to the Eco Park.

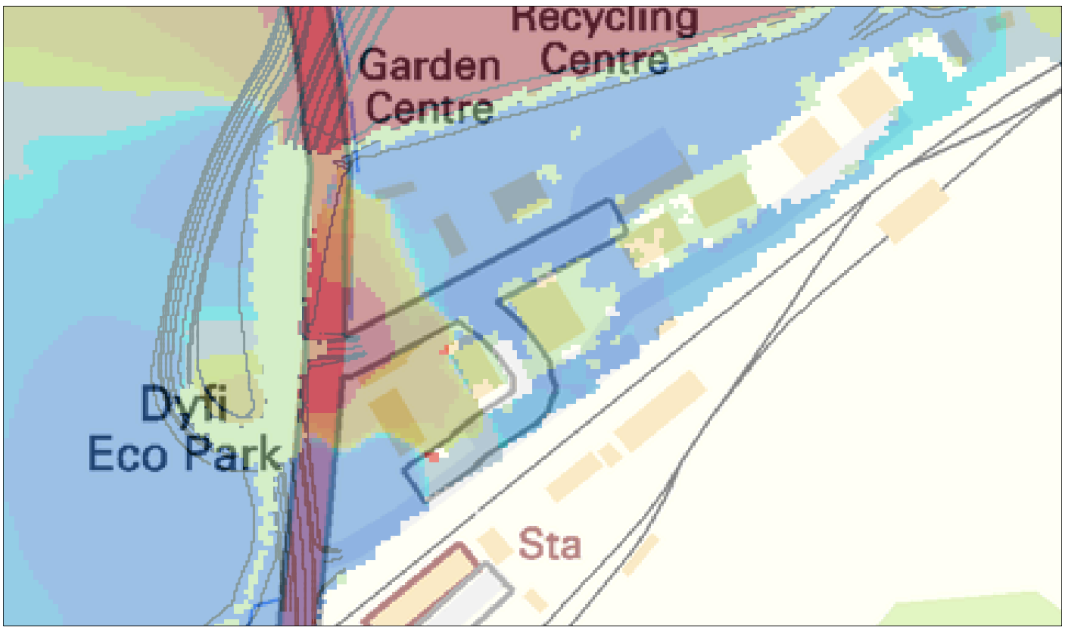


Figure 13: Impact of the proposed development at the Dyfi Eco Park during the 1 in 1000 year flood event

During the 1 in 1000 year event, model outputs indicate a detrimental impact at the property immediately upstream of the existing Pont-ar-Ddyfi, 7 Dyfi Bridge, of approximately 60mm. Modelling has confirmed that the peak flood depth upstream of the bridge for the baseline (existing) scenario is 1.33m during the 1 in 1000 year event at a level of 10.06 mAoD. This level is estimated to increase to 10.12mAoD following completion of the scheme.

However, based on a topographic survey undertaken by NRG Engineering Services dated September 2015, ground levels rise significantly to 10.75m AoD immediately outside the main entrance to the property, which fronts on to the existing A487. The threshold level for the property has not been surveyed, but is likely to be greater than 10.75mAoD and hence would not be affected by the 1 in 1000 year event in pre or post development scenarios.

The property No.7 Dyfi Bridge has recently changed ownership. A copy of the sales brochure for the property, see Appendix N, confirms that use of the lower levels of the property facing the river is currently non-habitable, and described as 2 store sheds, a large outbuilding (formerly garage) and a lean to store to the front of the property. There is no reference to existing internal access to these lower levels from

within the upper habitable rooms. Therefore, it is concluded that there is no material impact on habitable accommodation at this property.

Regarding the storage areas on the river side of the property, ground levels adjacent to the property vary between 9.1 and 9.5 mAoD, giving existing flood depths of between 0.96m and 0.56m. With the scheme in place, these flood depths are predicted to increase to 1.02m and 0.62m. Given the current use of these areas and significant existing flood risk, it is considered that the predicted 60mm increase in flood depth is not a significant increase in flood risk, particularly when viewed in the context of the improved access to the town centre that would be provided by the new viaduct.

The project team has met with the new owner to ensure they were aware of the scheme proposals and fully understood the impacts. The new owner has confirmed that the predicted 60mm increase in flood levels will have no adverse effect on the property, see Appendix N for record of communications, and as such is deemed an acceptable flooding consequence in accordance with TAN15 Section 6.2.

Immediately downstream of Pont-ar-Ddyfi, the road fronting the row of Pen-y-Bont terraced cottages is predicted to be affected by increased flood depths of approximately 65mm during the 1 in 1000 year event. The road floods to depths of 180mm during the baseline scenario. Peak flood levels along the road at this location range between 10.10m AOD and 9.67m AOD. Flood levels of 10.28m AOD are predicted adjacent to the easternmost property, which has a surveyed threshold level of 9.61m AOD. Peak levels of 9.67m AOD are predicted at the western end of the terrace (No.1 Pen-y-Bont cottage), where a threshold level of 9.09m AOD is recorded for the end property. It is concluded that the additional flood depths predicted as a result of the proposed development would have a slight impact on flooding at this location for this extreme event, and as such should be mitigated.

6.3 Residual Flood Risk

The results indicate a small residual flood risk impact at the Pen-y-Bont Cottages, located north of River Dyfi, as a result of the design proposals.

In order to fully quantify the flooding and survey the properties, the project team have attempted to make contact with the owners of the cottages by visiting on numerous occasions, and by posting letters. Despite numerous visits, no contact has been made with the majority of owners as summarised below:

Property	Contact
No.1	Spoken with new owner who is aware of existing flooding issues and welcomes proposed scheme.
No.2	No answer/ contact
No.3	No answer/ contact
No.4	No answer/ contact
No.5	Spoken with owner who reports no internal flooding issues at number 5, but reports that No.1 and No.2 suffer from flooding
No.6	No answer/ contact

Table 9 – Attempted contact with property owners at Pen-y-Bont Cottages.

In the absence of access to the properties, threshold levels have been surveyed to the properties. A sample point located on the A493 adjacent to Numbers 1 & 2 Pen-y-Bont Cottages has also been used to compare model outputs for the baseline model and proposed model. The surveyed threshold levels and sample point locations are shown in Figure 14.

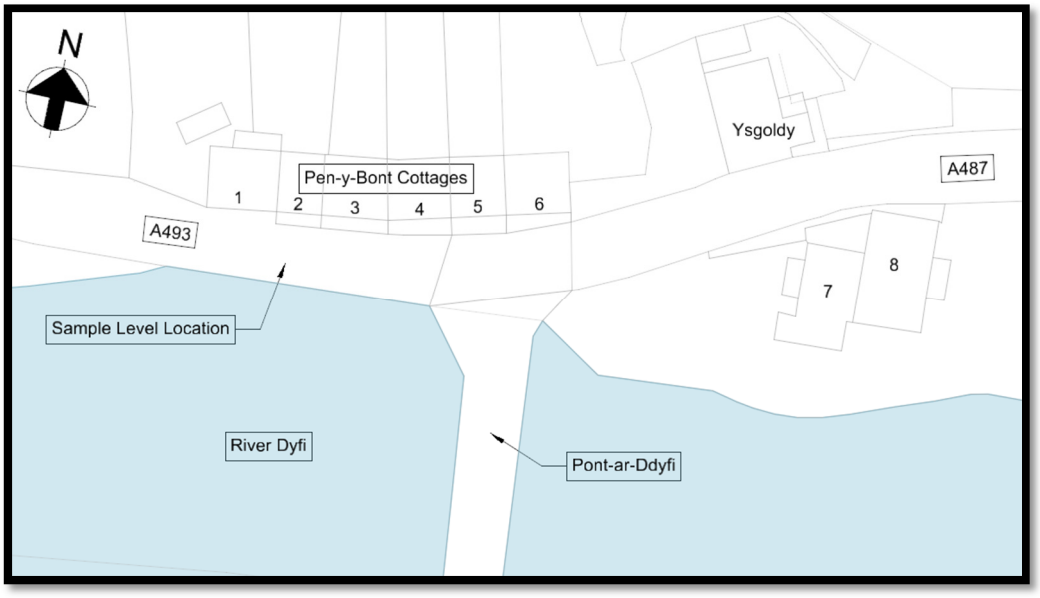


Figure 14: Property numbers at Pen-y-Bont Cottages (Properties 1-6) and Sample Level Location used to inform Table 10;

Based on the model outputs presented in Section 6.1.2, it is concluded that as a result of the proposed scheme, flood levels will be marginally increased for all events up to the 1 in 1000yr event at the sample point as summarised in Table 10 below:

Return Period	Baseline Flood Level (mAOD)	Proposed Scheme Flood Level (m AOD)	Change in Flood Level in post-development (mm)
2yr	9.052	9.052	-
5yr	9.105	9.106	+1
10yr	9.136	9.138	+2
30yr	9.172	9.182	+10
50yr	9.193	9.204	+11
75yr	9.208	9.223	+15
100yr	9.218	9.237	+19
100yr + CC	9.36	9.41	+50
1000yr	9.613	9.678	+55

Table 10 – Increased level of flooding at the Pen-y-Bont Cottages as a result of the proposed scheme.

Comparing the modelled flood levels against surveyed property threshold levels provides an indication of the threshold of flooding at each property. These are summarised in Table 11 below and show good agreement with the local reports of regular flooding to Cottages No. 1 & 2.

Property	Surveyed Threshold Level (mAOD)	Property at risk from:
1	9.09	5yr fluvial flood event
2	9.11	10yr fluvial flood event
3	9.16	30yr fluvial flood event
4	9.34	1000yr fluvial flood event
5	9.66	>1000yr fluvial flood event
6	9.61	1000yr fluvial flood event

Table 11 – Threshold of flooding at the Pen-y-Bont Cottages for the Baseline Scenario.

The modelled levels presented in Table 10 suggest that Nos 5 and 6 would be introduced to flood risk in the 1 in 1000 year event post-construction. The thresholds – 9.66m AOD and 9.61m AOD respectively – would not flood in the current-day 1 in 1000 year event, but it is indicated that due to a 55mm increase in flood depth as a result of the scheme, these properties would be classed as at risk of flooding. Similarly, it is suggested that the onset of flooding for other properties would become more frequent, with No. 4 predicted to flood in the 1 in 100 year plus climate change event compared to the 'baseline' threshold of flooding which is the 1 in 1000 year event. However, it should be noted that the property thresholds are set lower than the road levels along the A493, with surveyed levels along the road recording levels of 10.18m AOD at the existing A487/A493 junction, and 9.3m AOD adjacent to No. 1. Therefore, it is clear that there is no flow path for river levels to encroach into properties Nos.4, 5 and 6, as the road provides an additional level of protection. Therefore, they remain elevated above the 1 in 1000 year threshold despite the localised increase in flood depths of 55mm.

In order to mitigate impacts options have been considered

1 – Proprietary Flood Defence Products

2 – Provision of a raised kerb along the northern edge of A493

3 – Raise level of A493 carriageway

4 – Consolidate drainage network + Install flap valves + Seal stone wall

5 – Consolidate drainage network + Install flap valves + Seal stone wall + Reduce catchment

6 – Consolidate drainage network + Install flap valves + Seal stone wall + Provide pumping station

7 – Consolidate drainage network + Install flap valves + Seal stone wall + Reduce catchment + Provide pumping station

As described in Section 6.1 and Flood Options Report in Appendix H, it was not feasible to introduce measures to the scheme to prevent any increase in flood levels. Therefore, following consultation with NRW, and in order to achieve the Transport Planning Objectives (TPOs) set out for the scheme, see Section 1.4, Option 6 has been determined as the most appropriate solution to mitigate impact on flooding of the scheme by reducing existing risk of flooding to Pen-y-Bont Cottages and A493, improving accessibility, and minimising the impact on landscape, biodiversity, water resources and heritage.

In order to protect the A493 and Pen-y-Bont Cottages from fluvial flooding, a single longitudinal carrier drain will be installed underneath the A493 in order to intercept and consolidate the numerous existing drainage networks into a single network with a single gravity outfall to the river. A non-return flap valve will be installed on the single gravity outfall. Existing drainage outfalls will be removed or grouted up, and the existing stone parapet wall sealed to provide an effective flood barrier. These measures will act to prevent any flow path for river flood water, and thereby protect the A493 and Pen-y-Bont Cottages from fluvial flooding. See Appendix K for proposed General Arrangement drawing.

An emergency pump station will be provided within a chamber under the A493 which will operate when the river is in flood and the flap valve on the drainage gravity outfall is closed, preventing outflow. The pump station would be sized at detailed design to ensure no flooding of the cottages up to the 100yr pluvial storm event. Initial modelling has been undertaken utilising Microdrainage software and indicates that a 150l/s pump station would protect the A493 from flooding up to the 100yr pluvial storm event. Run-off from a large section of steep hillside located directly behind Pen-y-Bont cottages has been included within the catchment. Initial drainage layout and Microdrainage output are presented in Appendix K.

The exact layout and position of the longitudinal carrier drain and pump station chamber will be determined at detailed design following detailed drainage and utility survey.

The details of the A493 pump station arrangement will be confirmed at detailed design and in agreement with Gwynedd Council as adopting authority. It is

envisaged that the pump station would operate in a 3 pump duty/ assist/ standby arrangement in order to provide a full level of protection in the event of a pump failure. The pump station would also have a pump failure warning system that would alert the authority or maintenance agency. These measures, along with a regular maintenance and testing regime will ensure a reliable system is provided.

It is proposed that the existing A493 stone parapet retaining wall will be repaired and sealed to act as a fluvial flood defence. As such an initial structural assessment has been undertaken, see Appendix M, which confirms the ability of the existing wall to withstand the relatively low retained flood depths (up to 578mm retained fluvial flood water depth in 1000yr return period). The wall will be further surveyed and assessed during detailed design to ensure structural stability under fluvial flood conditions.

6.4 Dyfi Flow Gauging Station

River levels in the Dyfi are monitored by the Dyfi Gauge (Station No. 64001 – Dyfi at Dyfi Bridge). The National River Flow Archive (NRFA) records that this gauge is located at grid reference SH744019. The station location is described as a 'Natural river section controlled by d/s gravel bar. Natural flow regime' and has been in operation since 1962. This gauge is used by NRW to provide trigger levels for Flood Warning, and gauging at high flows has also been undertaken to derive a rating curve. It is therefore pertinent to examine whether the proposed bridge development will impact on the Dyfi gauge.

A hydrometric description of the gauge is provided by the NRFA data, which describes the Dyfi gauge as:

'Stable section. Downstream gravel bar acts as control, original control was the invert and arches of the historical Dyfi road bridge d/s. Multiple peak flow ratings applied across period of record, the most recent is valid from January 2002. Provides good fit to gaugings'.

Bankfull stage is 4.3m. The Annual Maxima (AMAX) data indicates that this stage has not been exceeded since the gauge was opened in 1962. It is possible that the bankfull height may have changed during this time as different rating curves have been developed. Spot gaugings have been completed at the gauge up to approximately 3.8m.

NRFA data notes that the channel is gauged to within 16% of AMAX3, but that flows upstream may go out of bank and bypass the station. Interrogation of the model outputs indicate that flows initially spill out of the River Dyfi channel both downstream and upstream of the gauge location, as shown in Figure 15 below:

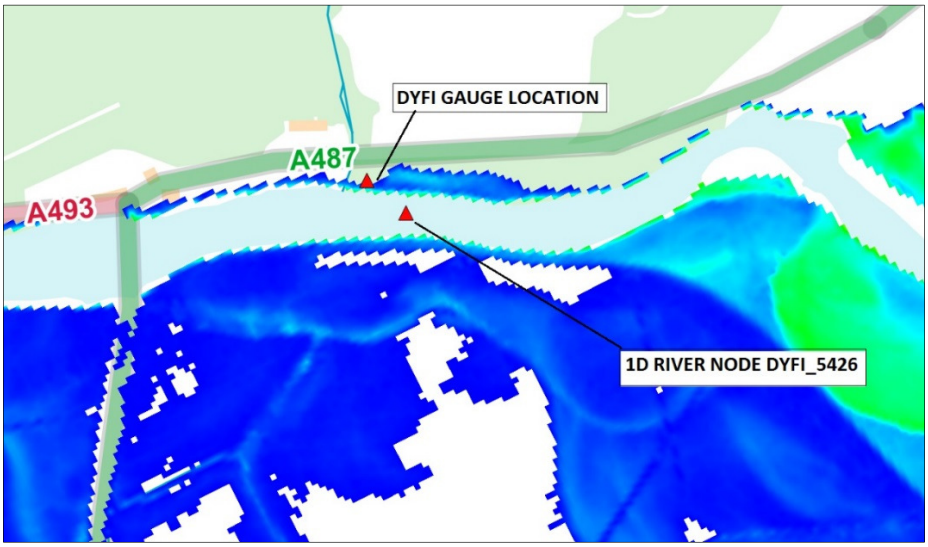


Figure 15: Dyfi Gauge location and nearest 1D cross-section

The nearest 1D river cross section in the Dyfi model is DYFI_5426, which is some 30m upstream of the gauge, as shown in Figure 15 above. This cross section is based on surveyed data, which indicates a top of bank level of 8.6m AOD on the

left bank, and 9.3m AOD on the right bank. The outputs from the model at DYFI_5426 have been extracted and are presented in Figure 16 below. It can be seen that the modelled levels are the same for both the baseline and proposed scenarios up to a stage of 9.7m AOD. Based on the NRFA data, which reports that spot gauges have been undertaken up to a stage of 3.8m, the maximum gauged level is 9.139m AOD (5.839m AOD (gauge datum) + 3.8m). Therefore, it can be assumed that the river has not been gauged above 9.7m AOD, and that the proposed development will have no impact on the rating curve at gauged flows. There may be changes however to the rating curve at high flows, which could be based on the outputs from the hydraulic model if required.

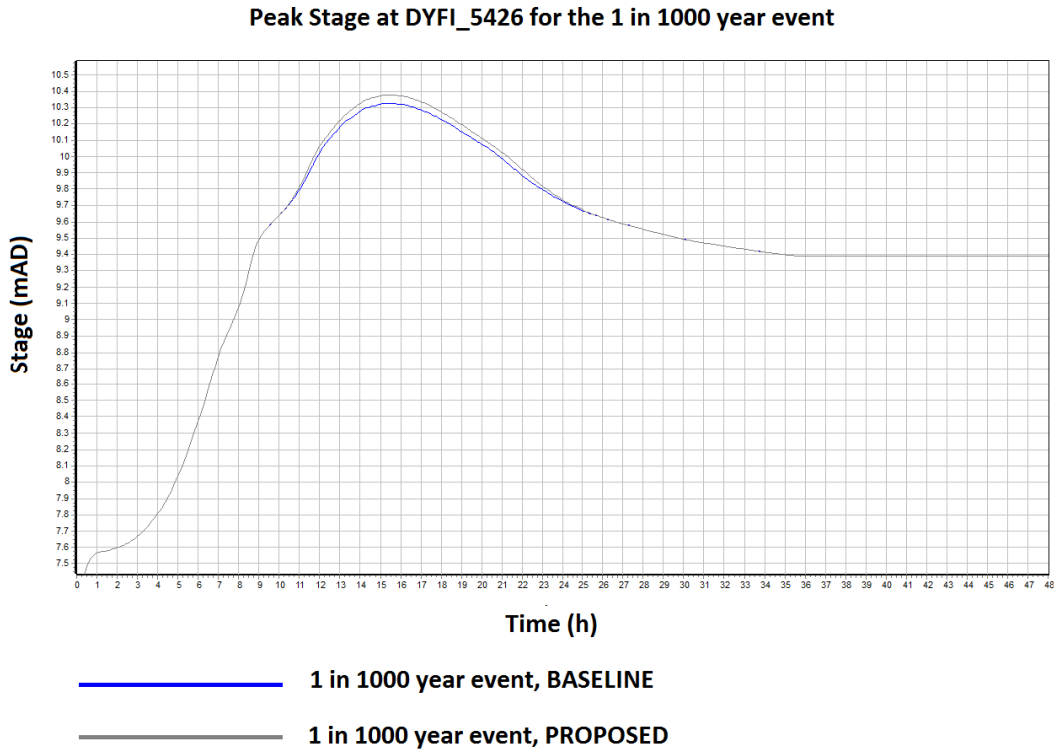


Figure 16: Peak modelled stage at DYFI_5426 for the 1 in 1000 year event

NRW have provided their flood warning service result thresholds for Dyfi. These are detailed in Table 12 below:

Flood Warning Service	Stage (Staff Gauge)	Level (mAOD)
Flood Alert Dyfi Catchment Result Threshold	2.71m	8.6m AOD
Flood Warning Dyfi Valley Result Threshold	3.61m	9.5m AOD
Flood Alert River Dyfi at Machynlleth & Derwenlas Result Threshold	4.21m	10.1m AOD
Flood Warning River Dyfi at Machynlleth & Derwenlas Result Threshold	4.51m	10.4m AOD

Table 12 – Threshold of flooding at the Pen-y-Bont Cottages for the Baseline Scenario.

It is concluded that the level of 9.7m AOD is above the trigger level used to issue Flood Alerts and Flood Warnings for the Dyfi catchment and Dyfi Valley respectively. Therefore, the proposed A487 scheme will have little to no impact on these trigger levels.

NRW confirm that the two highest thresholds – the Dyfi at Machynlleth & Derwenlas Result Thresholds – are forecasting model thresholds and have not been exceeded since their introduction 2 years ago. The model outputs indicate that during the proposed scenario, the level of 10.1m AOD is reached approximately 10 minutes earlier than the baseline scenario. Furthermore, the peak flood level at the gauge location is 10.38m AOD in the proposed scenario, compared to 10.33m AOD in the baseline scenario. Therefore, the proposed A487 scheme increases peak 1D flood levels by approximately 50mm at the gauge location. Liaison with the NRW Flood Incident Management Team has confirmed that Flood Alerts and Flood Warnings are issued for Machynlleth & Derwenlas solely on the basis of river levels reaching the trigger levels detailed in Table 12.

The baseline model scenario shows that when levels reach 10.1m AOD at the gauge location, at approximately 12:15 hours into the design hydrograph, overland flows flow towards Heol y Ddol and the Dyfi Eco Park. However, in the proposed scenario, when river levels at the gauge reach 10.1m AOD, then the flood extent is reduced, with the properties at the Dyfi Eco Park protected by the proposed embankment, and a reduced flood extent to the west of Heol y Ddol. However, as stated in Section 6.1.2 of this FCA, there is some instability in the model at the location of the Garsiwn Ditch, and the model outputs should be treated with caution at this location. Therefore, it is concluded that the proposed scheme will have a negligible impact on the area covered by the River Dyfi at Machynlleth & Derwenlas Result Threshold Flood Alert.

6.5 Existing Earth Bund

It is also considered that the existing earth bund in the agricultural fields may provide a certain level of defence. As an informal structure, it is possible that the landowner may modify or remove the structure in the future. Furthermore, there is no available information as to the construction materials of the bund and the structural integrity. Therefore, this FCA has assessed whether the scheme is reliant on the presence of the bund, and whether the design levels of the road and defence embankment are sufficient in the event that the bund is removed entirely.

The results for the 1 in 100 year plus climate change (20%) event are shown in Drawing No. WHS-1345-F01-010-r03, which is included in Appendix I herewith. The model outputs demonstrate that peak flood levels immediately downstream of the bund are increased by up to 70mm when the bund is removed, whilst upstream, peak flood levels are decreased by up to 400mm. Notwithstanding this local increase, peak flood levels are not sufficient to overtop the proposed Eco Park defence embankment or encroach onto the new road way and are within the proposed freeboard allowances. Therefore, it is confirmed that the design is not reliant on the presence of the bund, and the proposed scheme remains compliant and operational in the event of its breach and/or total removal.

The sensitivity test has been carried out for the 1 in 100 year plus climate change event. Please note that at the time of undertaking this sensitivity test, the climate change allowance of 20% was used. This sensitivity test has not been updated subsequent to the revised climate change guidance which recommends 30% climate change, on the basis that it is primarily a sensitivity scenario rather than a design scenario and the increase in climate change would not change the significance.

6.6 Surface Water Run-off from the Proposed Development

6.6.1 Highways Drainage

The proposed A487 scheme affects 2 No. existing highway drainage catchments as shown in Existing Highways Drainage Catchment Drawing, 900237-ARP-ZZ-ZZ-DR-CD-00001, which is included in Appendix K herewith.

Existing A487 highway drainage is via kerb & gulley. It is proposed that the new highway drainage will be split into 3 catchment areas as shown by Proposed Highways Drainage Catchment Drawing, 900237-ARP-ZZ-ZZ-DR-CD-00002, which is included in Appendix K herewith.

The proposed A487 highway drainage will be predominantly via kerb & gulley. Highway drainage from the proposed bridge/ viaduct will be conveyed in combined kerb/ drainage units to the abutments where it will connect into the respective pipe drainage networks. Combined kerb drainage units on the viaduct will allow for ease of maintenance, and reduce the need for pipes and/ or intermediate outfalls along the structure.

Flow isolation devices will be provided on all networks as a means of isolating any spillage events

Due to the topography of the site, and proximity to the floodplain, scope for providing attenuation within the scheme is limited. It is also thought that attenuation of highway outflow would result in a delayed highway peak discharge coinciding with the later river peak flow. For this reason free outfalls are proposed for catchments 1 and 2.

Highway drainage outflow would be negligible in comparison to fluvial flows and as such would have no effect on river or flood levels.

6.7 Groundwater Flooding

The principal mechanism of flooding is considered to be fluvial in nature. Due to the nature of the proposed development, which is to be raised above the floodplain, ground water flooding is not considered to be a critical. The new road will be constructed on piers, which will utilise piling techniques to create the foundation platform. There will be minimal impact on the groundwater regime, and flooding from this source does not warrant further consideration.

7 Temporary Works

In order to construct the new bridge, a temporary embankment will be required at the southern end of the structure and a crane access platform towards the northern end of the structure. The embankment will enable the new bridge to be push-launched into position, minimising the amount of plant within the floodplain. Temporary haul roads within the floodplain will be kept at grade to ensure no impedance of flood flows. Following completion of the construction works, the temporary crane platform will be removed and the bridge launch platform will be incorporated into the permanent road embankment.

Although unlikely, it is possible that an extreme flood event will occur at Machynlleth during the construction phase of the bridge development. Therefore, the temporary works were incorporated into the proposed scenario, and the model was rerun to ensure that the scheme can remain compliant with TAN15 even during the construction phase. The results for the 1 in 2 year flood event and the 1 in 100 year flood event are presented in Appendix O. It can be seen that the temporary works do not cause an adverse impact on third party property immediately upstream of the existing Pont-ar-Ddyfi. Furthermore, there are no predicted impacts for additional areas than those already presented above in Section 6.

It should be noted that climate change was not incorporated into this scenario, as the scheme is to be completed within the next 18-24 months. Therefore, it was not considered appropriate to apply climate change to the peak flows.

8 Summary

Table A1.14 in Appendix 1 of TAN15 outlines the frequency threshold of flooding below which flooding of development should not be allowed. For general infrastructure, the threshold frequency is the 1 in 100 year probability fluvial event. It is clear that the road itself will not be at risk of flooding.

TAN15 requires that a site-specific FCA carries out an assessment of the likely impact of any displaced water on neighbouring or other locations which might be affected subsequent to development. This should address the potential for change of the flooding regime both upstream and downstream of the site due to ground raising or flood embankments.

This FCA has sought to summarise the comprehensive optioneering modelling that was carried out to derive an appropriate design. A key consideration throughout this process was minimising the impact on third party land and/or property. In line with TAN15, the scheme has been designed to remain compliant for the design flood event which is the 1 in 100 year plus climate change event. However, modelling has also been carried out for a full range of events, from the 1 in 2 year event to the 1 in 1000 year event. The outputs from this confirm that there are no significant changes to the flooding mechanisms across the return periods.

Hydraulic modelling has been carried out in order to establish the flood risk at Machynlleth and the results have been presented in this FCA. The hydraulic model was also used to derive a scheme that remained compliant with the requirements of PPW and the DMRB in respect of flood risk. The following section summarises the key findings and confirms that the proposed development is appropriate in terms of flood risk.

8.1 Baseline Flood Risk

The existing A487 Dyfi River crossing floods regularly causing closure of the road restricting access to and from Machynlleth.

Modelling indicates that the road has a high frequency of flooding, of greater than 1 in 2 years. The A487 road was closed as recently as November 2015 due to the risk of flooding.

The modelled flood extent indicates that flooding within the Dyfi floodplain impacts on the Dyfi Eco Park and the area of business and residential property adjacent to the railway bridge over the A487. During the 1 in 100 year plus climate change event, flood depths of over 0.5m are predicted for parts of the Dyfi Eco Park site, and peak flood depths along Heol y Doll are predicted to exceed 0.8m. Furthermore, properties off Railway Terrace are predicted to be affected by floodwaters approximately 0.1m deep.

Residential properties, Pen-y-Bont Cottages, located north of the river next to the existing A487/A493 junction suffer from regular flooding as shown within the baseline model, and validated by reports from residents. Cottage No.1 is at risk of flooding from the 5yr fluvial flood event.

8.2 Post-Development Flood Risks

The design of the new bridge has been undertaken with consideration of minimising the impacts on the flood regime within the Dyfi floodplain.

The proposed A487 trunk road bridge is to be elevated above the floodplain on piers spaced at regular intervals. The raised section has also been extended following initial modelling work in order to minimise the amount of embankment and associated impediment to floodplain flows. Furthermore, the bridge is to be built in conjunction with a new flood defence embankment at the Dyfi Eco Park which will serve to protect business park properties, as well as protecting the lower levels of the A487 trunk road as it passes under existing Cambrian Railway at Heol y Doll.

The proposed scheme will bring significant transport benefits, with a reduction in the requirement for road closure- from a frequency greater than the 1 in 2 year event to less than a 1 in 100 year event. The scheme will also provide wider benefits in terms of improved connectivity, improved emergency service access, improved road and public safety, safeguarding of national heritage assets and reduced flood risk to both A487 and A493.

The Dyfi Eco Park will also be protected up to the 1 in 100 year event, and properties off the existing A487/Heol y Doll will also experience a reduced frequency of flooding from the River Dyfi. The proposed development provides protection for approximately 10 properties up to the 1 in 100 year event.

Flood protection will be also provided to the residential Pen-y-Bont Cottages at the existing A487/A493 junction north of the river, by incorporation of a flood protection wall to prevent fluvial flooding to beyond the 1 in 1000yr fluvial flood event, and provision of a surface water pumping station to manage pluvial water. These measures will provide betterment by reducing the existing flood risk to Pen-y-Bont Cottages to 1 in 100yr flood event.

The flood protection provided by the proposed development will however result in a displacement of flood water that previously inundated these assets, into agricultural fields and the basement and garden of residential property No.7 Dyfi Bridge. The impact of the displaced flood water will have a localised impact on the existing flood regime, with an increase in modelled flood levels of approximately 60mm. However, modelling and analysis of results has confirmed that this has no significant change to the frequency or duration of flooding, and as such is a minor impact with low significance in terms of the land's use as grazing pasture, or basement storage. It is therefore considered that the minor adverse impacts are justified and acceptable given the wider benefits of the scheme

The hydraulic modelling work, which informs this FCA, confirms that the proposed development is compliant with PPW and the DMRB in terms of flood risk.

Appendix A

Letter from Welsh Government Transport Infrastructure Delivery Division

Trafnidiaeth • Yr Is-adran Cyflenwi Seilwaith
Transport • Infrastructure Delivery Division

Llywodraeth Cymru
Welsh Government

MRS M W Read
Natural Resources Wales
Llwyn Brain
Ffordd Penlan
Parc Menai
Bangor
LL57 4TW

Eich cyf . Your ref
Ein cyf . Our ref
11 August 2017

Dear Mrs Read

A487 New Dyfi Bridge FCA Report

We write in response to letter dated 5 July from Natural Resources Wales containing review comments on Draft Issue 02 of "A487 New Dyfi Bridge FCA Report", dated 24 March 2017.

Welsh Government are proposing a new section of the A487 trunk road north of Machynlleth, comprising a new bridge and viaduct across the River Dyfi and associated floodplain.

The existing Pont-ar-Ddyfi was not designed to carry the current volume of traffic and is often closed due to frequent flooding. This results in a loss of connectivity preventing all users from crossing the river at this location, and requiring traffic (including emergency vehicles) to take a diversion of up to 30 miles. In addition, the existing A493 and adjacent Pen-y-Bont cottages (located north west of Pont-ar-Ddyfi) are prone to regular flooding. A report by the Lead Local Flood Authority, Gwynedd Council in December 2015 noted that the road and cottages had a history of flooding. Despite these findings no flood prevention measures have been proposed or implemented. On the south side of the river the existing Dyfi Eco Park is also located within the river Dyfi floodplain, and as such is at risk of flood from the river. Equally significant is a low spot on the existing A487 trunk road where the road passes underneath the Cambrian railway line. This low spot also currently suffers from significant flooding.

The existing Pont-ar-Ddyfi bridge is a Grade II* listed heritage feature and a Scheduled Monument so Welsh Government are restricted in what alterations can be undertaken.

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As part of the Environmental Impact Assessment (EIA) for the project, the project team has prepared the Flood Consequences Assessment (FCA) "A487 New Dyfi Bridge FCA Report" including a "Flood Options Report". These reports provide detail on the extensive flood modelling and optioneering which have been undertaken. Additional works including a flood protection bund, new drainage system, a pump and storage facility at the Pen-y-Bont cottages and a pump and sump facility at the railway bridge low spot have been incorporated into the scheme as a result. These additional measures mitigate the water displaced by the scheme, and provide enhancement by reducing the existing flood effects on the A493, A487 trunk road, Pont-ar-Dyfi, Dyfi Eco Park and the Pen-y-Bont Cottages.

TAN Technical Advice Note (TAN) 15 Section 6.2 states that:

"... Development, including transport infrastructure will only be justified if it can be demonstrated that:-

i. Its location in zone C is necessary to assist, or be part of, a local authority regeneration initiative or a local authority strategy to sustain an existing settlement; or,

ii. Its location in zone C is necessary to contribute to key employment objectives supported by the local authority, and other key partners, to sustain an existing settlement or region;

And

iii. It concurs with the aims of PPW and meets the definition of previously developed land (PPW fig 2.1); and,

iv. The potential consequences have been considered, and in terms of the criteria contained in sections 5 and 7 and appendix 1 found to be acceptable"

TAN 15 Section 7.2 states that:

"Whether a development should proceed or not will depend upon whether the consequences of flooding of that development can be managed down to a level which is acceptable for the nature/type of development being proposed, including its effects on existing development."

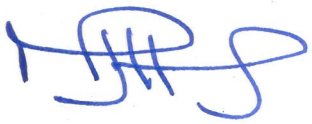
Also, Section A1.12 of TAN 15 states that a site should only be considered for development if it can satisfy a number of criteria including that there will be no flooding elsewhere as a result of the development.

Planning Policy Wales recognises that *"whilst flood risk can be reduced by using mitigation measures it can never be completely eliminated"* and goes on to further state that "*Development proposals should seek to reduce, and certainly not increase, flood risk arising either from river and/or coastal flooding or from additional run-off from development in any location".*

The Welsh Government project team notes that the proposed scheme does impact upon the floodplain.

Due to the existing adverse impacts on infrastructure from the current flooding regime, scheme options examined by the project team have focused on flood risk management. The proposed scheme will protect the high value assets of the A487 trunk road, Pont-ar-Dyfi, Dyfi Eco Park, A493 and Pen-y-Bont cottages: however there will be a displacement of the flood waters that previously inundated these assets, into the adjacent agricultural fields and the non-habitable basement/outdoor store room of residential property 'Minafon', No 7 Dyfi Bridge, located immediately upstream of Pont-ar-Ddyfi. The impact of the displaced flood water on these properties, located within the existing flood plain is in the order of an additional 60mm (in the 100yr + climate change flood event) above the existing flooding depths of greater than 1m. As the extent, frequency and duration of flooding are not increased, and hence the risk of flood is not increased, it is considered that this slight increase in flood depth is a minor impact with low significance. Welsh Government consider these minor impacts are justified and acceptable given the wider benefits of the scheme in terms of the improved connectivity, the improved road safety characteristics, the safeguarding of national heritage assets and the reduced flood risk to both the high value A487 trunk road and A493 highway asset. In addition, it should be noted that the project will provide improvements to the existing highway drainage at Pen-y-Bont cottages and the removal of the flood risk under the existing railway bridge. The extent of floodplain has not increased as a result of the proposed scheme, and as such there will be no flooding elsewhere as a result of the development.

Yours sincerely,



James Healey

James Healey. B.Eng. C.Eng. MHKIE. MICE.

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Appendix B

Proposed Scheme

A493 to Aberdyfi

A487 to Dolgellau

Proposed A493
Traffic Calming

Bythynnod Pen-y-Bont
Pen-y-Bont Cottages

Pont-ar-Ddyfi
Dyfi Bridge

Afon Dyfi
River Dyfi

A493

ADS

0+000.000

0+100.000

0+200.000

0+300.000

0+400.000

0+500.000

0+600.000

0+700.000

0+800.000

0+900.000

1+000.000

1+100.000

1+200.000

1+315.426

1+386.000

Fferm Y Fridd
Y Fridd Farm

0+290.695

Dyfi Eco Park

Flood Bund

Millennium Footbridge

Railway Bridge

Machynlleth Station

Rheilffordd Cambria
Cambrian Railway

Bus Depot

Railway Terrace

Heol Y Doll

Ffordd Mynydd Griffiths

MACHYNLLETH

Afon Dulas
River Dulas

0 10 20 30 40 50 100 Metres

Scale 1:2500

Legend

- Existing Vegetation
- Open Grassland
- Species Rich Grassland
- Highway Fenceline
- Site Extents
- Existing NMU Routes
- Proposed NMU Routes
- ADS — Advanced Directional Signs
- Proposed Culvert & Headwalls
- Proposed Drainage
- Existing Culvert & Headwalls

Notes:

1. Refer to Figure 8.9 for landscaping planning proposals.

Issue	Date	By	Chkd	Appd
P03.7	—	—	—	—

ARUP
GRIFFITHS civil engineering and construction
WHS
Blythe Gate Blythe Valley Park
Solihull B90 8AE
Tel +44 121 213 3000 Fax +44 121 213 3001
www.arup.com

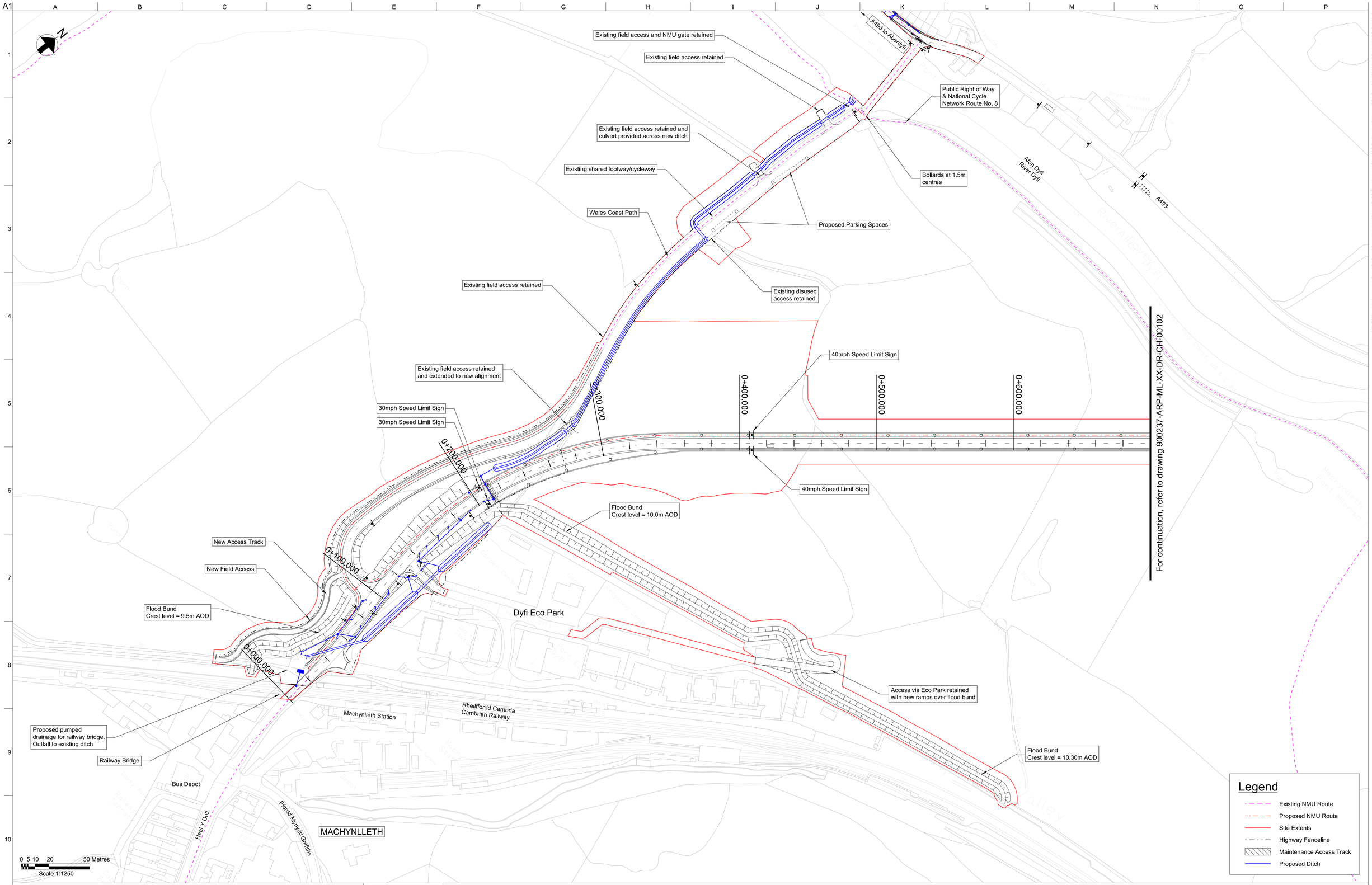
Client: Llywodraeth Cymru
Welsh Government

Project Title: A487 New Dyfi Bridge

Drawing Title: Scheme General Arrangement
1:2500

Scale at A1: 1:2500
Role: Civil - Highways
Suitability: S0 - Initial non-contractual
Arup Job No: 244562-00
Rev: P03.7
Name: 900237-ARP-ML-ZZ-DR-CH-00101

Do not scale



Notes:

Issue	Date	By	Chkd	Appd
P02.6	---	---	---	---

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Client
Llywodraeth Cymru
Welsh Government

Project Title
A487 New Dyfi Bridge

Drawing Title
General Arrangement for A487

Sheet 1 of 2

Scale at A1 1:1250
Role Civil Engineer - Highways
Suitability S0 - Initial non-contractual
Arup Job No 244562-00
Rev P02.6
Name 900237-ARP-ML-XX-DR-CH-00101

Do not scale

A1

Pont-ar-Ddyfi
Dyfi Bridge

A493

Afon Dyfi
River Dyfi

Public Right of Way & National Cycle Network Route No. 8

For continuation, refer to drawing 900237-ARP-ML-XX-DR-CH-00101

Shared footway/cycleway on western side of viaduct

0+700.000

0+800.000

0+900.000

1+000.000

1+100.000

1+200.000

1+300.000

1+315.426

Farm access gate

Private farm access track

Fferm Y Fridd
Y Fridd Farm

A487 to Dolgellau

Millennium Footbridge

Proposed cattlepass

Informal pedestrian crossing

Extended existing field access

Afon Dulas
River Dulas

Rheilffordd Cambria
Cambrian Railway

0 5 10 20 50 Metres
Scale 1:1250

Legend

- Existing NMU Route
- Proposed NMU Route
- Site Extents
- Highway Fenceline
- Maintenance Access Track
- Proposed Ditch

Notes:

Issue	Date	By	Chkd	Appd
P02.6	---	---	---	---

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Client
Llywodraeth Cymru
Welsh Government

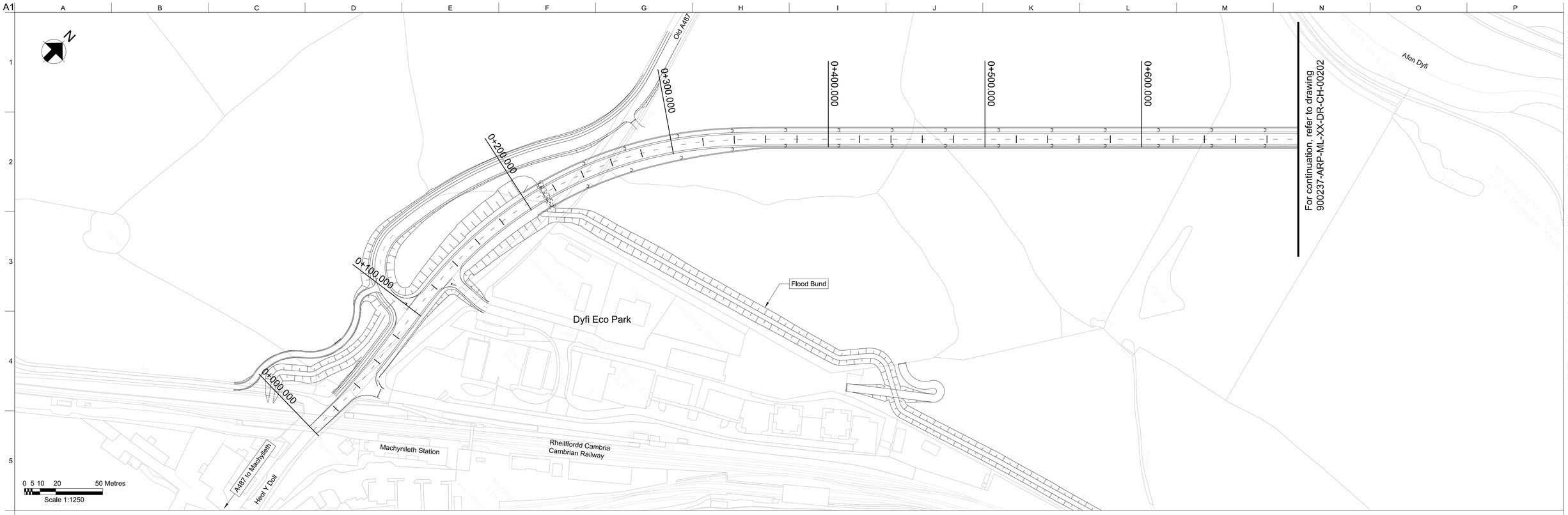
Project Title
A487 New Dyfi Bridge

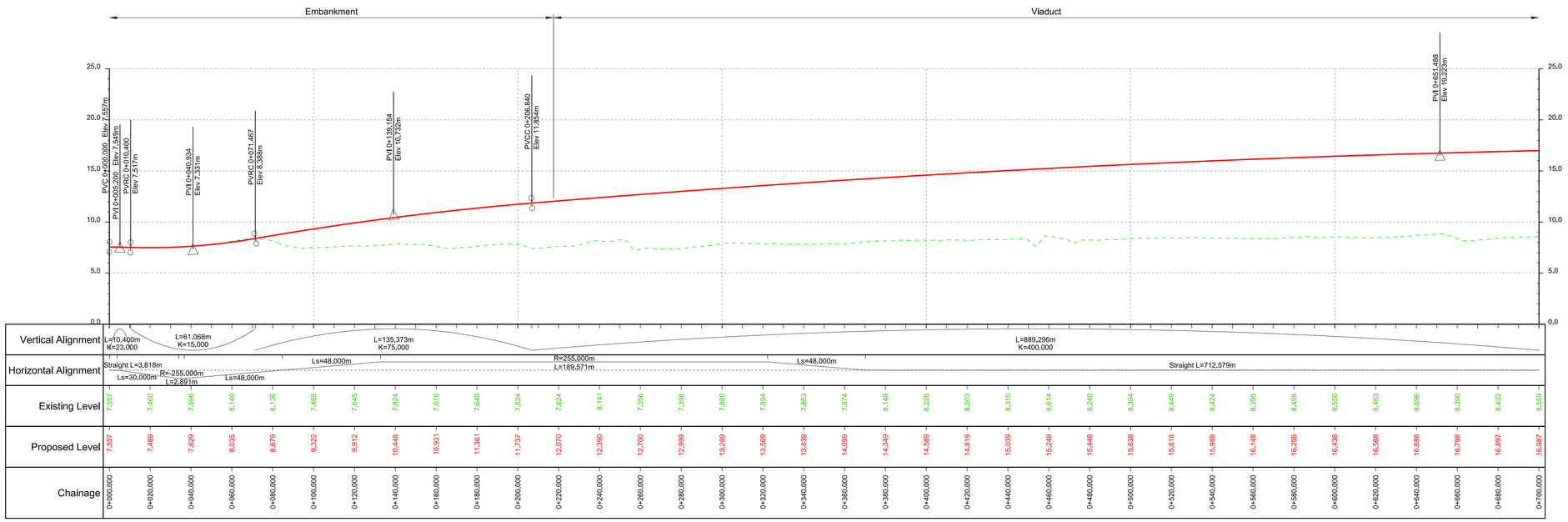
Drawing Title
General Arrangement for A487

Sheet 2 of 2

Scale at A1 1:1250
Role Civil Engineer - Highways
Suitability S0 - Initial non-contractual
Arup Job No **244562-00**
Rev **P02.6**
Name **900237-ARP-ML-XX-DR-CH-00102**

Do not scale





0 5 10 Metres
Vertical Scale 1:250

0 5 10 20 50 Metres
Horizontal Scale 1:1250

Mainline A487 Profile

Legend

- Existing Ground Level
- Proposed Centreline

Notes:

Issue	Date	By	Chkd	Appd
P03.6	—	—	—	—

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Client: Llywodraeth Cymru Welsh Government

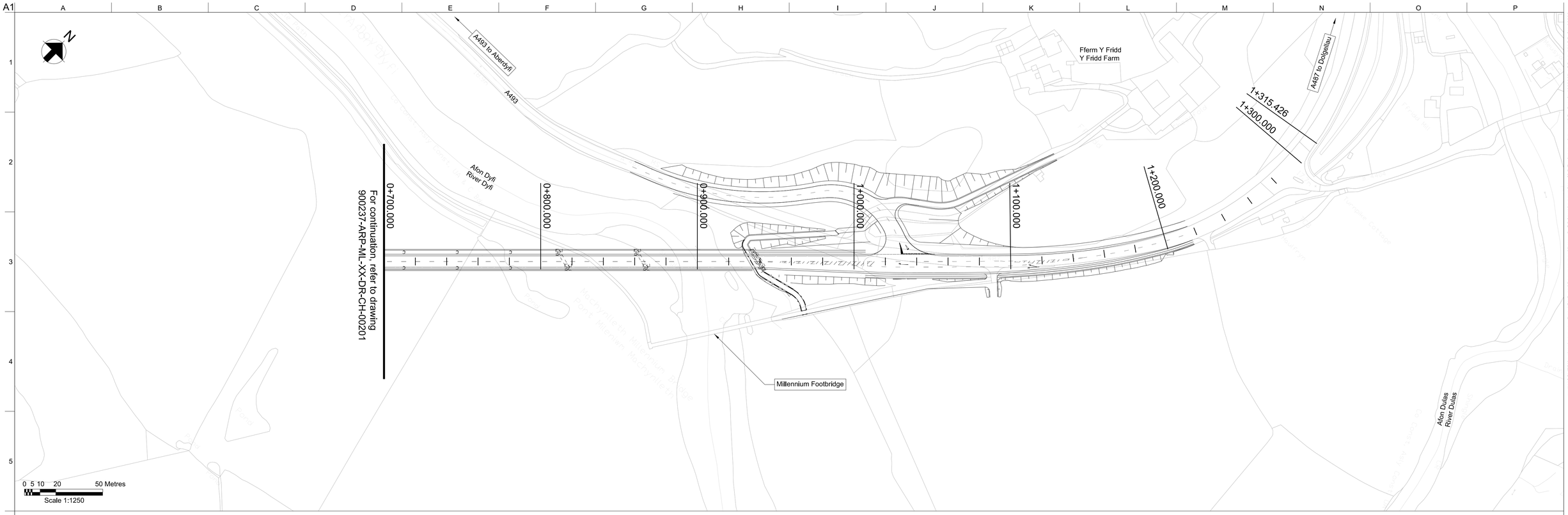
Project Title: A487 New Dyfi Bridge

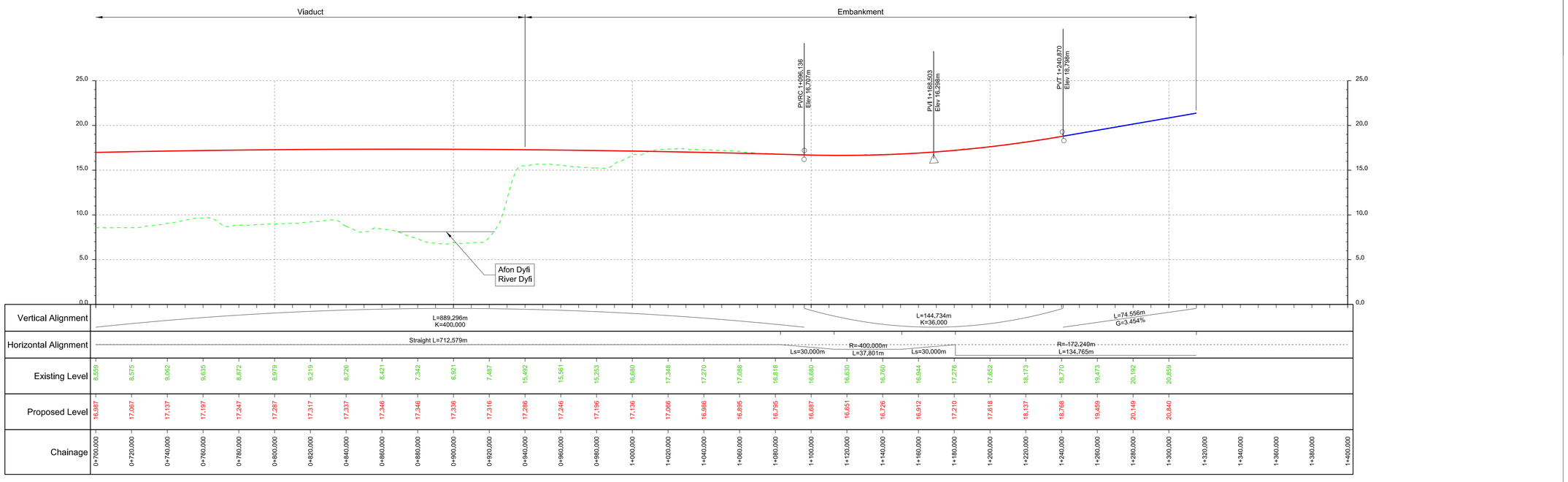
Drawing Title: A487 Plan & Profile

Sheet 1 of 2

Scale at A1: 1:1250
Role: Civil Engineer - Highways
Suitability: S0 - Initial non-contractual
Arup Job No: 244562-00
Rev: P03.6
Name: 900237-ARP-ML-XX-DR-CH-00201

Do not scale





Mainline A487 Profile

Legend

- Existing Ground Level
- Proposed Centreline

Notes:

Issue	Date	By	Chkd	Appd
P02.4	—	—	—	—

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Client: Llywodraeth Cymru Welsh Government

Project Title: A487 New Dyfi Bridge

Drawing Title: A487 Plan & Profile

Sheet 2 of 2

Scale at A1: 1:1250
Role: Civil - Highways
Suitability: S0 - Initial non-contractual
Arup Job No: 244562-00
Rev: P02.4
Name: 900237-ARP-ML-XX-DR-CH-00202

Do not scale

A1

N

A493 to Aberdyfi

A493

Proposed 30mph signs

Proposed A493 Traffic Calming

Line of Permanent and Demountable Bollards

3m Length of Dropped Kerbs to aid NMU and authorised access

Proposed 30mph signs

Proposed A493

Afon Dyfi
River Dyfi

Permanent and De-mountable bollards to be placed at 1.5m centres across carriageway

Pont-ar-Ddyfi
Dyfi Bridge

National Cycle Network Route No. 82 & Wales Coast Path

Existing Field Access and NMU Access Retained

Footpath No.14

Afon Dyfi
River Dyfi

Existing Field Access Retained

Existing fence and hedge to be retained

Kerbed and planted island

Proposed parking spaces

Kerbed and planted island

Existing Field Access Retained

Existing fence and hedge to be retained

National Cycle Network Route No. 8 and Wales Coast Path

Kerbed and planted island

Proposed parking spaces

Kerbed and planted island

New Culvert

National Cycle Network Route No. 8 and Footpath No.1

0 10 20 Metres
Scale 1:500

Legend

- Existing NMU Route
- Proposed NMU Route
- Site Extents
- Highway Fenceline
- Maintenance Access Track
- Proposed Ditch

Notes:

Issue	Date	By	Chkd	Appd
P02.3	---	---	---	---

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www.arup.com

Client: Llywodraeth Cymru Welsh Government

Project Title: A487 New Dyfi Bridge

Drawing Title: Existing Dyfi Bridge General Arrangement

Scale at A1: 1:500

Role: Civil Engineer - Highways

Suitability: S0 - Initial non-contractual

Arup Job No: 244562-00

Rev: P02.3

Name: 900237-ARP-OB-05-DR-CH-00101

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Do not scale

Appendix C

Survey Location Plan

274500 275000 275500 276000 276500

302500 302000 301500

Legend

Cross Section Locations

- 250m Centres
- 200m Centres
- 100m Centres
- 50m Centres

- String Line
- Urban Area to Survey

All survey points to be referance to NGR and AOD

Photos to be taken of each River Survey Section

N

String line - Top of Bank
Identifying ridge and changes in gradient. Min 100m spacing

Cross Section to include top of railway level

Finished Floor Levels withinof ALL properties

Bridge
Invert, sofit levels & width of underpass

River sections as close to confluence as possible

Bridge
Invert, sofit levels & width of underpass

String line - A487
Identifying ridge and changes in gradient. Min 100m spacing

Survey ALL culverts, invert/soffit level & Dimensions

Bridge
Invert, sofit levels & width of underpass

River Survey Sections

String line - Railway Line
Identifying ridge and changes in gradient. Min 100m spacing

Finished Floor Levels within the ECO Park

Bridge
Invert, sofit levels & width of underpass

Afon Dulas
Bryn-cae-Meilir
Glan-Gwynedd
Mill
Pont Felin-y-ffridd
Ffridd
Glan-fechan
Glan-dwr
Pont Mileniwm Machynlleth / Machynlleth Millennium Bridge
Hotel
Dolguog Farm
Coed Dolguog
Glandulas Bach
Garden Centre
Recycling Centre
Dyfi Eco Park
Coed Salter
Ysgubor-wen
Garth Caravan Park
Cae'r-lloi
Wind Turbine
Gallt y Gog
Pistyll Gwyn
Pen yr Allt
Railway Terrace
Brynteg
Brook y Beunes

0 100 200 300 400 m

Appendix D

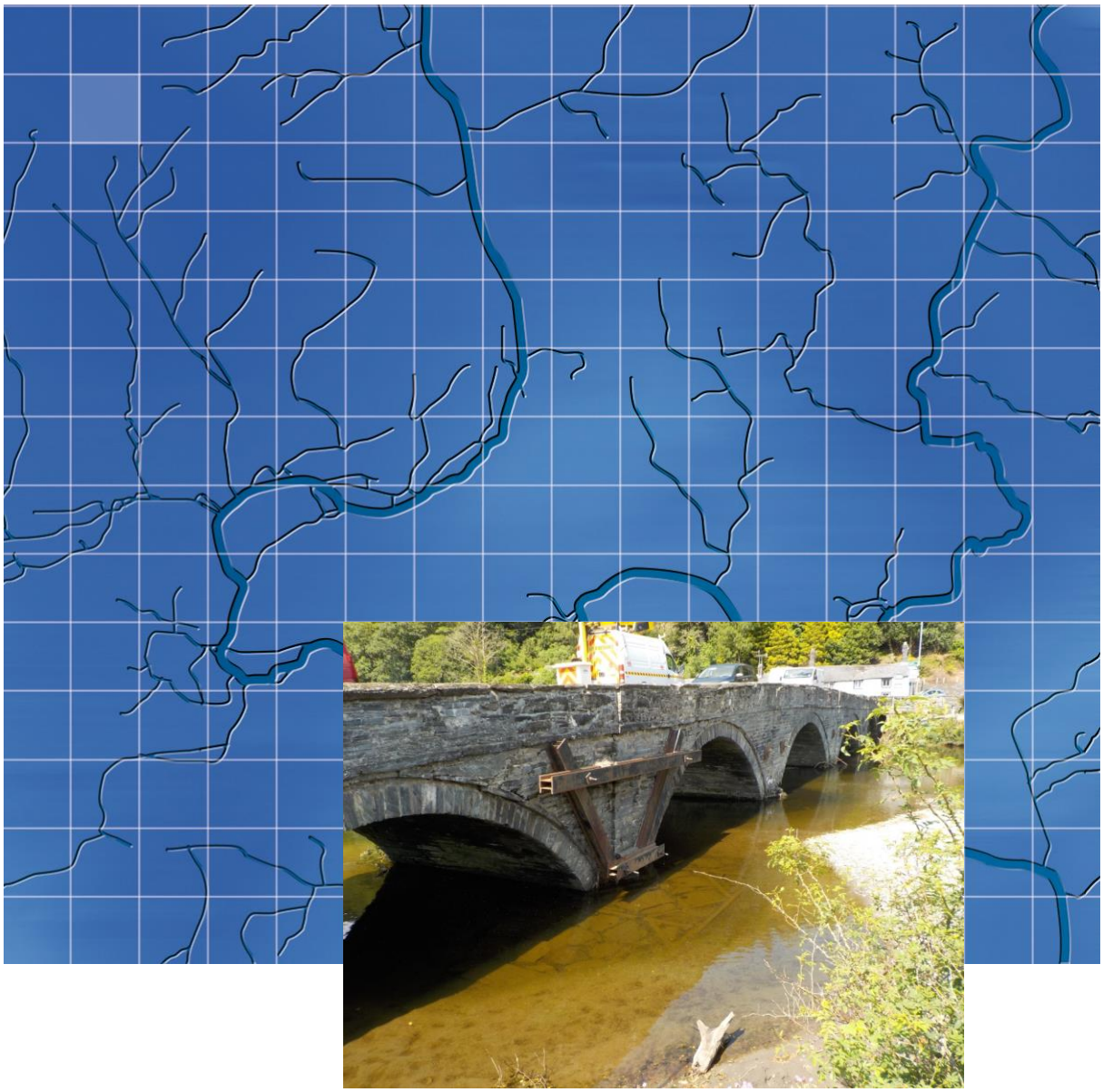
A487 New Dyfi Bridge
Hydraulic Model Report

Arup

December 2016

A487 New Dyfi Bridge

Hydraulic Model Report



Wallingford HydroSolutions Limited

Arup

A487 New Dyfi Bridge Hydraulic Model Report

Document issue details

WHS1345

Version number	Issue date	Issue status	Issuing Office
1.0	03/03/2016	Final	Cardiff
2.0	15/04/2016	Final	Cardiff
2.1	25/07/2016	Final	Cardiff
2.2	28/07/2016	Final	Cardiff
2.3	08/12/2016	Draft	Cardiff

For and on behalf of Wallingford HydroSolutions Ltd.

Prepared by Brett Park

Approved by Laura Clements
Position *Senior Consultant*

Date **8th December 2016**

This report has been produced in accordance with the WHS Quality Management system which is certified as meeting the requirements of ISO 9001:2008 and ISO 14001:2004

WHS

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Contents

1 Introduction

1.1 Scope of Study

Wallingford HydroSolutions (WHS) have been commissioned to undertake the Flood Consequence Assessment (separate document) to support a proposed new river crossing over the River Dyfi in Machynlleth (NGR: SH 74874 02002).

The River Dyfi is prone to flooding and as such the A487 and the existing A487 Bridge are regularly closed, resulting in significant disruptions to transportation links across the river. Hence there is the requirement for a new river crossing which can remain open during these frequent flood events.

In order to make a quantitative assessment of the impacts that the proposed bridge and associated works may have on the flooding mechanisms in Machynlleth, detailed hydraulic modelling of the River Dyfi and its associated floodplain has been undertaken.

The hydraulic modelling has been undertaken by updating the existing model of the River Dyfi and Garsiwn tributaries around Machynlleth, developed by NRW as part of the North Wales Work Package B in June 2011. This hydraulic model report outlines the amendments that have been made to the existing hydraulic model, and provides justification for the methodologies and assumptions made during the modelling study. It is recommended that the hydraulic modelling report[1] for the existing NRW Dyfi model is read prior to reading this report.

This report summarises the model development and sensitivity testing undertaken for the baseline hydraulic model to be used in assessing the impact of the A487 New Dyfi Road Bridge project. The report also details the additional modelling carried out to assess the proposed development and the potential impact of the new bridge on the existing flooding mechanisms. This work also included an assessment of the temporary works which will be required to construct the bridge.

1.2 Model History

In 2011, Capita Symonds were commissioned by NRW to develop a linked 1D/2D hydraulic model of the River Dyfi near Machynlleth. This model is a combination of an existing 1D Hec-Ras model and an existing 1D ISIS model. The two models were combined and extended into a linked 1D/2D model of the River Dyfi and its associated flood plain, where the 2D floodplain is based on LiDAR levels.

Additionally, the Garsiwn tributaries were surveyed in 2010 and included in the 2011 model as a 1D ESTRY domain.

1.3 Assumptions

The following assumptions were made during the modelling;

- Any inflows other than the River Dyfi, Nant Rhisglog tributary and Garsiwn tributaries are considered negligible and have not been included within the hydraulic model.
- No allowance for any drainage networks has been considered.
- A 20% increase in flows has been added to flows when allowance for climate change has been considered.

[1] Capita Symonds (2011). *North Wales Work Package B – Machynlleth Study*. WA029.

2 Extension to Model

2.1 Extent of Model

The upstream boundary of the existing hydraulic model of the River Dyfi is located approximately 350m upstream of the existing A487 Dyfi Bridge. It is considered that this boundary is too close to the point of assessment and as such it is appropriate to extend the model 2.5km upstream. Extending the model further upstream allows flood waters to establish their natural flow regime, thus ensuring that the flood levels at the point of assessment are not influenced by the upstream boundary location.

Extending the model upstream introduces the two tributaries of the River Dulas, these tributaries have been modelled as separate inflows to ensure the model is representative of the actual floodplain and the flooding mechanisms of the River Dyfi. Figure 1 shows the extent of the updated model and the location of the inflow for the River Dyfi and the two tributaries of the River Dulas, identified as Dulas North and Dulas South.

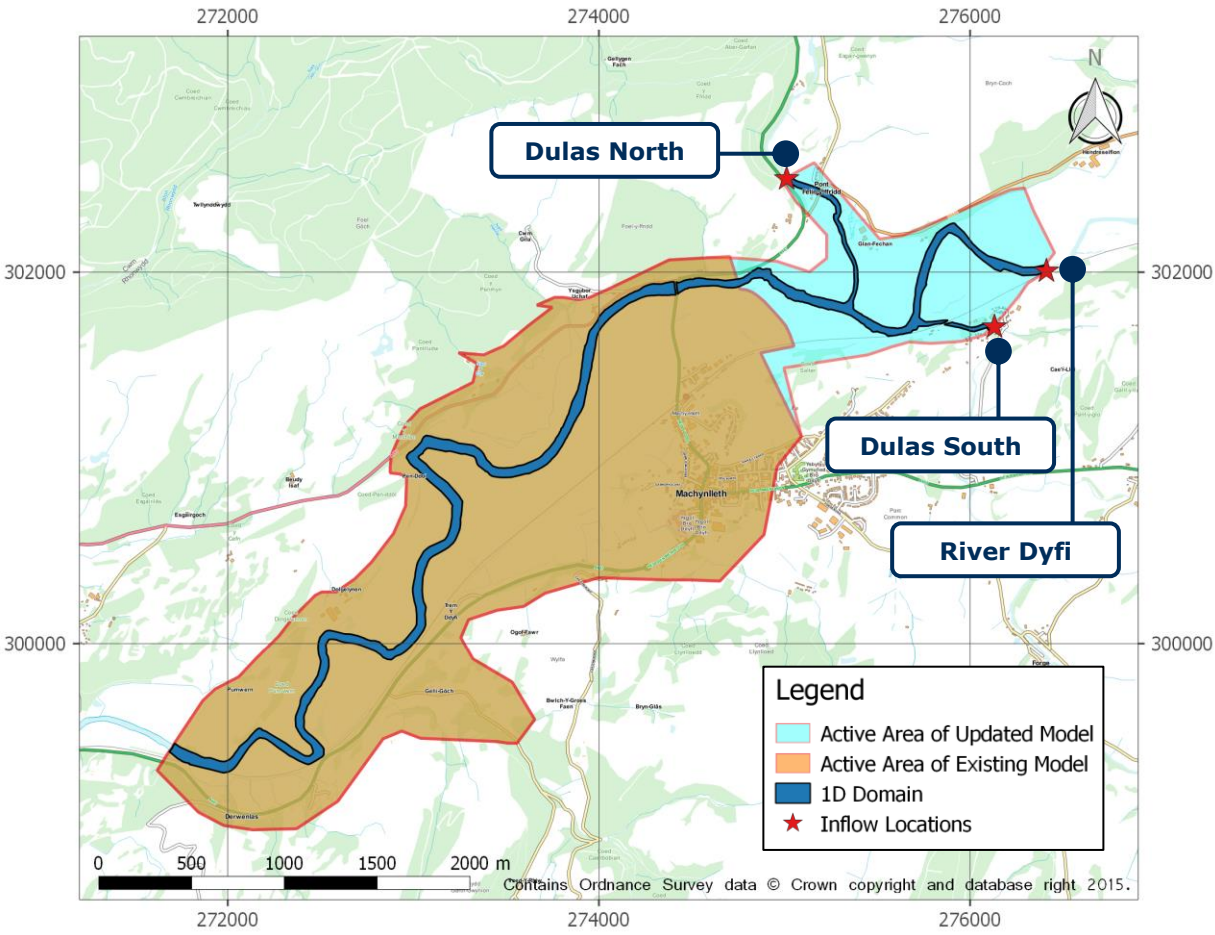


Figure 1 – Existing and updated model extent

2.2 Grid size and Orientation

The existing model used a grid resolution of 4m by 4m and it was orientated in the approximate direction of flow within the floodplain, which is considered to be best practice.

As such the existing grid size and orientation was considered to be appropriate for the updated model, the only change that was made was to increase the grid extent to ensure that it covered the extended active area.

2.3 River Channel

Extending the model upstream required additional surveying of the river channel, this was undertaken by NRG Engineering on 10th September 2015.

Thirty eight new cross sections were added to the model, starting from the existing A487 Bridge to the new upstream boundary of the model, including a survey of the Dulas North and Dulas South tributaries. The survey also included the road bridge spanning the Dulas North and the railway bridge spanning the Dulas South, which were incorporated into the 1D model domain.

At the location of the proposed bridge, cross sections were surveyed at 50m intervals to ensure that the bathymetry of the river was adequately represented at the location of interest. Further upstream of the proposed bridge, intervals between each cross section were increased to 100m. Beyond the confluence of the Dulas South with the River Dyfi the intervals between each cross section was increased to 250m.

The extent of the new river survey was discussed with NRW in July 2015, it was concluded that it would be suitable obtain new survey sections from the existing A487 bridge to an upstream location that would capture the backwater effect of the existing A487 bridge. Initial modelling of the River Dyfi in February 2015 suggested that the upstream boundary location identified in Figure 2 is far enough upstream to ensure the effect of the boundary condition doesn't impact the flow regime at the location of the proposed bridge. The exact locations of the new surveyed sections are shown in Figure 2, with the full surveyed sections provided in Appendix A.

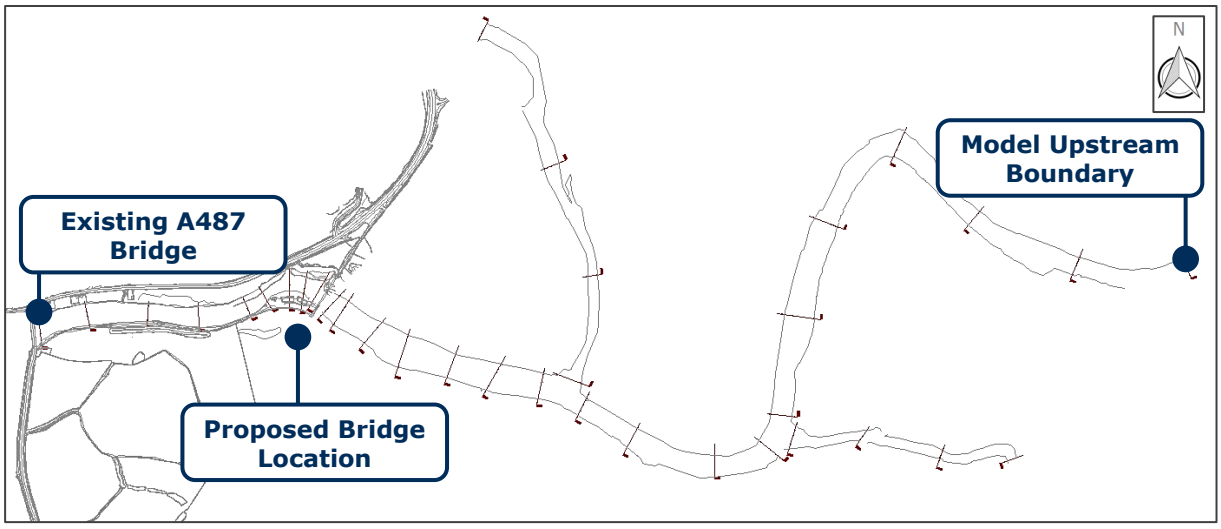


Figure 2 - Location of new River Sections

2.4 Floodplain and Structures

The ground levels representing the floodplain within the existing model are based on filtered 1m resolution Light Detection and Ranging (LiDAR) data, which is the most appropriate data source for modelling large areas such as floodplains. As such, the extended section of the model was also based on filtered LiDAR data at the same resolution. The existing Digital Terrain Model (DTM) was based on a series of elevation points. However for consistency this was replaced with an ASCII grid containing the LiDAR data for the entire model. This approach uses the same underlying data whilst ensuring that a consistent modelling approach is applied across the model.

In addition to the survey of additional river sections, a comprehensive survey of the floodplain, A487 and surrounding urbanised area was also undertaken by NRG Engineering. The purpose of this survey was to obtain details on small structures and identify any changes in the topography that were likely to be inadequately represented within the LiDAR data. This data was only incorporated into the model where its inclusion was considered to significantly impact on the final model outputs. Verification checks were made between the survey levels and the LiDAR, and where no significant differences were apparent, the baseline LiDAR data was utilised without modification.

Prior to the survey being undertaken, a review of the existing NRW model was completed which sought to identify any key features that may require a more detailed representation within the extended model. The existing model was originally constructed specifically to assess the key flood risk mechanisms around Machynlleth; therefore, it provided a good level of detail of the River Dyfi at the site of interest. The purpose of this site-specific modelling study is to derive an appropriate design for the new bridge and associated works for the extreme flood events: 1 in 100yr and 1 in 1000yr. It was considered that due to the size and volume of the River Dyfi floodplain, any small changes to the river channel since the survey/modelling was undertaken would have a negligible impact on the model outputs for the design events. The main control on flow at the location of the Dyfi Bridge is the existing stone arch bridge, and Section 2.5 below confirms that the new survey data is not significantly different to that collected previously. Therefore, it is concluded that the NRW model is appropriate for use to inform the site-specific modelling study at Dyfi Bridge.

The additional features surveyed are outlined below and their locations are shown in Figure 3, with full details provided in section 2.5.

1. Threshold levels of properties near existing A487 Bridge.
2. Threshold levels of nearby properties within the Dyfi Eco Park.
3. Top of bank levels.
4. Cross Sections and Deck levels of existing A487 Bridge.
5. Cross Sections and Deck levels of Millennium Footbridge.
6. Cross Sections and Deck levels of Dulas North Road Bridge.
7. Cross Sections and Deck levels of Dulas South Railway Bridge.
8. Culvert under Railway Track
9. A487 Kerb line
10. Dimension and level of small non-maintained flood bund near the Dyfi Eco Park.

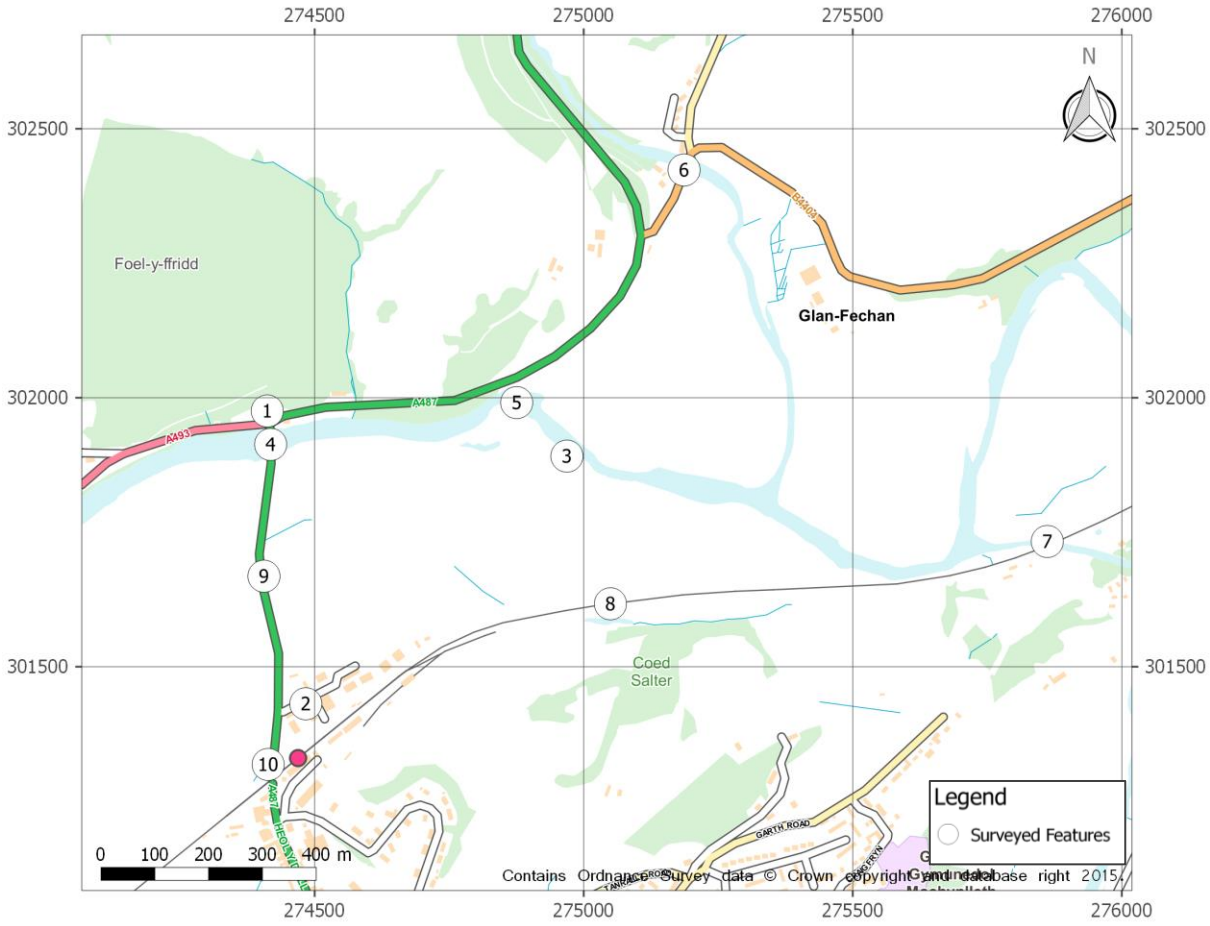


Figure 3 - Location of Surveyed Features

2.5 Details of Surveyed Structures

Name	Threshold levels of properties near existing A487 Bridge
Feature Number	001
Type	Threshold levels
Modelled	No
Additional Information	n/a

The threshold levels of the properties near the existing A487 bridge that are at risk of flooding were surveyed.

The purpose of this was to use the data to establish the depth of flooding within each property only for the reporting phase. The recorded levels were not incorporated into the model as it was considered they would have negligible impact on the modelled levels due to the size of the buildings compared to the extent of the floodplain.

Property	Eastings	Northings	Threshold Level (m AOD)
P-01	274382	301952	9.09
P-02	274388	301952	9.11
P-03	274391	301953	9.16
P-04	274400	301955	9.34
P-05	274407	301957	9.66
P-06	274411	301957	9.61
P-07	274440	301950	9.10

Name	Threshold levels of nearby properties within the Dyfi Eco Park
Feature Number	002
Type	Threshold levels
Modelled	No
Additional Information	n/a

The threshold levels of the properties near the existing A487 bridge that are at risk of flooding were surveyed.

A review of the grid data confirms that the base DTM is not significantly different from the surveyed threshold levels. The purpose of collecting the additional survey data was to establish the depth of flooding within each property only, in order to inform the reporting phase.

Property	Eastings	Northings	Threshold Level (m AOD)
EP-01	274448	301408	9.08
EP-02	274452	301410	9.13
EP-03	274442	301411	10.02
EP-04	274458	301414	9.24
EP-05	274460	301416	9.21
EP-06	274519	301478	9.44
EP-07	274512	301474	9.42
EP-08	274549	301476	9.51
EP-09	274578	301494	9.52
EP-10	274604	301476	9.93
EP-11	274589	301469	9.96
EP-12	274573	301460	9.87
EP-13	274636	301503	10.38
EP-14	274649	301514	10.35
EP-15	274527	301421	9.69
EP-16	274497	301400	9.46
EP-17	274461	301397	9.15
EP-18	274484	301414	9.42
EP-19	274691	301542	9.74
EP-20	274707	301549	9.76

Name	Top of bank levels
Feature Number	003
Type	Surveyed Points
Modelled	No
Additional Information	n/a

The top of banks were surveyed in order to verify the accuracy of the top of bank levels within LiDAR data.

- In total, 1,294 top of bank levels were surveyed within the extended section of the model, i.e. upstream of the existing A487 Bridge.
- 825 of the surveyed points were found to be within 300mm of the corresponding LiDAR level.
- The average error of the 825 points is -104mm. It is considered that the accuracy of the points is acceptable and further modifications to the model DTM are not required.

The remaining 469 surveyed points have a discrepancy of over 300mm when compared to the LiDAR level at the same location. These discrepancies are broken down below and their locations are shown in Figure 4, where it can be seen that they are evenly distributed across the river reach. Although it is not possible to report on all 469 survey points within this report, four examples are looked at in detail to discuss the source of the discrepancy. Reviewing all of these discrepancies concludes that that these four examples are indicative of all 469 points.

From reviewing all of the surveyed points that have a considerable discrepancy to LiDAR data, it is concluded that the LiDAR is of sufficient accuracy to derive the spill levels within the 1D/2D link. Therefore, the surveyed levels were not incorporated into the model and were not used to amend the baseline DTM. Due to the reasons given below, and the volume of the River Dyfi floodplain, this is considered to have a negligible impact on the modelled flood levels.

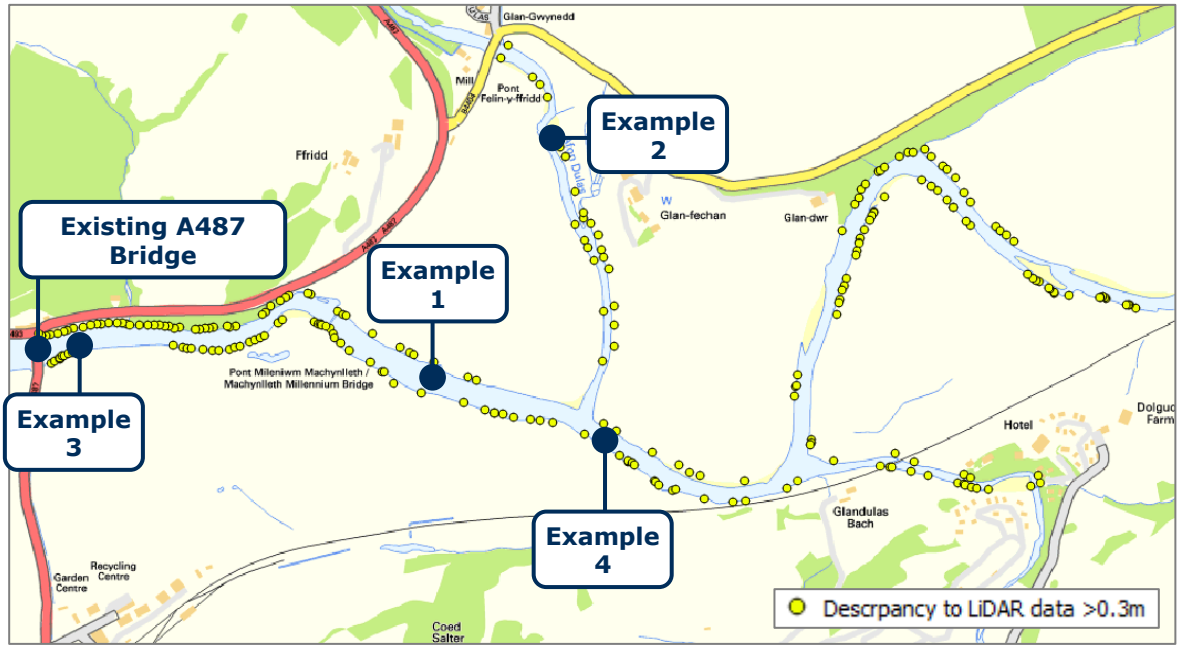


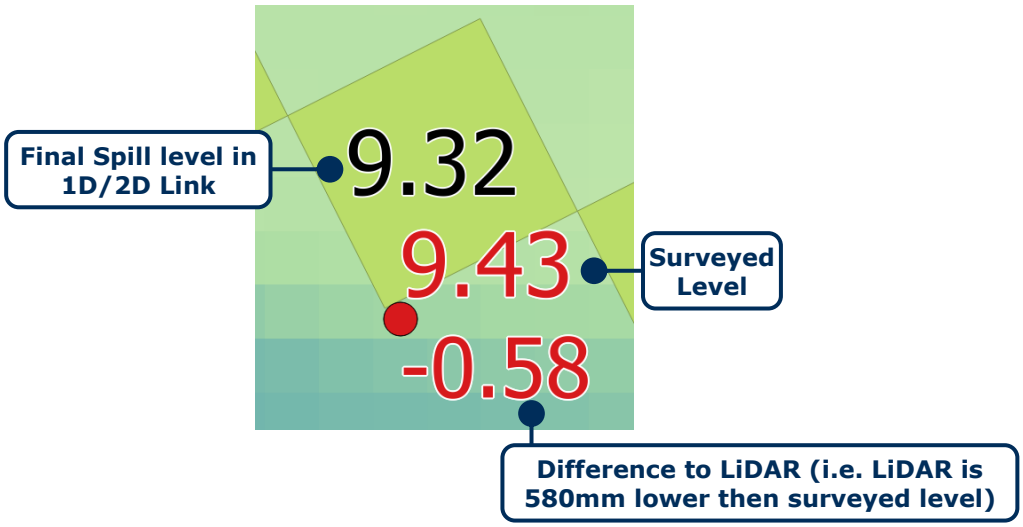
Figure 4 - Locations of Survey points with high discrepancies to LiDAR data

The four examples shown below look in detail at the discrepancies between the LiDAR data and surveyed levels, with justification to why it was decided that LiDAR data was accurate enough to derive the 1D/2D spill levels within the extended section of the model.

Example 1

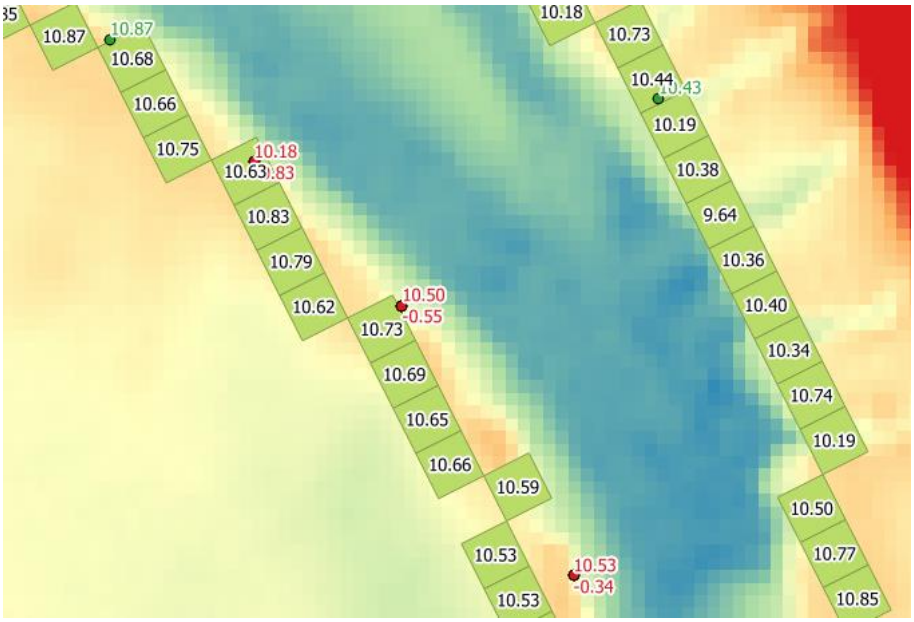
Example 1 shows the annotation used within the following four examples. It shows the surveyed point as a red dot, the corresponding surveyed level, the discrepancy between the surveyed level and the LiDAR level at the same location and finally the green square shows the 1D2D boundary cells, with the spill level in the centre of the square.

In this example, the surveyed level of 9.43m AOD is recorded for the top of bank along the northern bank of the River Dyfi. The corresponding LiDAR level is 8.85m AOD, which is some 0.58m lower. However, the actual spill level is determined by the hx line which is digitised along the top of bank as indicated by LiDAR levels. Due to the grid resolution (4m X 4m), it is considered that the difference between the LiDAR and the survey data is 'diluted'. Due to the location at the top of bank, LiDAR levels can vary substantially across a 4m length. It can be clearly seen that the actual spill level is 9.32m AOD, which is very close to the surveyed level of 9.43m AOD. This difference is considered to be acceptable.



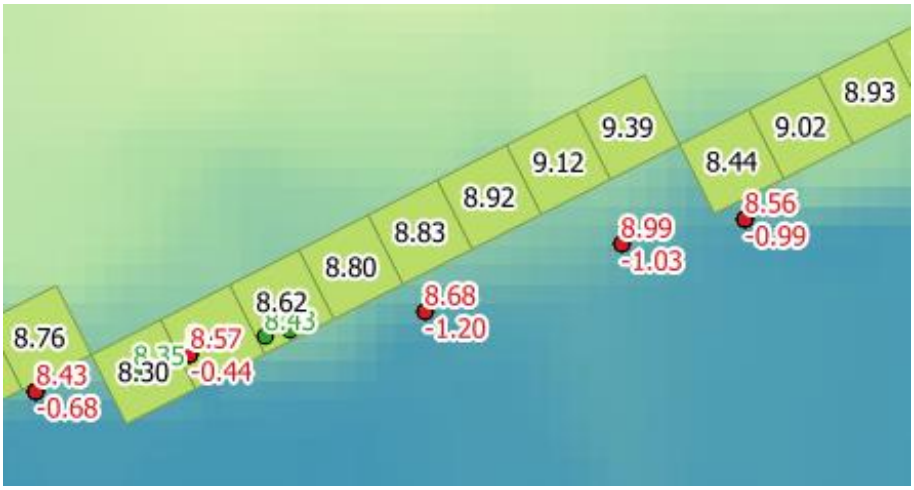
Example 2

The example below shows five surveyed points, of which three have a discrepancy to LiDAR of more than 0.3m. The 1D/2D link was digitised to maintain constant channel width and ensure that the model remained stable. This resulted in the final 1D/2D link location being offset by a few meters from the surveyed top of bank location, which is considered negligible when considering the 4m grid resolution and floodplain extent. When comparing the surveyed level to the final spill level as defined by the hx link, it is considered that deriving the spill level from LiDAR data results in acceptable spill levels.



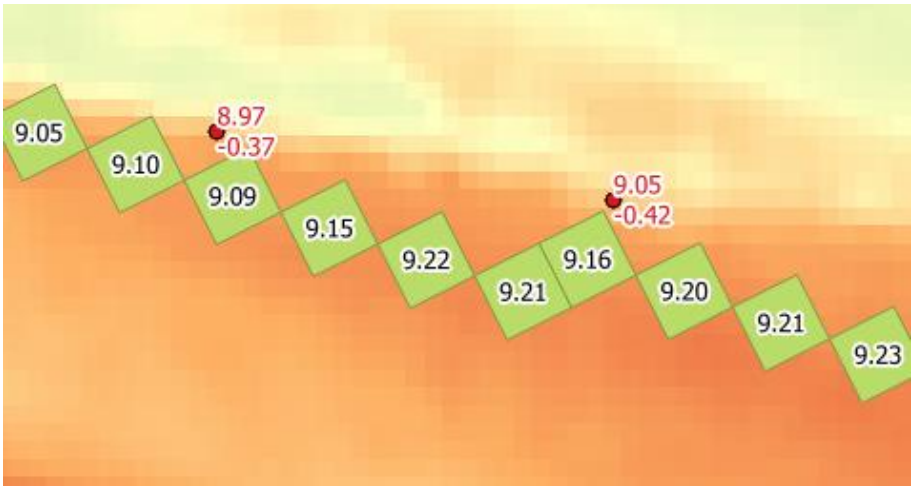
Example 3

This example has a relatively steep right hand bank and the discrepancy between surveyed levels and LiDAR levels is approximately 1m. The 1D/2D link has been digitised at along to the top of the bank as it is represented within the LiDAR data, which is slightly to the north of the surveyed top of bank. Comparison of the final spill levels to the surveyed levels shows that the difference is within an acceptable tolerance.



Example 4

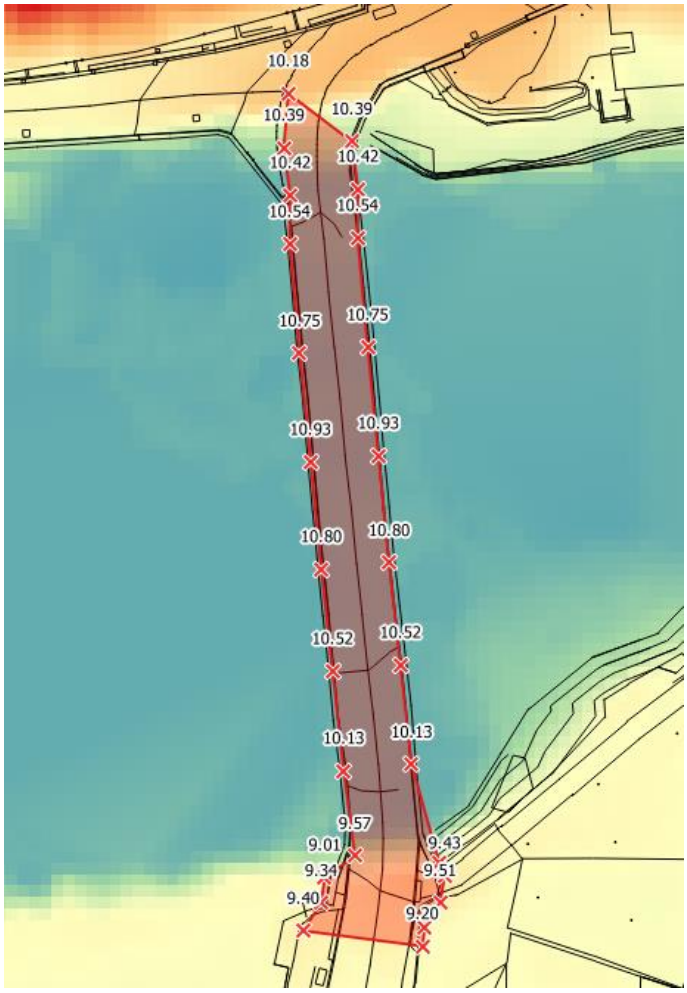
This example is similar to Example 1, where the surveyed points are higher than the LiDAR level. However when the average LiDAR level over a 16m^2 area is considered, the final spill level is within an acceptable tolerance of the adjacent surveyed level.



Name	Cross section and Deck Levels of Existing A487 Bridge
Feature Number	004
Type	1D Bridge Unit and DTM modification
Modelled	Yes
Additional Information	ISIS Node: DYFI_5226

The bridge deck of the existing A487 bridge is modelled within the 2D domain. Review of the modelled deck levels within the existing NRW model showed that they were significantly higher than the new surveyed levels.

The new survey levels (Left) were used update the DTM within the model (Right). The width of the bridge is approximately 6.5m, this width is modelled as between 1 and 2 cells wide, i.e 4m to 8m wide. It is not possible to model the width any more accurately then this due to the limitations associated with a 4m grid.

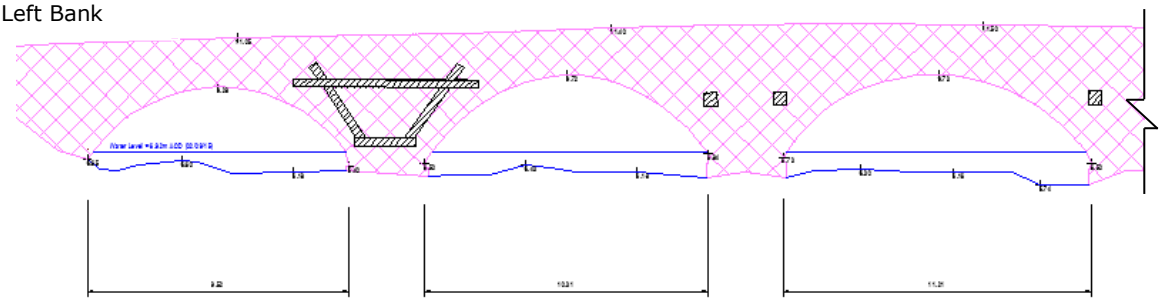


SHP Files
2d_zsh_DFY_BridgeDeck_P_022
2d_zsh_DFY_BridgeDeck_R_022

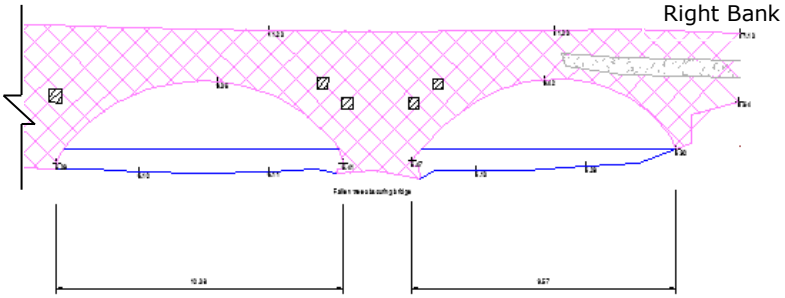
The cross section of the existing A487 bridge within the 1D domain of the existing model was also reviewed against the new survey data. The model was updated with the new survey data, although the changes to the springing levels and soffit levels were only minor (<10mm).

Surveyed Cross Section – See CAD drawing or model log for high resolution drawing

Left Bank



Right Bank



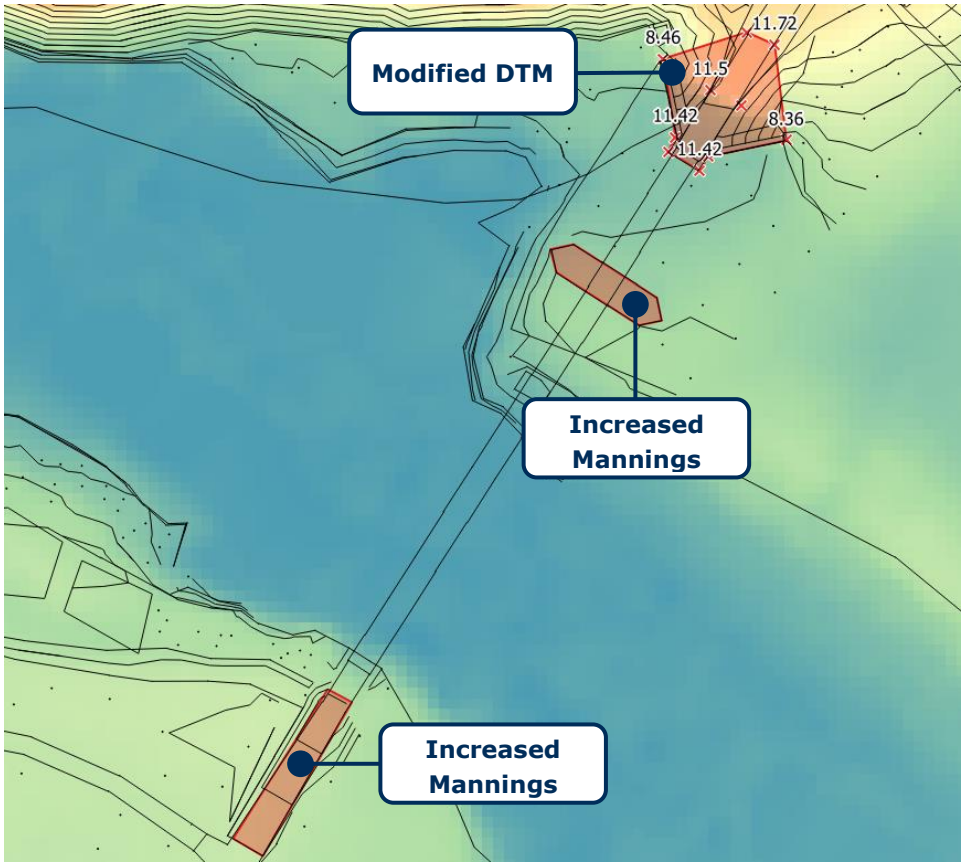
Name	Cross Sections and Deck levels of Millennium Footbridge
Feature Number	005
Type	DTM modification
Modelled	Yes
Additional Information	n/a

The Millennium footbridge was included within the model using two methods. The north abutment was represented by updating the DTM with the surveyed ground levels. This method was selected as the survey confirmed that ground levels were above the baseline flood level. It was therefore appropriate to adjust the DTM at this location so that it more accurately represented the surveyed levels.

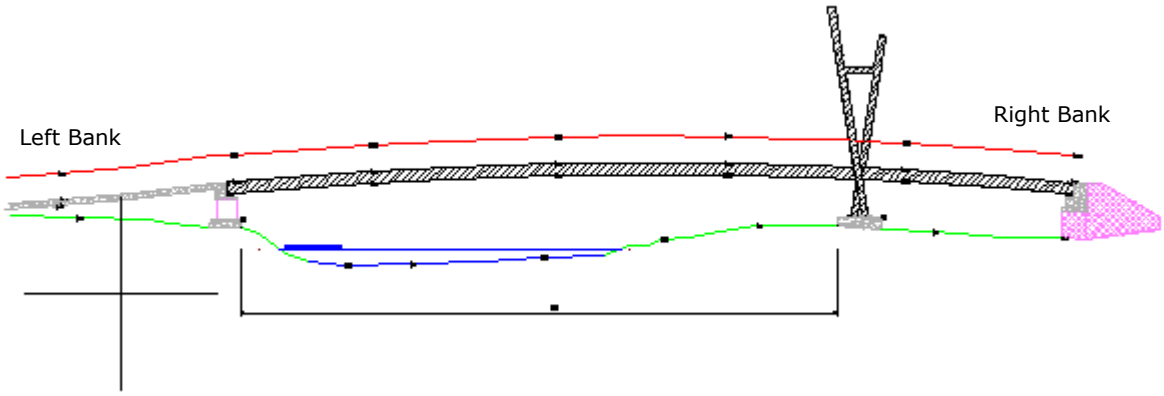
For the south abutment and central pier, the surface roughness was increased by modifying the manning's number to 0.8. This value was selected as it effectively represents an obstruction to flow, much like the representation of buildings within the model. It is noted that a Manning's value of 0.8 is already assigned to the buildings within the model.

Sensitivity analysis of the chosen Manning's value is undertaken as a part of the sensitivity analysis for the entire model in Section 3.

Due to the elevation of the bridge deck, which is above the maximum modelled flood level, no further losses were applied to the modelled structure.



Surveyed Cross Section – See CAD drawing or model log for high resolution drawing

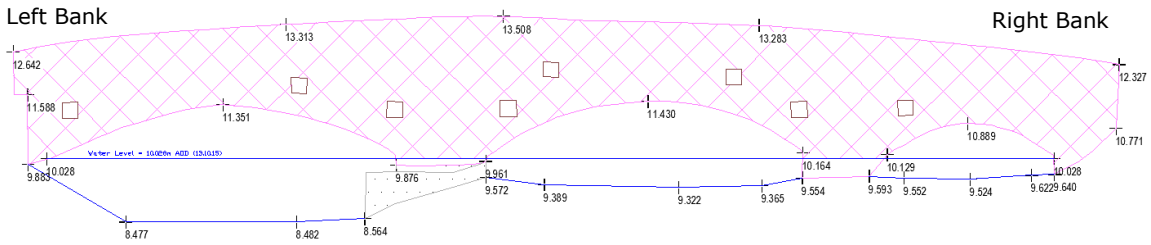


SHP Files
2d_zsh_DYF_MillenniumFootbridge_R_001
2d_zsh_DYF_MillenniumFootbridge_P_001
2d_mat_MFB_DYF_001.shp

Name	Cross Sections and Deck levels of Dulas North Road Bridge
Feature Number	006
Type	1D Bridge Unit and DTM modification
Modelled	Yes
Additional Information	ISIS Node: DLSN_0743d

The cross section of the B4404 bridge on the Dulas North is included within the 1D domain of the model. The cross section data, springing levels and soffit levels are taken from the new survey data.

Surveyed Cross Section – See CAD drawing or model log for high resolution drawing

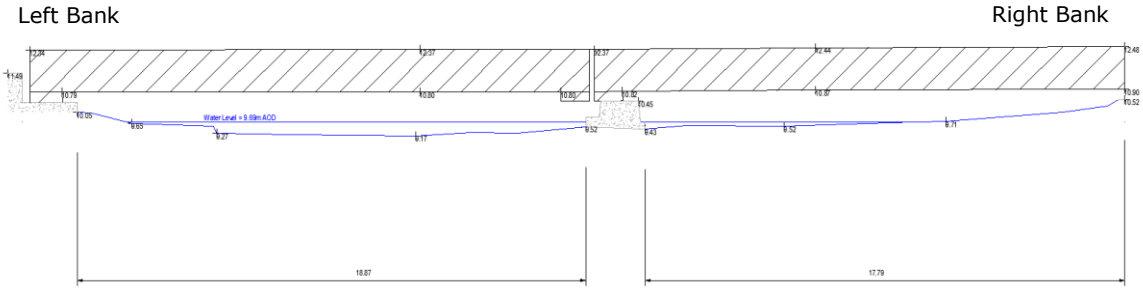


SHP Files
2d_zsh_DLSS_BD_R_001
2d_zsh_DLSS_BD_P_001

Name	Cross Sections and Deck levels of Dulas South Railway Bridge
Feature Number	007
Type	1D Bridge Unit and DTM modification
Modelled	Yes
Additional Information	ISIS Node: DLSS_Bu

The cross section of the railway bridge over the Dulas South is modelled within the 1D domain of the model. The cross section data and soffit levels are taken from the new survey data.

Surveyed Cross Section – See CAD drawing or model log for high resolution drawing



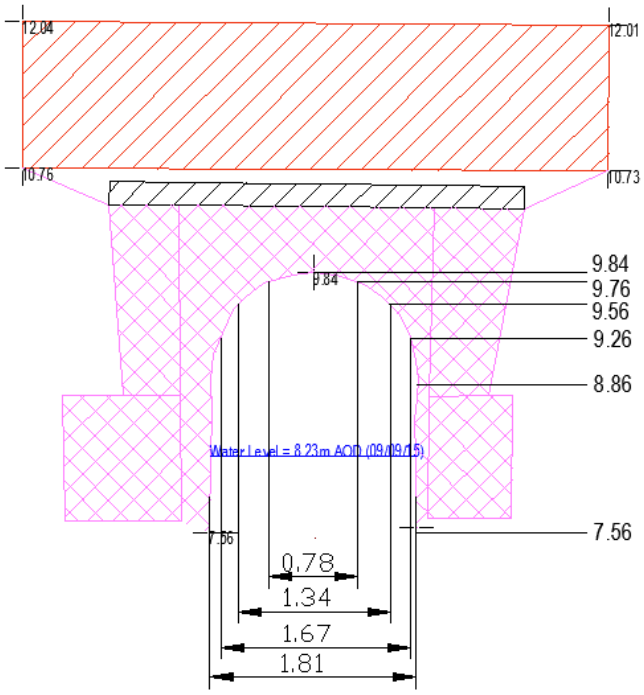
SHP Files
2d_zsh_DLSS_BD_R_001
2d_zsh_DLSS_BD_P_001

Name	Culvert under Railway Track
Feature Number	008
Type	1D ESTRY Unit
Modelled	Yes
Additional Information	Location: SH 7505 0161

The culvert under the railway track was surveyed and included within the 1D ESTRY domain of the model. The culvert was included as an irregular culvert where the elevation and width details are shown below. The 1D channel is linked to the 2D domain using an SX link: 2d_bc_RailwayCulvert_L_001.shp.

Elevation (m AOD)	Width (m)
7.56	1.81
8.86	1.81
9.26	1.67
9.56	1.34
9.76	0.78
9.84	0.001

Surveyed Cross Section – See CAD drawing or model log for high resolution drawing

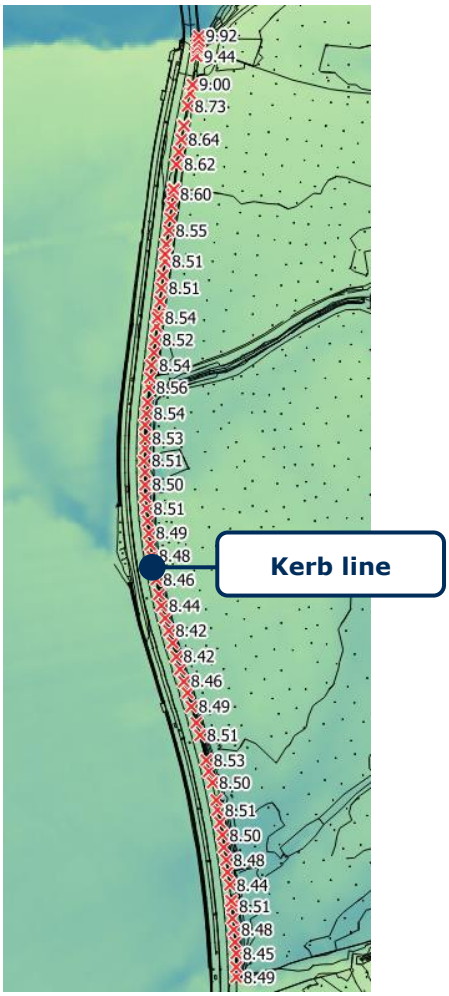


Files
1d_nwk_RailwayCulvert_L_001.shp
1d_tab_RailwayCulvert_L_01.shp
RailwayCulvert_01.csv

Name	A487 Kerb line
Feature Number	009
Type	DTM Modification
Modelled	Yes
Additional Information	n/a

A key control to flood levels with the area of the existing A487 is the level where water begins to weir over the A487. Although it is not possible to explicitly model the detailed road profile due to the 4m grid size, it is possible to raise the cell sides along the A487 to represent the highest elevation along the length of road where flood waters begin to weir over the road.

This was achieved by updating the cell sides within the DTM with the surveyed top of kerb levels along the eastern side of the A487.

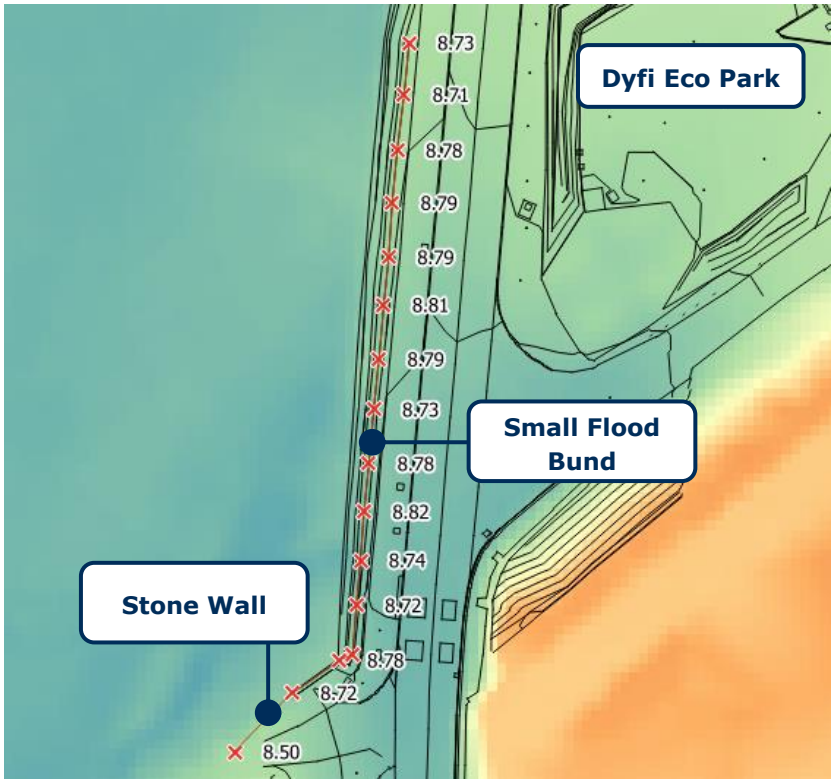


SHP Files
2d_zsh_A487KerbLine_P_001
2d_zsh_A487KerbLine_L_001

Name	Dimension and level of small flood bund near the Dyfi Eco Park.
Feature Number	010
Type	DTM Modification
Modelled	Yes
Additional Information	Location: SH 74421 01299

The location where the railway line crosses the A487 is very sensitive to flooding, so it is important that the model adequately represents possible flow routes in the area. During a site visit, a small section of raised ground and a stone wall was identified.

These two features are likely to impede flows and act as a basic form of flood defence. As such, they have been surveyed and included within the model by raising the cell sides within the DTM at their location. This is the most appropriate method of including them within the model as their small width is not initially represented within the 4m grid size of the model.



SHP Files
2d_zsh_SmallWallBund_P_001
2d_zsh_SmallWallBund_L_001

2.6 Boundary Conditions

Boundary Locations

There are a number of inflow and outflow boundaries within the model, these are shown in Figure 5 below. The three main inputs are the Dulas South, the Dulas North, and the Dyfi Eastern, the hydrology for these input boundaries has been updated in line with current best practice, see Appendix B for the detailed hydrology report. There are additional hydrological inputs for 'minor tributaries' to the south west of Machynlleth. These inputs were supplied with the existing NRW model, which are labelled GSWN101 and GSWN201. A review of the model indicates that these inflows are a considerable distance downstream of the site of interest. Furthermore, they are located to the south of the railway embankment, which influences the flow regime within the floodplain and effectively separates the floodplain into distinctive cells. The combined 1 in 100 year flow for the two tributaries is 6.2 cumecs, which is negligible when compared to the peak Dyfi flow of circa 640 cumecs. It is concluded that these tributaries have a negligible impact on the flood mechanisms at the site of interest. Therefore, the peak flows were not updated as part of this study. Table 1 summarises how all of the model boundaries have either been checked or updated.

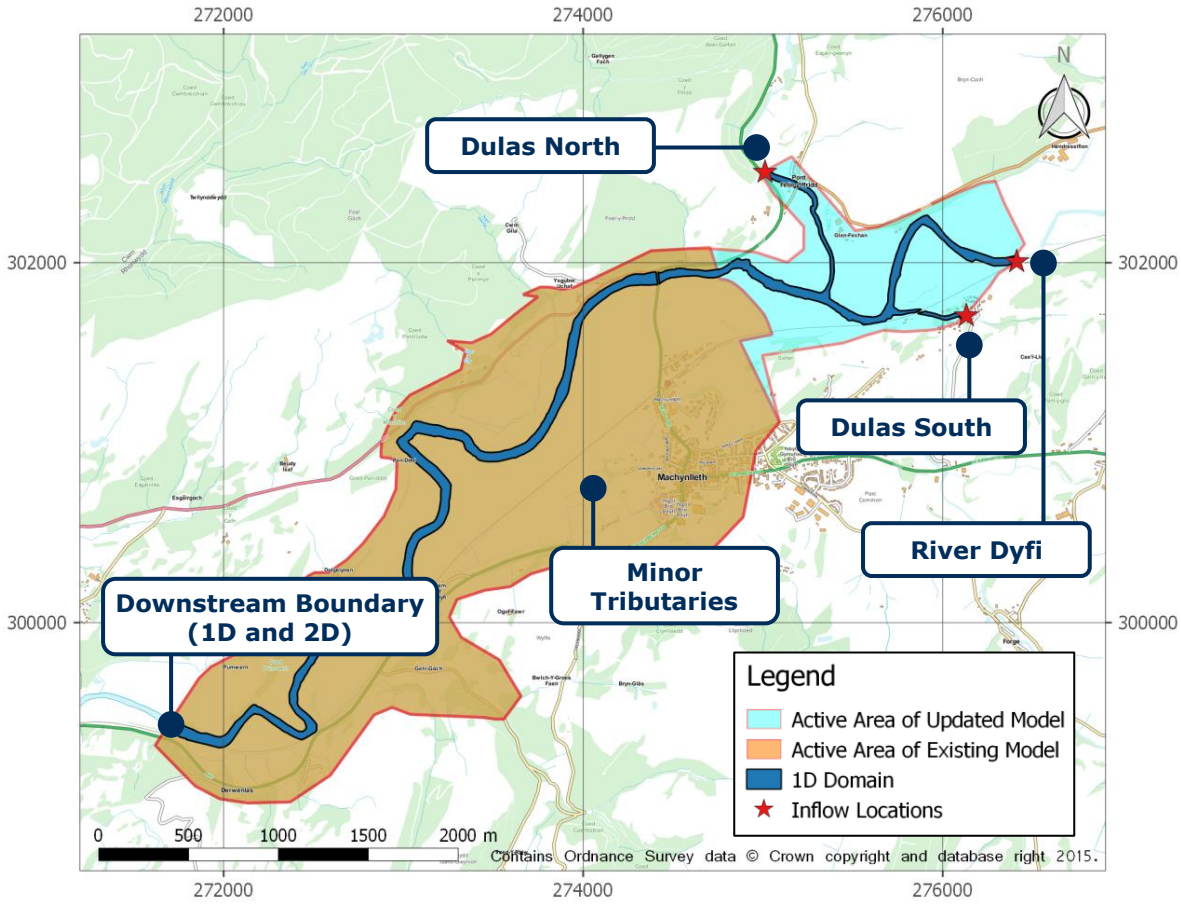


Figure 5 - Model Boundary Locations

Table 1 - Summary of Model Boundaries

Boundary	Boundary Type	Comments
River Dyfi	QT	New inflow boundary.
Dulas North	QT	New inflow boundary.
Dulas South	QT	New inflow boundary.
Downstream Boundary	HT	Existing boundary, review of the parameters within this boundary suggest that it is suitable for continued use.
Minor Tributaries	Various	Existing boundary, review of the parameters within this boundary suggest that it is suitable for continued use.

Upstream Boundaries

The upstream boundary on the original model consisted of a single flow vs time (QT) fluvial input boundary within the 1D domain, this was derived from hydrological analysis of the River Dyfi upstream catchment.

The extended model now goes beyond the Dulas North and Dulas South tributaries and it was considered appropriate to model these as three separate inflows. To achieve this, the hydrology of the upstream catchment was reassessed as three different catchments. The calculation methodology for these hydrological inputs was discussed and agreed with NRW prior to submission of this report. The associated Hydrology report provides details and the final hydrographs used within the model.

With the three hydrographs entering the model at different locations, it was necessary to ensure that their peaks coincided with each other. This was to confirm that the peak flow at the gauging station matched the peak flow within the model.

The 1 in 100year plus an allowance for climate change (20%) peak flow at the Dyfi Gauging Station and the peak flows that were abstracted from the hydraulic model are shown in Table 2, the location of these peak values is shown in Figure 6.

Table 2 - Peak Flows during the 100yrCC Flood Event

Location	Peak Flows at Gauging Station (m^3/s)	Peak Flows extracted from Hydraulic Model (m^3/s)
Hydrology Assessment	771.0	-
1D Domain	-	413.5
2D Domain	-	352.5
Total	**771.0**	**766.3**

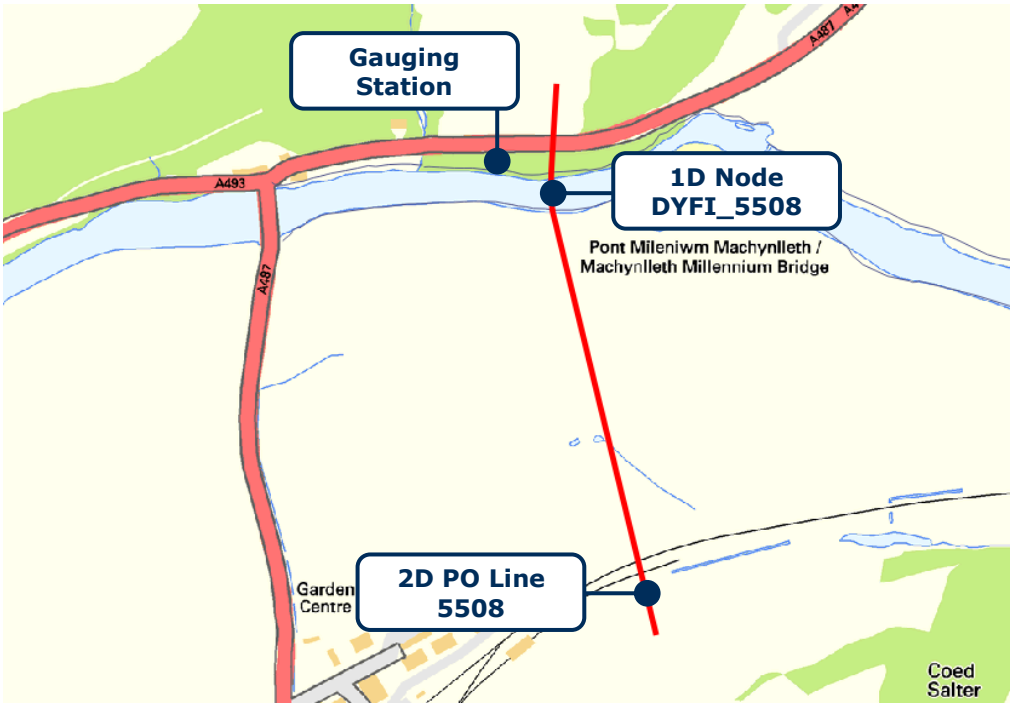


Figure 6 - Location of PO line to extract Peak Flows

The modelled peak flow (766.3m3/s) was 0.6% lower than the peak flow derived at the gauging station within the hydrology assessment. This difference is considered acceptable, especially given the complex flow regime within the flood plain.

2.7 Roughness Values

The Mannings values used to represent the surface roughness within the original model[2] have been reviewed and it was decided that they are appropriate for continued use within the updated model, see Table 3.

Two new Mannings values were added to the hydraulic model, these were to represent thick hedgerows and the Millennium Footbridge.

Within the area of interest there are several thick hedgerows and these will have a significant effect on flow passing through them, as such the Mannings number has been chosen to be 0.15, which is at the upper end of acceptable values for medium to dense brush[3]. For the Millennium Footbridge, a Manning's value of 0.8 was chosen, this is discussed in further detail within Section 2.5.

Table 3 - Summary of Manning's Values

Domain	Description	Mannings n	Comments
1D	Natural Channel	0.032 - 0.035	Existing Model
1D	Structures	0.030 – 0.035	Existing Model
2D	Grass	0.050	Existing Model
2D	Roads	0.020	Existing Model
2D	Inland Water	0.035	Existing Model
2D	Foot paths	0.020	Existing Model
2D	General Surface	0.050	Existing Model
2D	Buildings	0.800	Existing Model
2D	Trees	0.080 – 0.100	Existing Model
2D	Hedgerows	0.150	New - Thick hedgerows, denser than trees and generally 1 or 2 cells wide.
2D	Millennium Footbridge	0.80	New

[2] Capita Symonds (2011), *North Wales Work Package B – Machynlleth Study*
[3] Chow, V T (1959). *Open-channel Hydraulics.* McGraw-Hill.

3 Proposed A487 Bridge and Associated Works

3.1 Summary of Proposed Scheme

To enable a quantitative assessment of the impact that the proposed scheme will have on flood levels within the River Dyfi and the adjacent flood plain, the hydraulic model was also amended to incorporate the proposed scheme.

The features of the proposed scheme that were included within the hydraulic model are listed below and their corresponding locations are shown in Figure 7.

- The bridge piers within the flood plain for the new A487 Bridge.
- The south embankment and south abutment of the new A487 Bridge.
- A new flood defence embankment around the Dyfi Eco Park

No modification to the 1D domain was made at the location where the new bridge crosses the River Dyfi. This was because the new bridge is a clear span bridge over the main river channel and the soffit level is relatively high as a result of the steep topography at the location of the north abutment. Furthermore, the proposed bridge construction will not require piers to be built within the river channel.

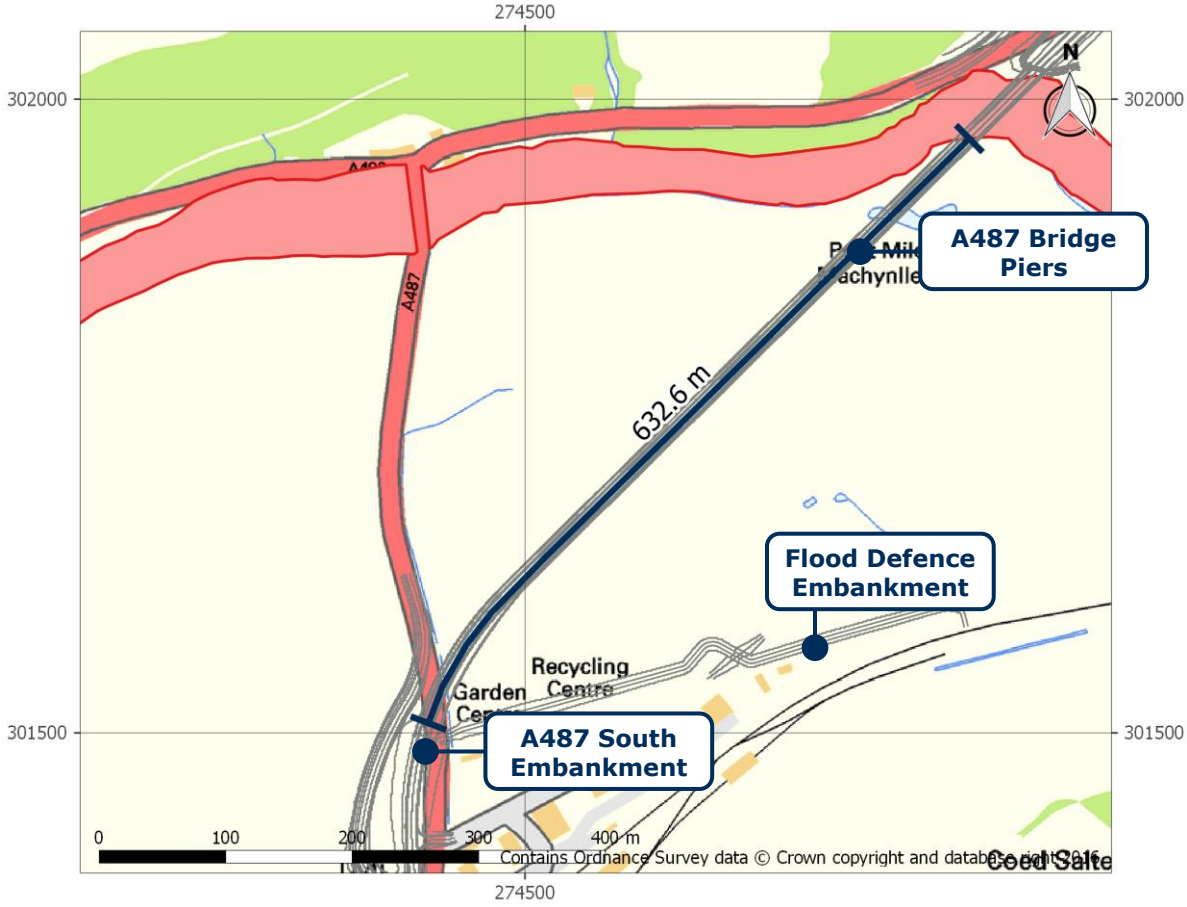


Figure 7 - Proposed Scheme (Note: Length of the bridge is the length within the 2D domain of the hydraulic model, not the total length of the proposed bridge)

3.2 Details of Proposed Structures

Name	Proposed A487 Bridge
Feature Number	P-001
Type	2D Form loss to represent bridge piers
Modelled	Yes
Additional Information	n/a

The new A487 bridge requires the construction of multiple bridge piers within the Dyfi flood plain. In order to assess the impact that these bridge piers will have on the flooding mechanisms within the hydraulic model, they have been repented as a flow constriction. Consideration was given to modifying the DTM to explicitly represent each bridge pier. However this was deemed to be inappropriate as the small size of the bridge piers relative to the 4m cell size used within the hydraulic model would result in an inaccurate representation of the impact that the piers would have.

There are two key attributes that are required to represent bridge piers as a flow constriction: Form Loss Coefficient (FLC) and percentage blockage (pB). The FLC used in the hydraulic model was derived using the method outlined in Hydraulics of Bridge and Waterways (Bradley 1978), which is outlined below. It was decided that the pB of the flow constriction would not be included and as such it was set to 0%. This decision was based on the conclusions made in the TuFLOW technical note 'Modelling Bridge Piers and Afflux in TuFLOW', which concluded that including pB resulted in an overestimation of Afflux when compared to the Hydraulic of Bridge and Waterways calculation.

The procedure set out in Hydraulics of Bridge and Waterways was undertaken to derive the FLC for the proposed bridge piers. This method is shown in Figure 9. The variables use in this method are summarised in Table 4. The width of the piers normal to the flow direction is derived in Figure 8.

Table 4 - Variables used to derive FLC

Item	Description	Value
b	Total Length of Bridge (m)	632.60
W_p	Pier Width normal to flow (m)	7.00
-	Pier Centres (m)	34.00
N	Number of Piers*	18.00
A_p	Total Pier Width (m)	126.00
J	J	0.20
FLC	**Δkp (from graph)**	**0.31**

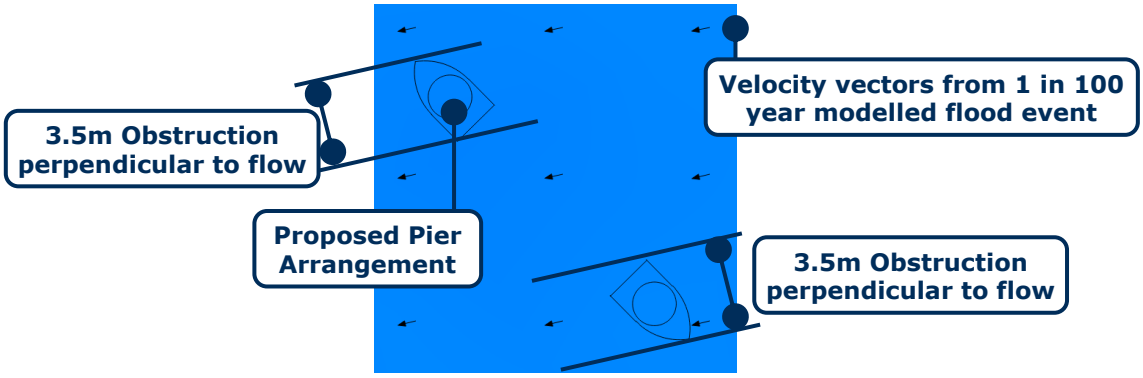


Figure 8 - Flow Direction in relation to Bridge Piers

*Number of piers derived from (length of bridge)/(Pier Centres)

There are a number of limitations that were encountered when deriving the FLC, these were related to the shape of the bridge piers and high skew angle of the bridge in relation the direction of flow.

The pier width normal to the flow direction was measured to be 3.5m for each pier, this was doubled to 7.0m to allow the fact that there are 2 piers located at each 34.0m centre. Additionally the irregular shape of the proposed piers are not included within Figure 9, however it was decided that a simple circular pier would be the closest match. The twin circular pier arrangement was not chosen because the high skewness of the proposed bridge results in the piers not being located one behind the other, as such two individual piers were considered. Due to the uncertainties in the FLC, sensitivity analysis was carried out by increasing and decreasing the FLC by 20%. This sensitivity analysis is discussed in detail in Section 4.6.

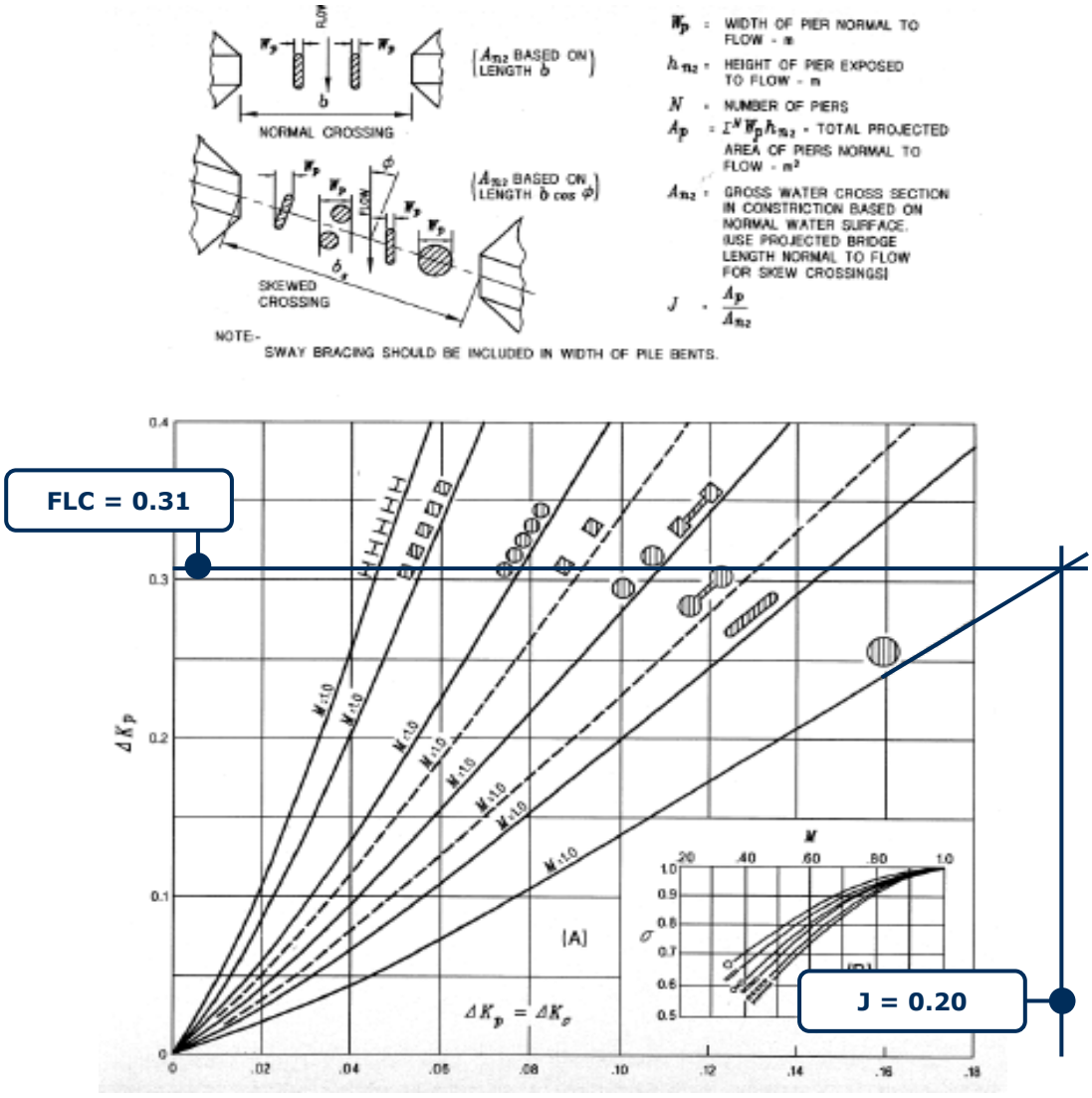


Figure 9 – Method to derive FLC, Hydraulics of Bridge and Waterways (Bradley 1978)

SHP Files
2d_fcsh_PIERS_SQUARE_L_004

Name	South Embankment and Eco Park Flood Bund
Feature Number	P-002
Type	DTM Modification
Modelled	Yes
Additional Information	n/a

The south embankment of the proposed bridge and the Dyfi Eco Park flood bund was incorporated into the model by modifying the DTM. This method was considered appropriate as these structures are at least 2 to 3 times the cell width used within the model.

The geometry and levels for the south embankment and Eco Park flood bund were obtained from the Arup CAD drawing dated 04th March 2016, these are shown in Figure 10 and are also provided in CAD format in Appendix D. For clarity the levels have been omitted from Figure 10, however two key levels for the flood bund are shown.

In addition, a z-line was digitised along the crest of the embankment to ensure a continuous topographic change that is represented in all of the 2D cells.

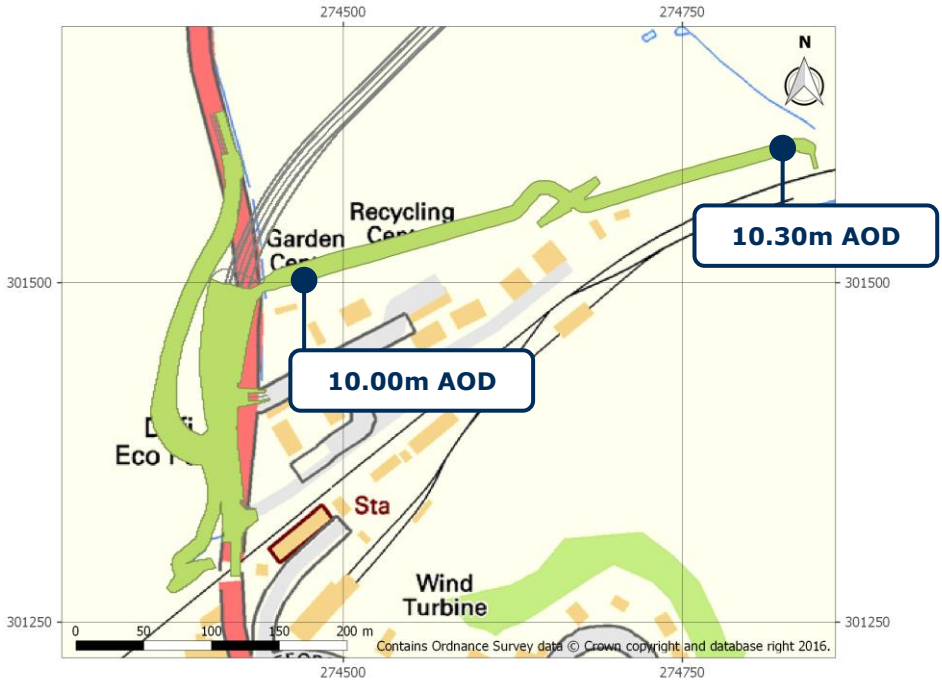


Figure 10 - Proposed South Embankment and Eco Park Flood Bund

SHP Files

2d_zsh_Final_South_Embankment_R_002
2d_zsh_Final_South_Embankment_P_002
2d_zsh_top_of_bund_P_001
2d_zsh_top_of_bund_L_001

3.3 Details of Temporary Works

Name	Temporary Works Platforms
Feature Number	T-001
Type	DTM Modification
Modelled	Yes
Additional Information	n/a

During the construction period of the proposed A487 Bridge, two temporary works platforms are required to be constructed within the Dyfi flood plain. Both of these temporary work platforms consist of raising the ground to a level above the predicted flood level. This is to ensure that any equipment located on top of the temporary works platform is protected from flooding if there is an extreme flood event. The location of the temporary works are shown in Figure 11.

These two temporary works platforms have been included within the hydraulic model by raising the DTM at each location using a z-shape layer. Ground levels have been raised to 12.5m AOD, which is significantly above the 1 in 1,000 year flood level. The final level of these temporary works platforms will be determined during their detailed design and they will be informed by the modelled flood levels for the relevant scenario.

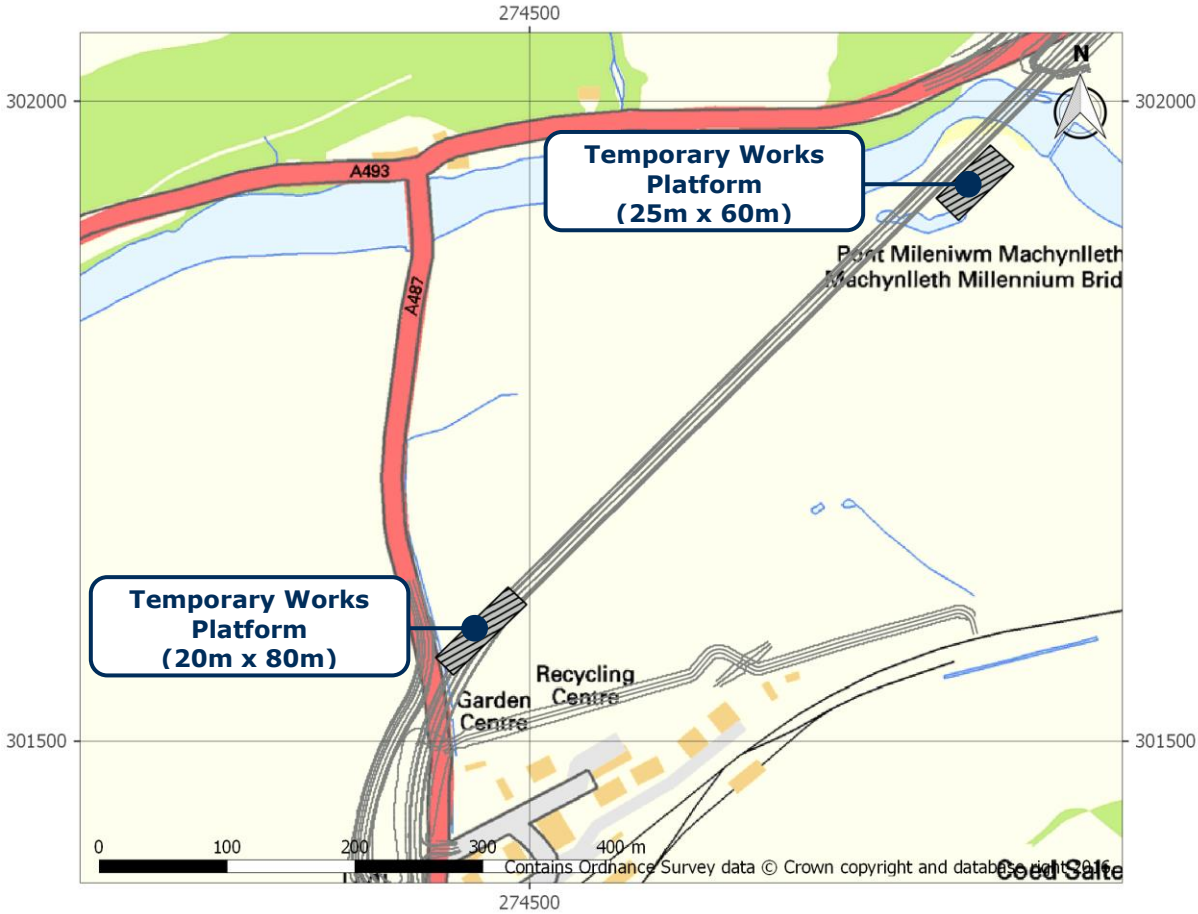


Figure 11 - Location of Temporary Works

SHP Files
2d_zsh_TemporaryWorks_R_001

4 Sensitivity Analysis

4.1 Summary

Sensitivity tests have been undertaken on the 1 in 100 year plus an allowance for climate change flood event to determine the impact of parameter uncertainties within the model. The sensitivity tests that have been undertaken are shown below and the impact on flood levels has been assessed by reviewing the change in flood level at 10 sample locations, as shown in Figure 12.

- **SEN_01** – 1,000 year plus Climate Change (CC) tidal boundary with a 1 in 2 year plus CC Fluvial Event.
- **SEN_02** – MHWS plus CC tidal boundary with a 1 in 1,000 year Fluvial Event.
- **SEN_03** – Removal of un-adopted Flood Bund to the east of the proposed scheme.
- **SEN_04** – Increase and decrease Manning's by 20%.
- **SEN_05** – Increase and decrease downstream boundary by 20%.
- **SEN_06** – Increase and decrease the form loss coefficient used to represent the bridge piers by 20%.
- **SEN_07 –** Increase the FLC value from 0.31 to 1.

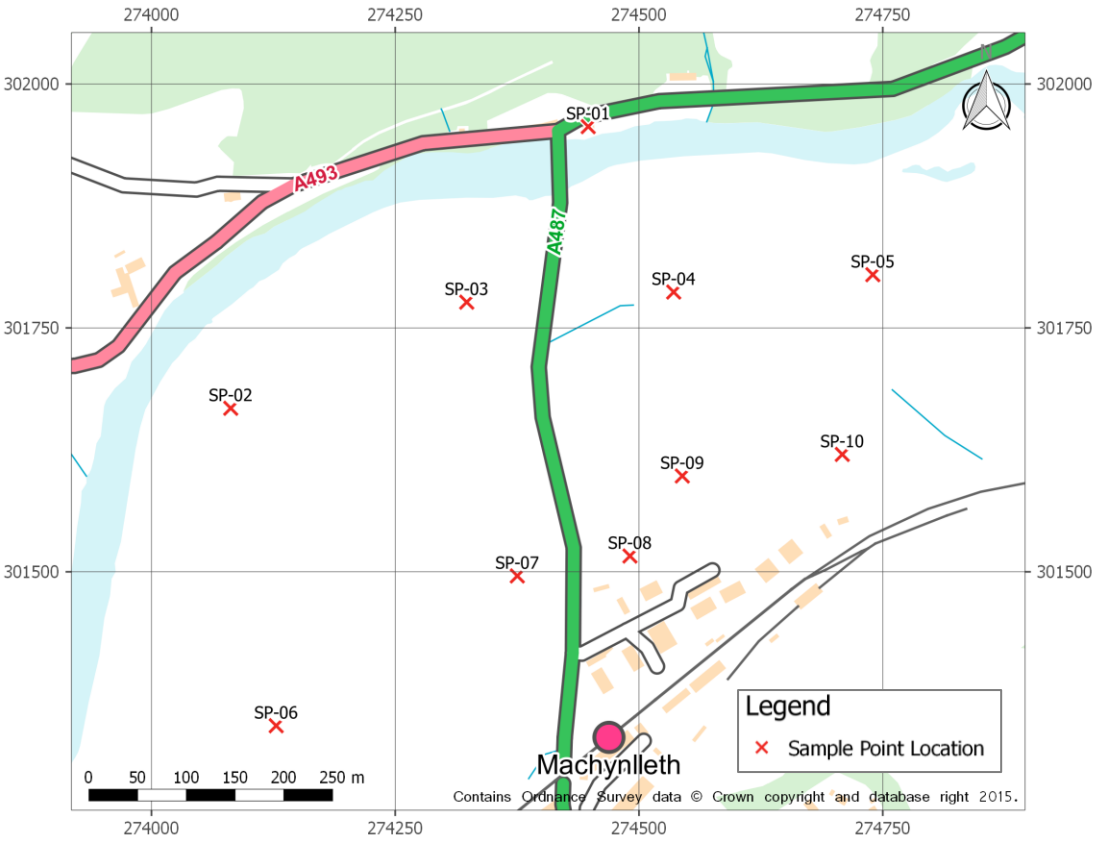


Figure 12 - Sensitivity Analysis Sample Points Locations

4.2 Tidal Boundary

To establish whether there is a tidal influence on flood levels at the location of the proposed bridge, sensitivity analyses were carried out by modelling two different combinations of tidal and fluvial flood events.

The first sensitivity test (SEN_01) included the 1 in 1,000 year tidal level plus climate change at the downstream boundary in combination with the 1 in 2 year plus climate change fluvial event.

The second sensitivity test (SEN_02) modelled the reverse combination of the first test, where the tidal boundary was specified as the Mean High Water Spring (MHWS) level plus climate change and the fluvial event was the 1 in 1,000 year fluvial event.

The fluvial flows were taken as those derived in the Hydrology report and climate change was accounted for by increasing these flows by 20%.

The Mean High Water Spring (MHWS) level was taken from the Barmouth Tide Gauge Site data which is available from the National Tidal and Sea Level Facility[4]. Due to the close proximity of Barmouth to the mouth of the River Dyfi, it is considered that this provides an appropriate assessment of tide level data. There are no data available to account for the potential impact of the Dyfi Estuary and the funnelling effect of tidal waters up the lower reaches of the River Dyfi. It is considered beyond the scope of this study to carry out an assessment of this. However, application of the Upper Confidence interval to the extreme 1 in 1000 year tide level as well as sea level rise up to 2116 is considered to provide a conservative assessment of the extreme tide level. The MHWS is 5.05m above chart datum (CD), which when converted to ordinance datum is 2.62m AOD. The extreme tidal levels[5] climate change[6] data were obtained from current Environment Agency (EA) guidance.

A sinusoidal wave was initially used to represent the four tidal cycles that occur during the modelled 48 hour flood event. The period of this tidal hydrograph is based on the tidal period at Barmouth, which is located approximately 20km west of the proposed bridge. The peaks of the tidal hydrograph are scaled to match the peak tidal levels shown in Table 5 and Figure 13 shows the tidal hydrograph that were used in this sensitivity analysis.

[4] National Tidal and Sea Level Facility. http://www.ntslf.org/tgi/portinfo?port=Barmouth. Accessed 12th January 2016.
[5] Environment Agency (2010). *Coastal flood boundary conditions for UK mainland and islands.* Project: SC060064/TR4: Practical guidance design sea levels.
[6] Environment Agency (2010). Adapting to Climate Change: Advice for Flood and Coastal Erosion Risk Management Authorities.

Table 5 - MHWS and Extreme Tidal Levels

Year	MHWS (m AOD)	1,000 (m AOD)
2008 Level	2.620	4.110
2008-2025 (17yrs @ 3.5mm/yr)	+0.060	+0.060
2026-2055 (30yrs @ 8.0mm/yr)	+0.240	+0.240
2056-2085 (30yrs @ 11.5mm/yr)	+0.345	+0.345
2086-2116 (31yrs @ 14.5mm/yr)	+0.450	+0.450
2116 Level	**3.714**	**5.204**

The results of the sensitivity analysis for SEN_01 and SEN_02 are shown in Table 6 and Table 7 respectively, where it can be seen that incorporating downstream tidal levels into the model has no impact on the flood levels at the location of the proposed bridge.

The extent of the tidal influence can be seen in Figure 14 and Figure 15, which clearly indicates that the tidal extent does not reach the location of the proposed bridge.

The sensitivity analysis confirmed that there was no tidal influence at the location of the proposed bridge; therefore it was not considered necessary to refine the tidal cycles to incorporate the combined effect of the base astronomical tide, surge shape and extreme tidal levels.

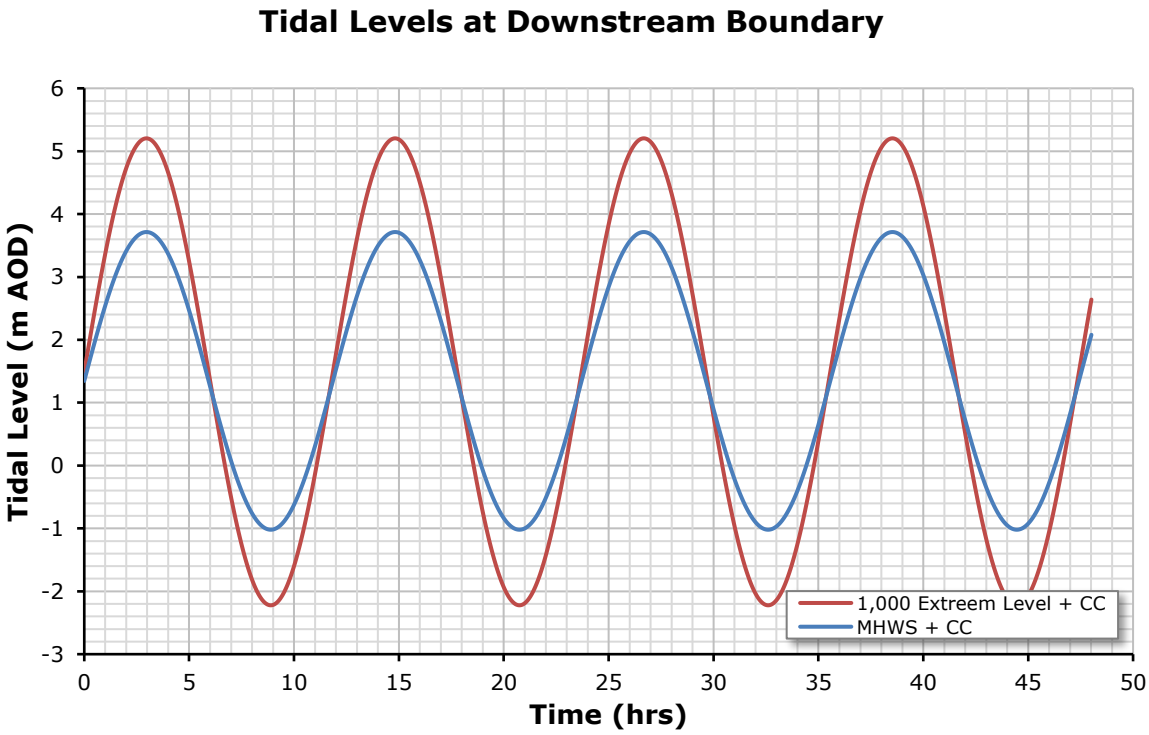


Figure 13 - Tidal Hydrographs used in Sensitivity Analysis

Table 6 - Results of Sensitivity Analysis SEN_01

Sample Point	Baseline 2yr Event + CC (m AOD)	SEN_01 2yr Event + CC (m AOD)	Change in Flood Level (m)
SP-01	-	-	-
SP-02	8.38	8.38	-
SP-03	8.58	8.58	-
SP-04	8.90	8.90	-
SP-05	9.07	9.07	-
SP-06	8.17	8.17	-
SP-07	8.36	8.36	-
SP-08	8.79	8.79	-
SP-09	8.82	8.82	-
SP-10	8.95	8.95	-

Table 7 - Results of Sensitivity Analysis SEN_02

Sample Point	Baseline 1,000yr Event (m AOD)	SEN_02 1,000yr Event (m AOD)	Change in Flood Level (m)
SP-01	10.03	10.03	-
SP-02	9.12	9.12	-
SP-03	9.48	9.48	-
SP-04	10.01	10.01	-
SP-05	10.31	10.31	-
SP-06	8.89	8.89	-
SP-07	9.27	9.27	-
SP-08	9.67	9.67	-
SP-09	9.85	9.85	-
SP-10	10.14	10.14	-

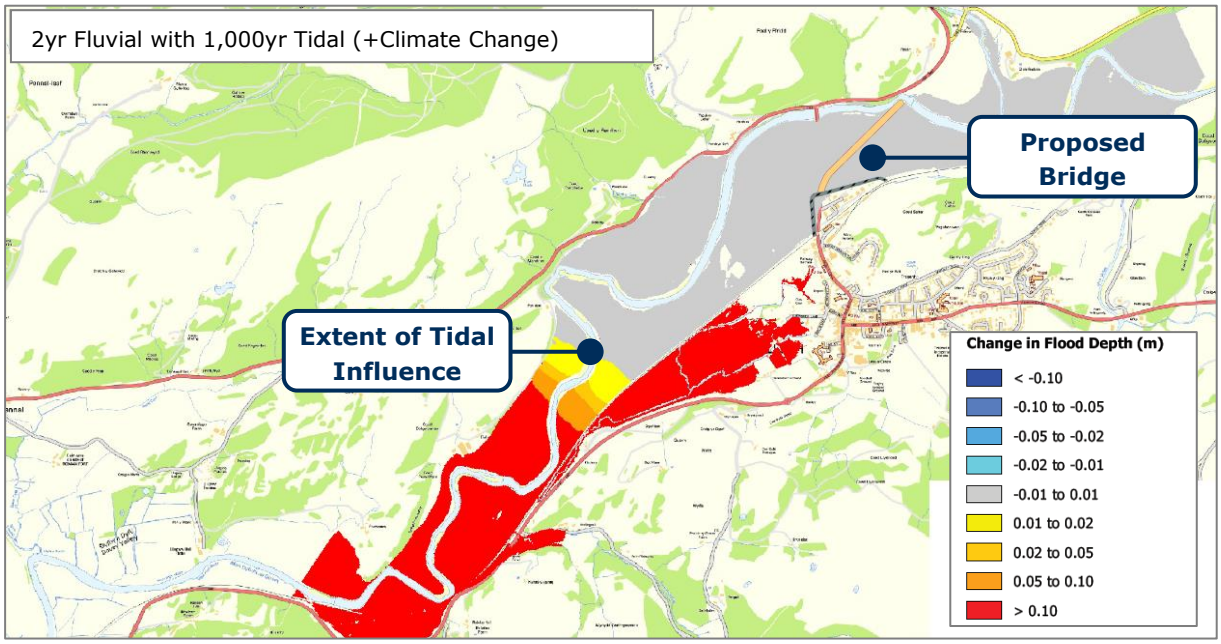


Figure 14 - Tidal Influence during SEN_01

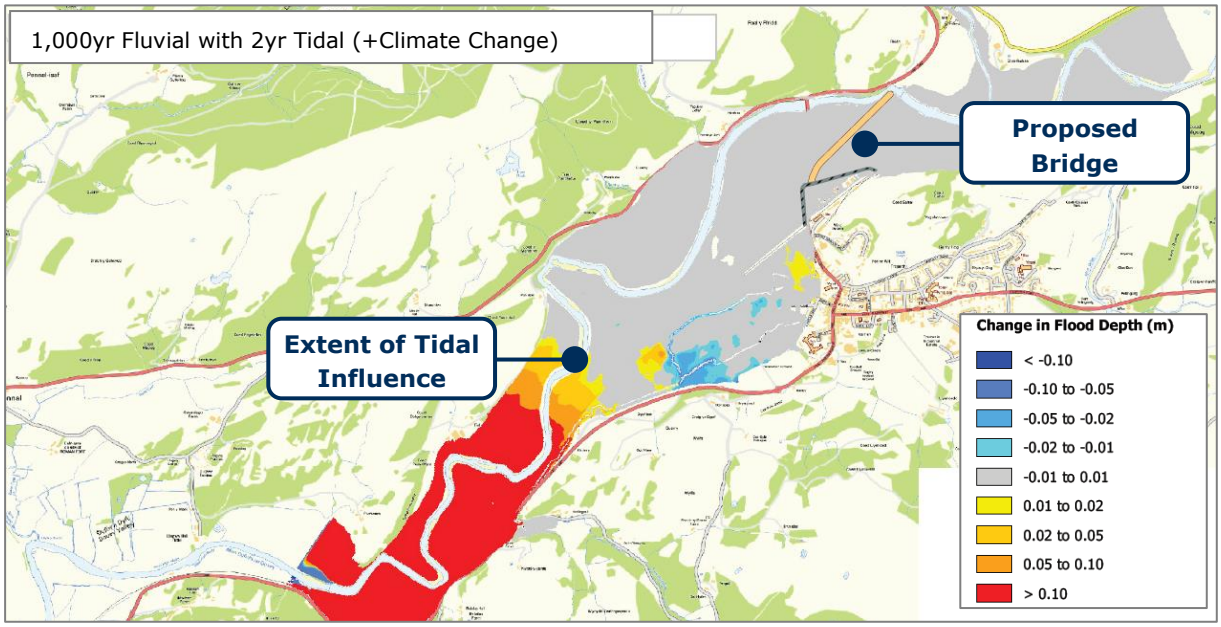


Figure 15 - Tidal Influence during SEN_02

4.3 Removal of Arch Flood Bund

To the east of the proposed A487 Bridge there is an un-adopted flood bund (NGR: 274930 301790) which currently provides a degree of flood protection at the location of the proposed bridge. As there is some uncertainty to the longevity of this flood bund, sensitivity analysis has been carried out to assess whether removal of this feature would impact on the final scheme design. The model outputs for the scenario with the arch bund and final scheme in situ were compared with the model outputs for the scenario with the final scheme but with removal of the flood bund. This sensitivity analysis has been completed for both the 1 in 2 year flood event and the 1 in 100 year plus an allowance for climate change flood event.

The results for the 1 in 2 year event (SEN_03a) are shown in Table 8 and Figure 16 and the results for the 1 in 100 year plus an allowance for climate change event (SEN_03b) are shown in Table 9 and Figure 17.

The sensitivity analysis shows that the during the 1 in 2 year flood event, the un-adopted flood bund reduces flood levels immediately downstream by approximately 300mm. This reduction in flood level slowly reduces further downstream of the flood bund, where it reaches zero impact at approximately 1.8km downstream.

During the 1 in 100 year plus an allowance for climate change flood event, the impact of the un-adopted flood bund is less significant. This is primarily due to the fact that the weir effect produced as floodwaters spill over the crest of the bund is drowned out as a result of a greater volume of floodwaters within the Dyfi flood plain.

The increases in flood levels during this sensitivity analysis are typically in the range of 10mm to 70mm during the 1 in 100 year plus climate change event. These outputs indicate that during the 1 in 100 year plus climate change event, the scheme still remains compliant with Planning Policy Wales even in the event that the arch bund is removed from the flood plain. The freeboard allowance between this design flood level and the proposed scheme levels is sufficient to accommodate this minor change.

Table 8 - Results of Sensitivity Analysis SEN_03a

Sample Point	Final Scheme 2yr Event (m AOD)	SEN_03a 2yr Event (m AOD)	Change in Flood Level (m)
SP-01	9.15	8.94	-0.21
SP-02	8.26	8.30	0.04
SP-03	8.42	8.54	0.12
SP-04	8.73	8.96	0.23
SP-05	8.89	9.17	0.28
SP-06	8.05	8.10	0.05
SP-07	8.23	8.38	0.15
SP-08	8.64	8.84	0.20
SP-09	8.66	8.88	0.22
SP-10	8.74	9.05	0.31

Table 9 - Results of Sensitivity Analysis SEN_03b

Sample Point	Final Scheme 100yrCC Event (m AOD)	SEN_03b 100yrCC Event (m AOD)	Change in Flood Level (m)
SP-01	9.74	9.64	-0.10
SP-02	8.83	8.83	0.00
SP-03	9.19	9.20	0.01
SP-04	9.63	9.64	0.01
SP-05	9.86	9.93	0.07
SP-06	8.58	8.58	0.00
SP-07	8.90	8.91	0.01
SP-08	9.41	9.43	0.02
SP-09	9.51	9.55	0.04
SP-10	9.75	9.82	0.07

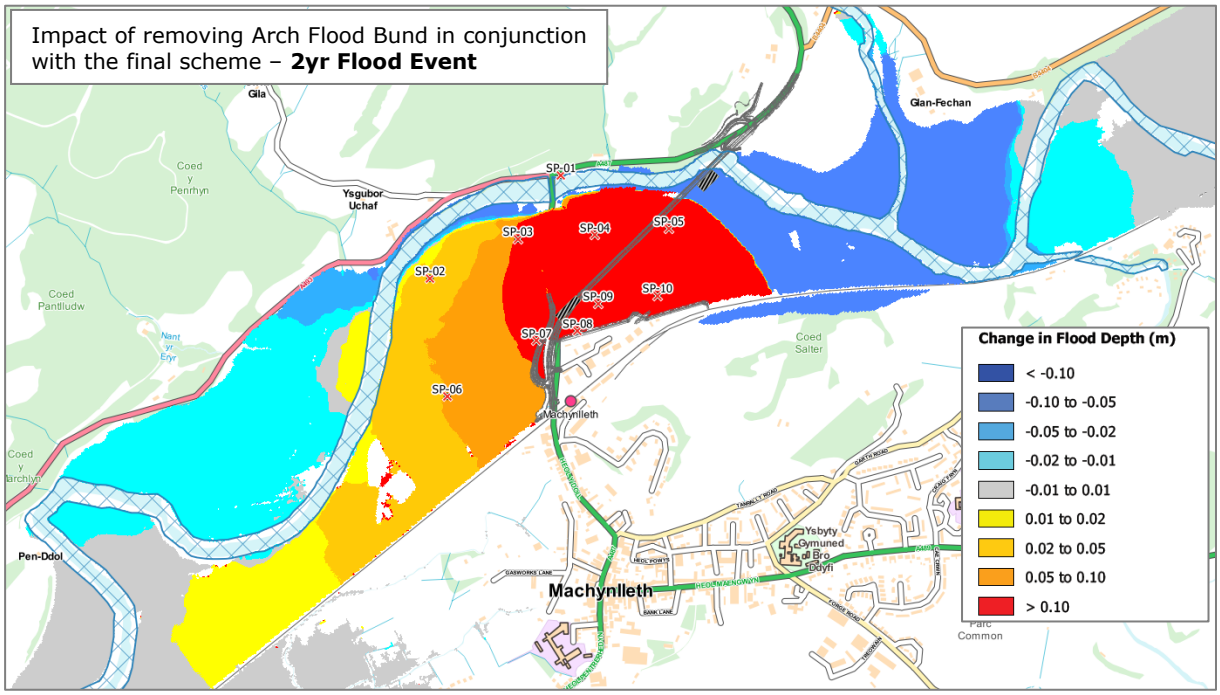


Figure 16 - Results from Sensitivity Analysis SEN_3a

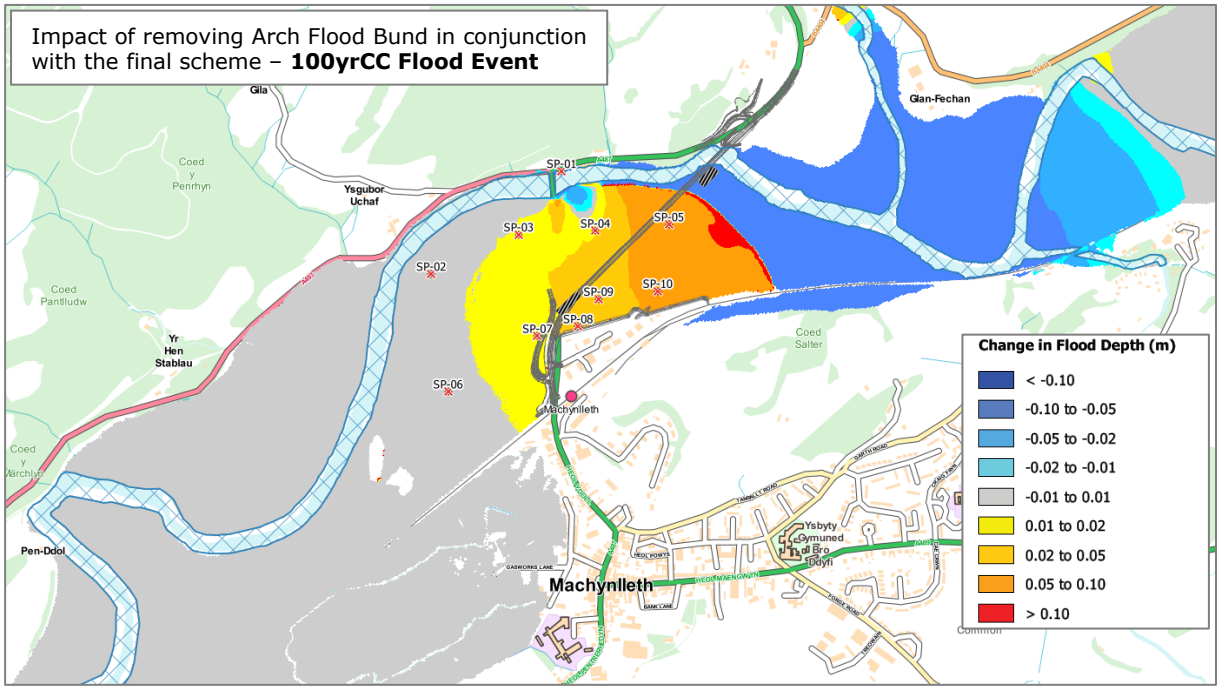


Figure 17 - Results from Sensitivity Analysis SEN_3b

4.4 Surface Roughness

To assess the sensitivity of the model to the surface roughness, as represented with the Manning's number, sensitivity analysis has been carried out by increasing (SEN_04a) and decreasing (SEN_04b) the values by ±20%. The Manning's numbers have been globally increased and decreased in both the 1D and 2D domains.

The results of the sensitivity test are shown in Table 10 and Table 11 below. Increasing the Manning's numbers by 20% results in an increased flood level of up to 190mm and decreasing the Manning's numbers by 20% results in a decreased flood level of up to 180mm.

Table 10 - Results of Sensitivity Analysis SEN_04a

Sample Point	BSC - 100yrCC (m AOD)	SEN_04a (m AOD)	Change in Flood Level (m)
SP-01	9.67	9.79	0.12
SP-02	8.80	8.93	0.12
SP-03	9.14	9.28	0.15
SP-04	9.56	9.72	0.16
SP-05	9.80	9.99	0.19
SP-06	8.59	8.70	0.11
SP-07	8.92	9.06	0.15
SP-08	9.29	9.43	0.13
SP-09	9.42	9.58	0.16
SP-10	9.67	9.85	0.18

Table 11 - Results of Sensitivity Analysis SEN_04b

Sample Point	BSC - 100yrCC (m AOD)	SEN_04b (m AOD)	Change in Flood Level (m)
SP-01	9.67	9.59	-0.08
SP-02	8.80	8.67	-0.13
SP-03	9.14	8.99	-0.15
SP-04	9.56	9.42	-0.14
SP-05	9.80	9.62	-0.18
SP-06	8.59	8.47	-0.12
SP-07	8.92	8.75	-0.17
SP-08	9.29	9.22	-0.07
SP-09	9.42	9.31	-0.11
SP-10	9.67	9.50	-0.17

4.5 Downstream Boundary

This report has already detailed the sensitivity analysis that has been carried out regarding the tidal influence on the downstream boundary. This confirmed that the tidal influence did not extend as far as the Dyfi Bridge location and the existing normal depth boundary was retained for the analysis. To assess the sensitivity of the model to this downstream boundary, sensitivity analysis has been carried out by increasing (SEN_05a) and decreasing (SEN_05b) the gradient of the downstream boundary by ±20%. Within the 1D domain, the gradient of the downstream boundary was changed from 0.00214 to 0.00267 and 0.00178, whereas within the 2D the downstream boundary was changed from 0.0030 to 0.0036 and 0.0024.

The results of this sensitivity test are shown in Table 12 and Table 13 below, where it can be seen that the downstream boundary has no effect on flood levels at the location of the proposed bridge.

Table 12 - Results of Sensitivity Analysis SEN_05a

Sample Point	BSC - 100yrCC (m AOD)	SEN_05a (m AOD)	Change in Flood Level (m)
SP-01	9.67	9.67	-
SP-02	8.80	8.80	-
SP-03	9.14	9.14	-
SP-04	9.56	9.56	-
SP-05	9.80	9.80	-
SP-06	8.59	8.59	-
SP-07	8.92	8.92	-
SP-08	9.29	9.29	-
SP-09	9.42	9.42	-
SP-10	9.67	9.67	-

Table 13 - Results of Sensitivity Analysis SEN_05b

Sample Point	BSC - 100yrCC (m AOD)	SEN_05a (m AOD)	Change in Flood Level (m)
SP-01	9.67	9.67	-
SP-02	8.80	8.80	-
SP-03	9.14	9.14	-
SP-04	9.56	9.56	-
SP-05	9.80	9.80	-
SP-06	8.59	8.59	-
SP-07	8.92	8.92	-
SP-08	9.29	9.29	-
SP-09	9.42	9.42	-
SP-10	9.67	9.67	-

4.6 Form Loss Coefficient for the Proposed Bridge

To assess the sensitivity of the model to the form loss coefficient (FLC) that was derived in Section 3.2, sensitivity analysis has been carried out by increasing (SEN_06a) and decreasing (SEN_06b) the FLC by 20%. The FLC was changed from 0.31 to 0.37 and 0.25. In addition a further sensitivity test was run, where the FLC value was increased by over 300% to 1.0. The results are presented in Appendix E. The image shows the initial design of the scheme with a FLC value of 0.31 compared to a sensitivity test where the FLC value is increased to 1.0. This was not the final scheme and shows a simplified bridge pier across the Dyfi floodplain. Overall, no significant changes in depth changes are seen at SP-01, where depth decreases by 0.01m and SP-05 where depth increases by 0.01m. The remaining sample points show changes of 0.00m.

The results of this sensitivity test are shown in Table 14 and

Table 15 below, where it can be seen that the FLC has minimal effect on flood levels at the location of the proposed bridge. From this it is concluded that the impact that the proposed scheme has on flood levels within the localised area is primarily as a result of the Eco Park Flood bund and the new A487 south embankment which result in a reduced flow area within the flood plain. Further confidence is added to this conclusion by the results presented in Appendix E, where the FLC was set to 1.0.

Table 14 - Results of Sensitivity Analysis SEN_06a

Sample Point	Final Scheme - 100yrCC (m AOD)	SEN_06a (m AOD)	Change in Flood Level (m)
SP-01	9.74	9.73	-0.01
SP-02	8.83	8.83	0.00
SP-03	9.19	9.19	0.00
SP-04	9.63	9.63	-0.01
SP-05	9.86	9.86	0.00
SP-06	8.58	8.58	0.00
SP-07	8.90	8.90	0.00
SP-08	9.41	9.41	0.00
SP-09	9.51	9.51	0.00
SP-10	9.75	9.75	0.00

Table 15 - Results of Sensitivity Analysis SEN_06b

Sample Point	Final Scheme - 100yrCC (m AOD)	SEN_06b (m AOD)	Change in Flood Level (m)
SP-01	9.74	9.73	-0.01
SP-02	8.83	8.83	0.00
SP-03	9.19	9.19	0.00
SP-04	9.63	9.62	-0.01
SP-05	9.86	9.86	0.00
SP-06	8.58	8.58	0.00
SP-07	8.90	8.90	0.00
SP-08	9.41	9.41	0.00
SP-09	9.51	9.51	0.00
SP-10	9.75	9.75	0.00

5 2016 Climate Change Updates

New guidance issued by Welsh Government came into effect on the 1st of December 2016[7]. The updated flow allowances suggest a central change factor (50th percentile) of +30% by the 2080's for West Wales. To assess the impacts of this 30% increase in flow through the River Dyfi, the baseline and post development scenarios were run. Table 16 shows the increase in flow for all of the contributing watercourses in the model.

Table 16 – Flow comparisons in contributing watercourses

Watercourse ID	100yr Peak Flow (m^3/s)	100yr + 20% CC Peak Flow (m^3/s)	100yr + 30% CC Peak Flow (m^3/s)
DYFI_7805	441.83	530.20	574.38
DLSN_0890	123.06	147.67	159.98
DLSS_0402	77.64	93.17	100.93
GSWN101	1.87	2.25	2.43
GSWN201	4.40	5.28	5.72
NRH01	9.01	10.81	11.71

The results of the modelling of the new climate change values are shown in

[7] Flood Consequence Assessments: Climate change allowances - http://gov.wales/docs/desh/publications/160831guidance-for-flood-consequence-assessments-climate-change-allowances-en.pdf

Table 17. The results indicate increased flood levels when compared to the original 1 in 100 year +20% allowance for climate change event. As an example, sample point 1 (SP-01) shows a baseline flood level of 9.78m AOD and a post-development level of 9.84m AOD, this is an increase of approximately 0.06m.

As flood levels are increased during the 1 in 100 year +30% allowance for climate change event, some overtopping from the railway embankment into the eco-park is evident. Flood water enters the eco-park from the railway embankment, which is not protected by the bund. Water spills from the railway directly into the eco-park and propagates along the southern edge of the proposed bund. No spill over the bund from the floodplain is evident and as shown in Figure 19 there is still significant betterment to flood depths within the eco-park.

Table 17 – 1 in 100 + 30% allowance for climate change results

Sample Point	100CC+30% BSC Level (m AOD)	100CC+30% PD Level (m AOD)	Depth Change (m)
SP-01	9.78	9.84	0.06
SP-02	8.86	8.89	0.03
SP-03	9.21	9.26	0.05
SP-04	9.65	9.73	0.08
SP-05	9.90	9.97	0.07
SP-06	8.65	8.64	-0.01
SP-07	8.98	8.96	-0.02
SP-08	9.37	9.50	0.13
SP-09	9.51	9.61	0.10
SP-10	9.76	9.86	0.10
SP-11	10.85	10.85	0.00
SP-12	9.98	10.07	0.09
SP-13	9.06	8.95	-0.11

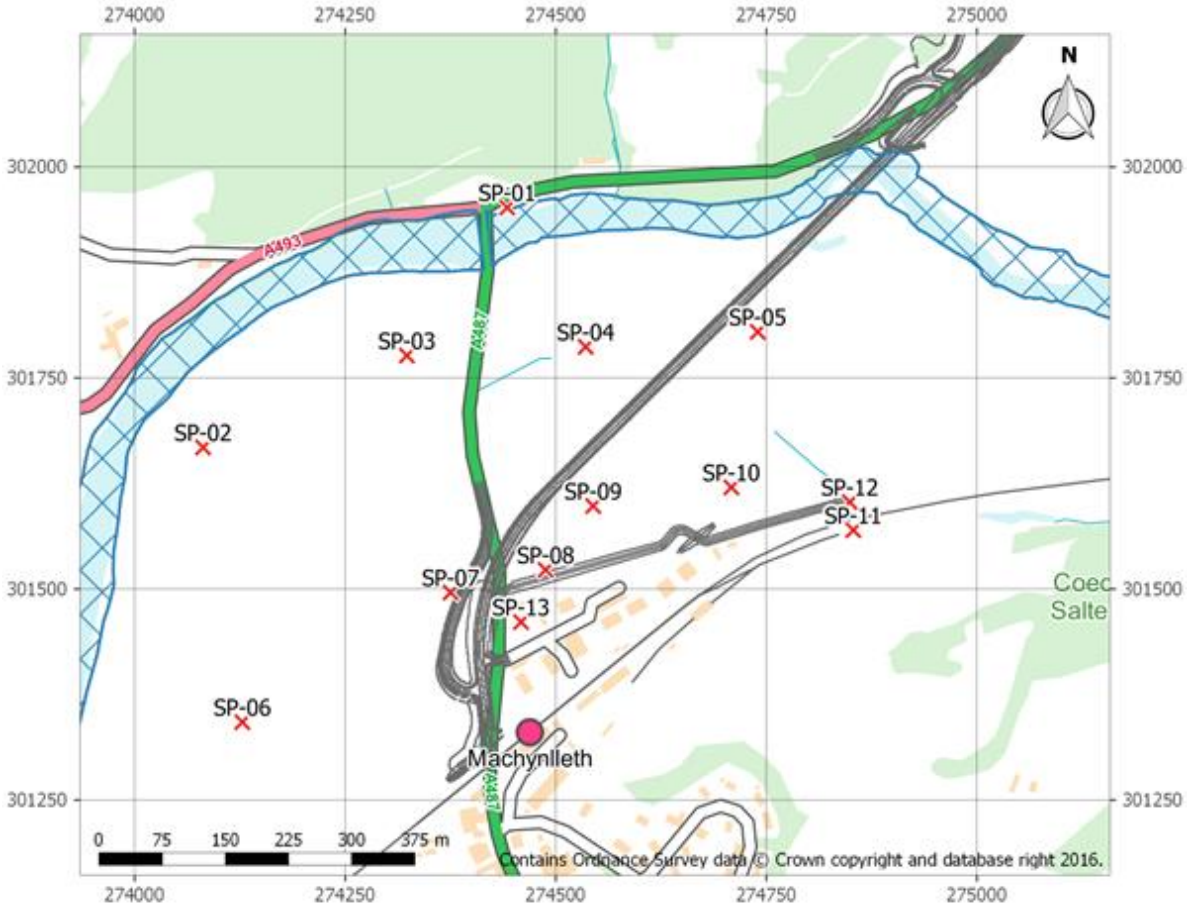


Figure 18 – Sample point locations

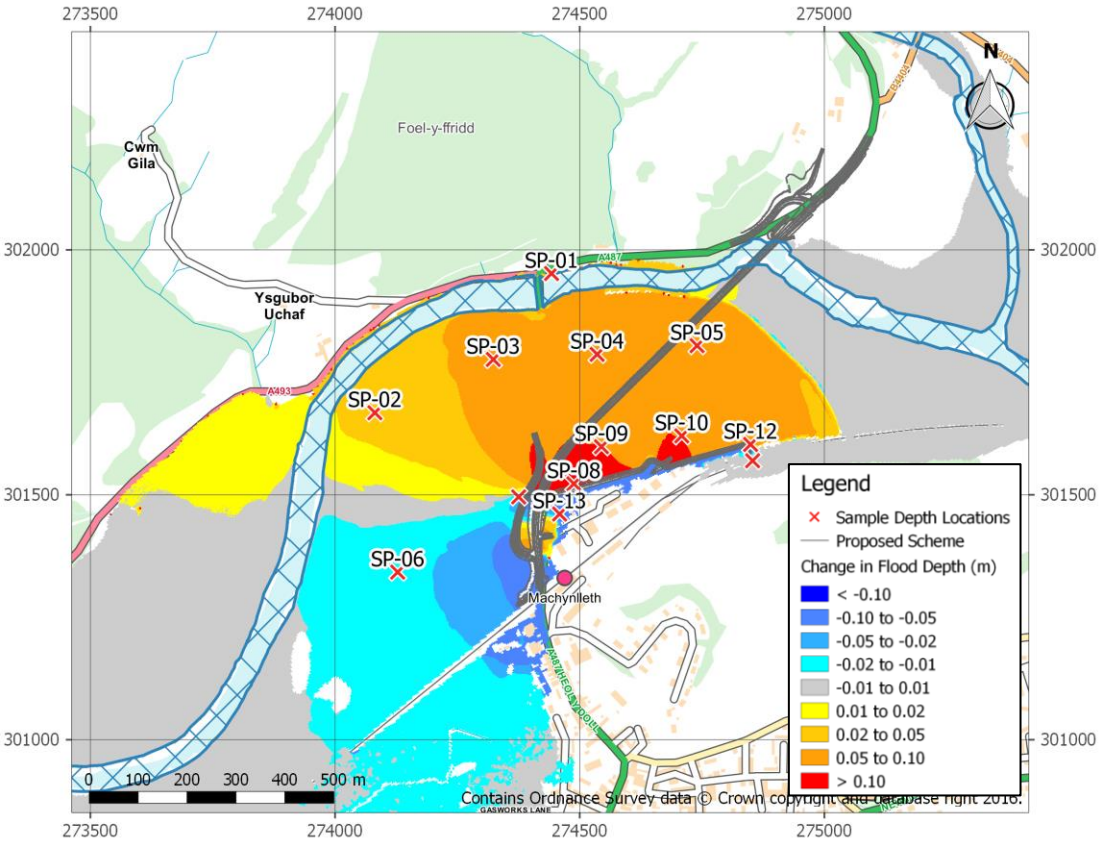


Figure 19 – Depth change plot for the baseline and post-development 1 in 100yr+30% CC event

6 Model Stability

Review of the key model stability parameters show that the model runs stable over all model runs that were undertaken. The cumulative Mass Error (ME) for the key model runs are shown in Figure 20, all of the final cumulative ME values are within the acceptable range of ±1.0%.

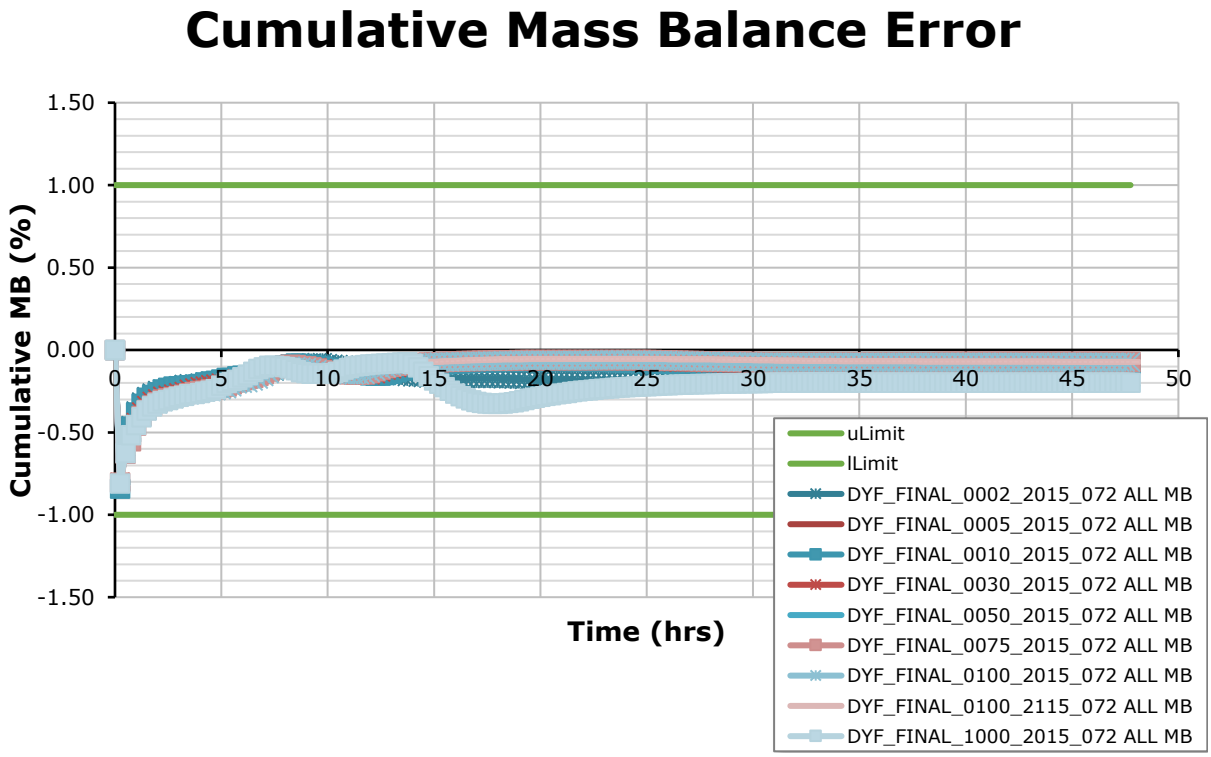


Figure 20 - Cumulative Mass Balance Error for Proposed Scheme (Final Design Runs)

There were however some model instabilities around the minor tributaries (Nant Rhisglog tributary and Garsiwn tributaries) located to the south west of Machynlleth. The relative size of these tributaries compared to the flows within the River Dyfi meant that these localised instabilities had little impact on the overall model mass error. However, these instabilities led to some unexpected and improbable changes in flood depth.

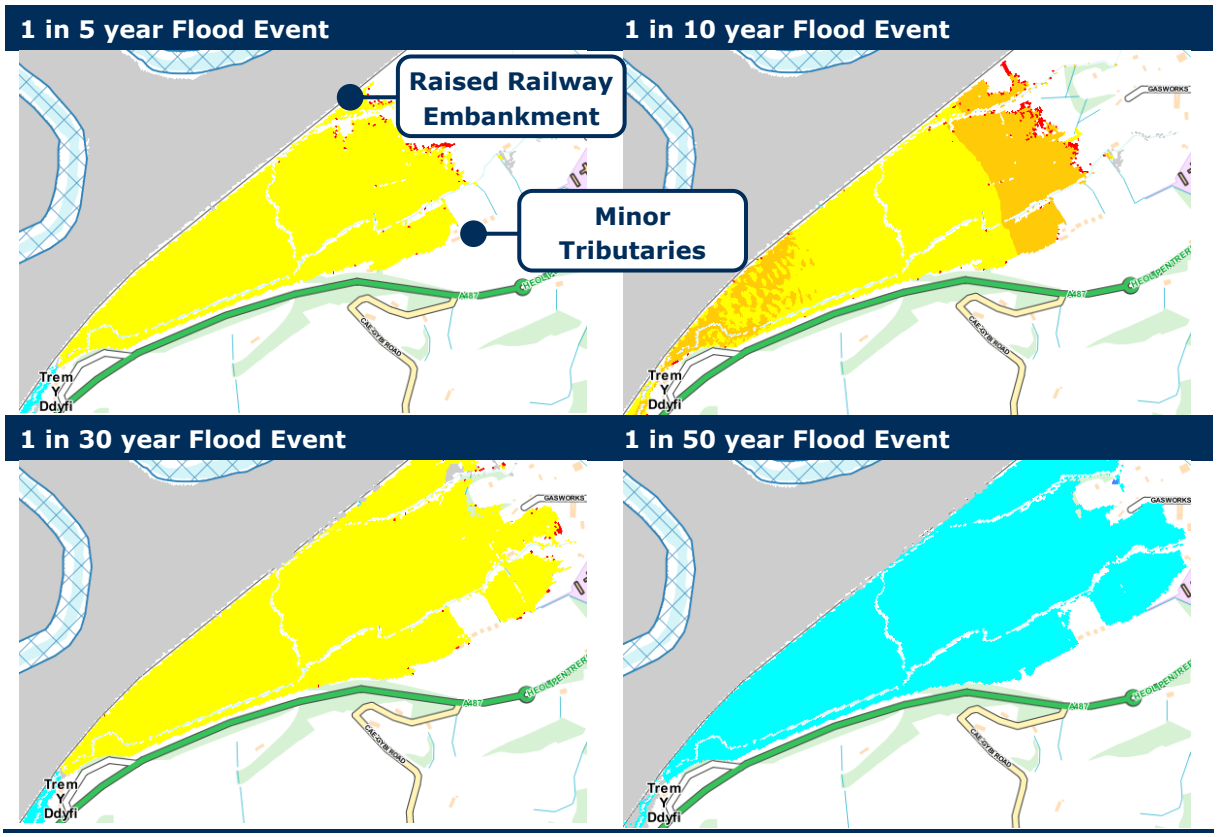
These unexpected changes in flood depth are shown in Table 18. For the 1 in 5 year, 10 year, 30 year and the 1 in 75 year flood events, the model shows a relative increase in flood level. However the model predicts a relative decrease in flood levels during the 1 in 50 year, 100 year and the 1 in 100 year plus climate change flood events. Finally the 1 in 1,000 year change in flood level as a result of the proposed scheme shows both an increase and decrease in levels.

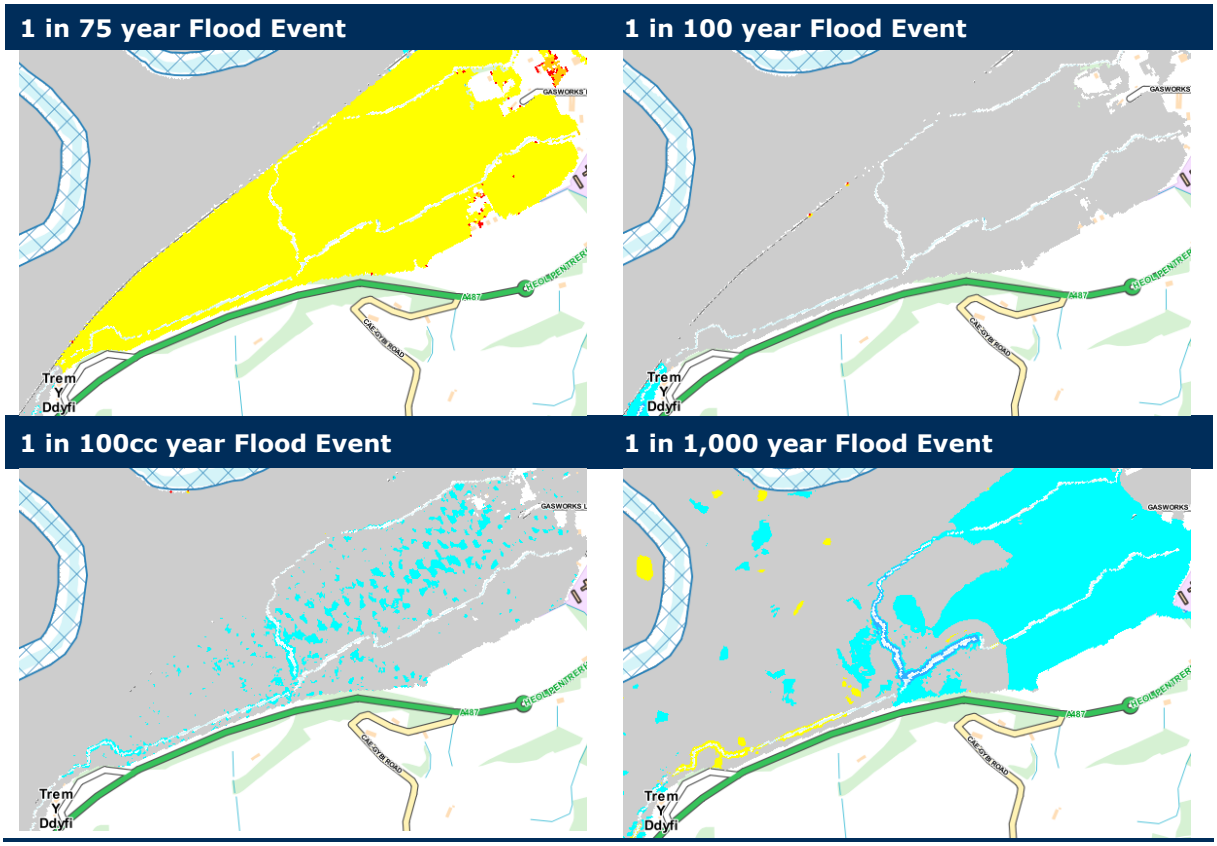
Further investigation of the water level within the 1D ESTRY domain of the model has identified further evidence of these instabilities. In particular the water level at node M1_01158.1 shows an unstable head vs time hydrograph for the 1 in 1,000 year flood event. These instabilities result in erratic water levels as illustrated by the hydrograph at node M1_01158.1 shown in Figure 21. Due to the location of the tributaries, which are downstream of the site and to the east of the raised

railway embankment, the instabilities during peak flows are concluded to be remote from the area of interest and to not affect the modelled flood levels which inform the proposed design. This section of the model isn't hydraulically connected to the main flood plain until the railway embankment levels falls below the flood level, which is approximately 1km to the south west of the proposed scheme during the 1 in 5 year flood event, decreasing to 0.5km during the 1 in 1,000 year flood event.

Furthermore, it is considered that the apparent impact of the proposed development scheme is not a realistic prediction of potential detriment/betterment as a result of the proposed works. Due to the disconnectivity of the flood regime of these tributaries from the main Dyfi flood regime, the model outputs demonstrate the inherent instability within the model rather than the realistic impacts. This is further corroborated by the fact that the impacts of the proposed development on the main Dyfi flood plain indicate a distinct and separate extent and mechanism.

Table 18 - Unexpected changes in Flood Depth at Minor Tributaries





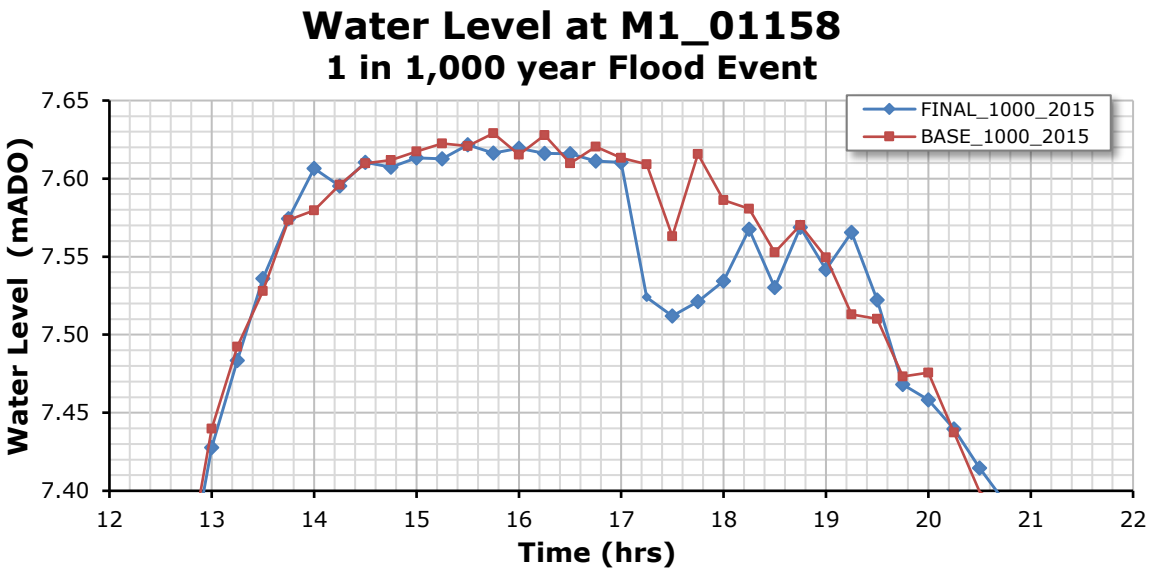


Figure 21 - Hydrograph at Node M1-01158.1 within the 1D ESTRY domain during the 1 in 1,000 year event

7 Model Results and conclusion

7.1 Baseline and Post Development Model Results

The following tables provide peak flood levels, depths and velocities for the baseline model scenario and the post development model scenario. Tables also detail the subsequent change in flood levels between these two scenarios, as predicted by the revised and extended River Dyfi hydraulic model. The location of these sample points are the same as the sample points used in the sensitivity analysis and their locations are shown in Figure 12.

This report has provided details and justification of the modelling approach, and it is considered that the baseline scenario and post development scenario provide a good indication of flood risk at the site.

Sensitivity testing has provided further confidence in the model outputs which confirm that the model has incorporated the key features that influence the flood mechanisms at the location of Dyfi Bridge at Machynlleth.

The change in flood levels during a 1 in 100 year plus a 20% allowance for climate change is shown in Figure 22. The impact that the proposed scheme over a range of return periods between the 1 in 2 year flood event and the 1 in 1,000 year flood event is provided in Appendix C.

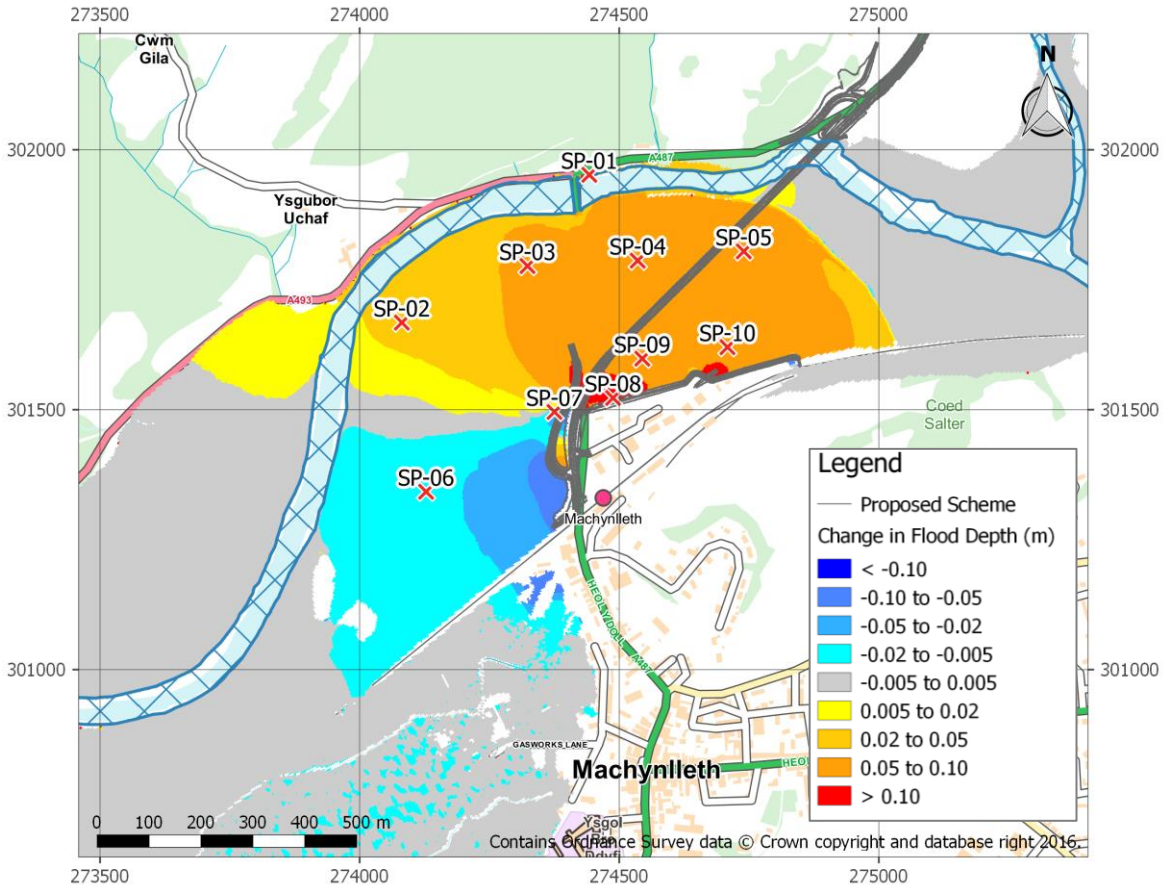


Figure 22 - Change in Flood levels as a result of the proposed A487 Bridge during the 1 in 100 year flood event plus an allowance for climate change

Table 19 - Baseline Flood Levels

Sample Point	2 year	5 year	10 year	30 year	50 year	75 year	100 year	100 year +CC	1,000 year
SP-01	9.16	9.22	9.27	9.35	9.40	9.44	9.47	9.68	10.06
SP-02	8.26	8.42	8.50	8.59	8.63	8.66	8.68	8.80	9.12
SP-03	8.43	8.64	8.74	8.87	8.92	8.96	8.98	9.14	9.48
SP-04	8.73	8.95	9.07	9.22	9.28	9.32	9.35	9.56	10.01
SP-05	8.89	9.14	9.26	9.43	9.49	9.54	9.58	9.80	10.31
SP-06	8.05	8.21	8.28	8.38	8.42	8.44	8.46	8.59	8.89
SP-07	8.19	8.41	8.52	8.65	8.70	8.73	8.76	8.92	9.27
SP-08	8.66	8.83	8.91	9.02	9.07	9.10	9.13	9.29	9.67
SP-09	8.67	8.87	8.97	9.10	9.16	9.20	9.23	9.42	9.85
SP-10	8.74	9.02	9.15	9.31	9.37	9.42	9.45	9.67	10.14

Table 20 – Post Development Flood Levels

Sample Point	2 year	5 year	10 year	30 year	50 year	75 year	100 year	100 year +CC	1,000 year
SP-01	9.15	9.22	9.27	9.36	9.42	9.46	9.50	9.74	10.12
SP-02	8.26	8.43	8.51	8.61	8.65	8.68	8.70	8.83	9.15
SP-03	8.42	8.65	8.76	8.90	8.96	9.00	9.03	9.19	9.56
SP-04	8.73	8.97	9.09	9.25	9.32	9.37	9.40	9.63	10.10
SP-05	8.89	9.15	9.28	9.46	9.53	9.58	9.62	9.86	10.39
SP-06	8.05	8.20	8.28	8.37	8.41	8.43	8.45	8.58	8.88
SP-07	8.23	8.44	8.54	8.66	8.70	8.73	8.76	8.90	9.21
SP-08	8.64	8.84	8.93	9.08	9.14	9.18	9.21	9.41	9.84
SP-09	8.66	8.88	8.99	9.15	9.22	9.26	9.30	9.51	9.98
SP-10	8.74	9.05	9.18	9.36	9.43	9.48	9.52	9.75	10.26

Table 21 – Change in Flood Levels

Sample Point	2 year	5 year	10 year	30 year	50 year	75 year	100 year	100 year +CC	1,000 year
SP-01	0.00	0.00	0.00	0.01	0.02	0.03	0.03	0.05	0.06
SP-02	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.03
SP-03	-0.01	0.02	0.02	0.04	0.04	0.04	0.04	0.05	0.07
SP-04	-0.01	0.01	0.02	0.04	0.04	0.05	0.05	0.07	0.09
SP-05	0.00	0.01	0.02	0.03	0.04	0.04	0.04	0.06	0.08
SP-06	0.00	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
SP-07	0.04	0.03	0.02	0.01	0.00	0.00	0.00	-0.02	-0.06
SP-08	-0.02	0.01	0.02	0.06	0.07	0.08	0.08	0.12	0.17
SP-09	-0.02	0.01	0.02	0.05	0.06	0.06	0.07	0.09	0.13
SP-10	0.00	0.02	0.03	0.05	0.06	0.06	0.06	0.09	0.12

Table 22 - Baseline Flood Depths

Sample Point	2 year	5 year	10 year	30 year	50 year	75 year	100 year	100 year +CC	1,000 year
SP-01	0.22	0.28	0.32	0.40	0.44	0.48	0.51	0.72	1.09
SP-02	0.78	0.94	1.02	1.11	1.15	1.18	1.20	1.33	1.64
SP-03	0.18	0.38	0.49	0.61	0.67	0.70	0.73	0.88	1.23
SP-04	0.34	0.56	0.67	0.82	0.88	0.93	0.96	1.16	1.61
SP-05	0.72	0.96	1.09	1.25	1.32	1.37	1.40	1.62	2.13
SP-06	0.65	0.81	0.88	0.98	1.02	1.04	1.06	1.19	1.49
SP-07	0.33	0.55	0.65	0.78	0.83	0.87	0.90	1.05	1.41
SP-08	1.12	1.28	1.37	1.47	1.52	1.56	1.58	1.75	2.13
SP-09	0.69	0.88	0.98	1.12	1.17	1.21	1.24	1.43	1.86
SP-10	0.21	0.48	0.61	0.77	0.84	0.89	0.92	1.13	1.60

Table 23 - Post Development Flood Depths

Sample Point	2 year	5 year	10 year	30 year	50 year	75 year	100 year	100 year +CC	1,000 year
SP-01	0.22	0.28	0.32	0.41	0.46	0.51	0.54	0.77	1.15
SP-02	0.79	0.96	1.04	1.13	1.17	1.20	1.22	1.35	1.67
SP-03	0.17	0.40	0.51	0.65	0.71	0.75	0.77	0.94	1.30
SP-04	0.33	0.57	0.69	0.86	0.92	0.97	1.01	1.23	1.71
SP-05	0.72	0.98	1.11	1.29	1.36	1.41	1.45	1.69	2.22
SP-06	0.65	0.80	0.88	0.97	1.01	1.03	1.05	1.18	1.48
SP-07	0.37	0.58	0.68	0.79	0.84	0.87	0.89	1.03	1.35
SP-08	1.09	1.29	1.38	1.52	1.58	1.63	1.66	1.86	2.29
SP-09	0.67	0.89	1.01	1.17	1.23	1.28	1.31	1.53	1.99
SP-10	0.20	0.51	0.65	0.82	0.89	0.95	0.98	1.22	1.72

Table 24 - Change in Flood Depths

Sample Point	2 year	5 year	10 year	30 year	50 year	75 year	100 year	100 year +CC	1,000 year
SP-01	0.00	0.00	0.00	0.01	0.02	0.03	0.03	0.05	0.06
SP-02	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.03
SP-03	-0.01	0.02	0.02	0.04	0.04	0.04	0.04	0.05	0.07
SP-04	-0.01	0.01	0.02	0.04	0.04	0.05	0.05	0.07	0.09
SP-05	0.00	0.01	0.02	0.03	0.04	0.04	0.04	0.06	0.08
SP-06	0.00	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
SP-07	0.04	0.03	0.02	0.01	0.00	0.00	0.00	-0.02	-0.06
SP-08	-0.03	0.00	0.01	0.05	0.07	0.07	0.08	0.11	0.16
SP-09	-0.02	0.01	0.02	0.05	0.06	0.06	0.07	0.09	0.13
SP-10	0.00	0.02	0.03	0.05	0.06	0.06	0.06	0.09	0.12

Table 25- Baseline Flood Velocities

Sample Point	2 year	5 year	10 year	30 year	50 year	75 year	100 year	100 year +CC	1,000 year
SP-01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.05	0.08
SP-02	0.53	0.53	0.56	0.61	0.63	0.64	0.65	0.71	0.92
SP-03	0.24	0.49	0.59	0.71	0.76	0.80	0.82	0.95	1.22
SP-04	0.28	0.45	0.52	0.62	0.65	0.68	0.69	0.79	1.03
SP-05	0.20	0.30	0.36	0.44	0.48	0.50	0.52	0.63	0.87
SP-06	0.28	0.36	0.41	0.47	0.49	0.51	0.52	0.60	0.77
SP-07	0.37	0.64	0.75	0.91	0.97	1.01	1.04	1.21	1.55
SP-08	0.22	0.49	0.62	0.80	0.87	0.92	0.96	1.14	1.50
SP-09	0.21	0.47	0.59	0.72	0.77	0.80	0.83	0.97	1.28
SP-10	0.22	0.47	0.56	0.67	0.72	0.75	0.77	0.90	1.23

Table 26- Post Development Flood Velocities

Sample Point	2 year	5 year	10 year	30 year	50 year	75 year	100 year	100 year +CC	1,000 year
SP-01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.05	0.08
SP-02	0.53	0.54	0.58	0.63	0.65	0.67	0.67	0.76	1.00
SP-03	0.22	0.50	0.61	0.75	0.80	0.84	0.87	1.00	1.30
SP-04	0.29	0.46	0.53	0.62	0.66	0.68	0.70	0.80	1.04
SP-05	0.20	0.30	0.37	0.45	0.49	0.51	0.53	0.63	0.88
SP-06	0.29	0.37	0.41	0.46	0.48	0.50	0.51	0.58	0.75
SP-07	0.49	0.75	0.89	1.06	1.13	1.18	1.22	1.48	1.93
SP-08	0.43	0.54	0.68	0.80	0.81	0.88	0.91	1.06	1.33
SP-09	0.25	0.50	0.60	0.72	0.77	0.80	0.82	0.96	1.27
SP-10	0.22	0.46	0.55	0.65	0.69	0.72	0.74	0.87	1.16

Table 27- Change in Flood Velocities

Sample Point	2 year	5 year	10 year	30 year	50 year	75 year	100 year	100 year +CC	1,000 year
SP-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SP-02	0.00	0.00	0.02	0.02	0.02	0.03	0.03	0.05	0.08
SP-03	-0.02	0.01	0.02	0.04	0.04	0.04	0.04	0.05	0.09
SP-04	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
SP-05	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.01
SP-06	0.01	0.00	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.02
SP-07	0.12	0.11	0.14	0.15	0.16	0.17	0.18	0.27	0.38
SP-08	0.21	0.06	0.06	0.00	-0.06	-0.04	-0.04	-0.08	-0.18
SP-09	0.03	0.02	0.02	0.00	0.00	-0.01	-0.01	-0.01	-0.02
SP-10	0.00	-0.01	-0.01	-0.02	-0.03	-0.03	-0.03	-0.04	-0.07

7.2 Temporary Works Model Results

The impact that the temporary works platforms will have on the flood mechanisms within the localised area of the proposed scheme has been assessed by modelling the two proposed platforms in combination with the south embankment, Dyfi Eco Park flood bund and the proposed bridge piers.

This modelling scenario does not consider any allowance for climate change as the temporary works will only be in situ for the construction period, which is likely to be within the next 12-18 months.

The results of the 1 in 2 year flood event and the 1 in 100 year flood event are shown in Figure 23 and Figure 24 respectively. These figures show the change in flood depth as a result of the combined proposed scheme and the temporary works when compared to the baseline scenario. Both flood events show lower flood levels at the location of the properties to the north of the existing A487 Bridge.

The detrimental impacts predicted with the temporary works are confined to the agricultural land in the immediate vicinity of the proposed works. Modelling has confirmed that no residential/commercial properties are affected by increased flood levels as a result of the temporary works.

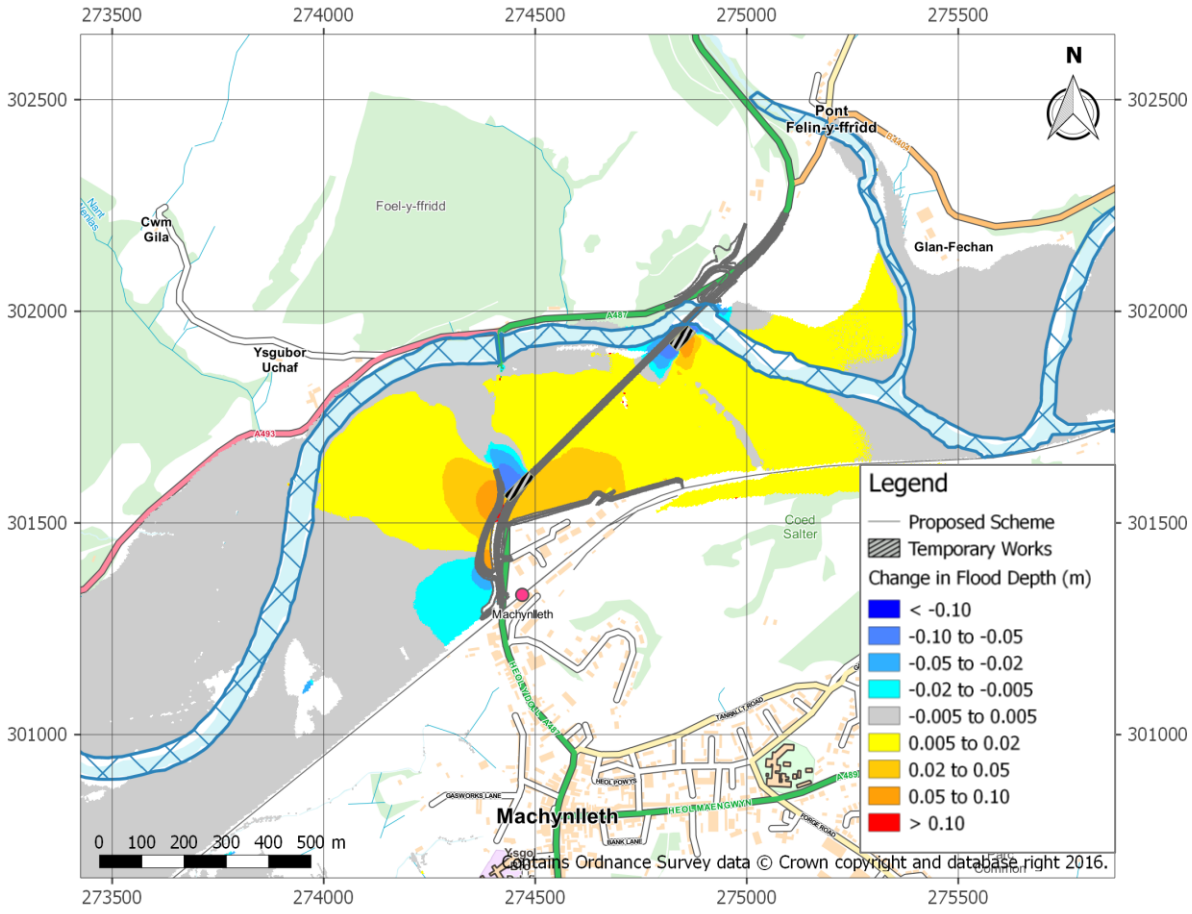


Figure 23 - Impact of Temporary Works and the Proposed Scheme during the 1 in 2 year flood event

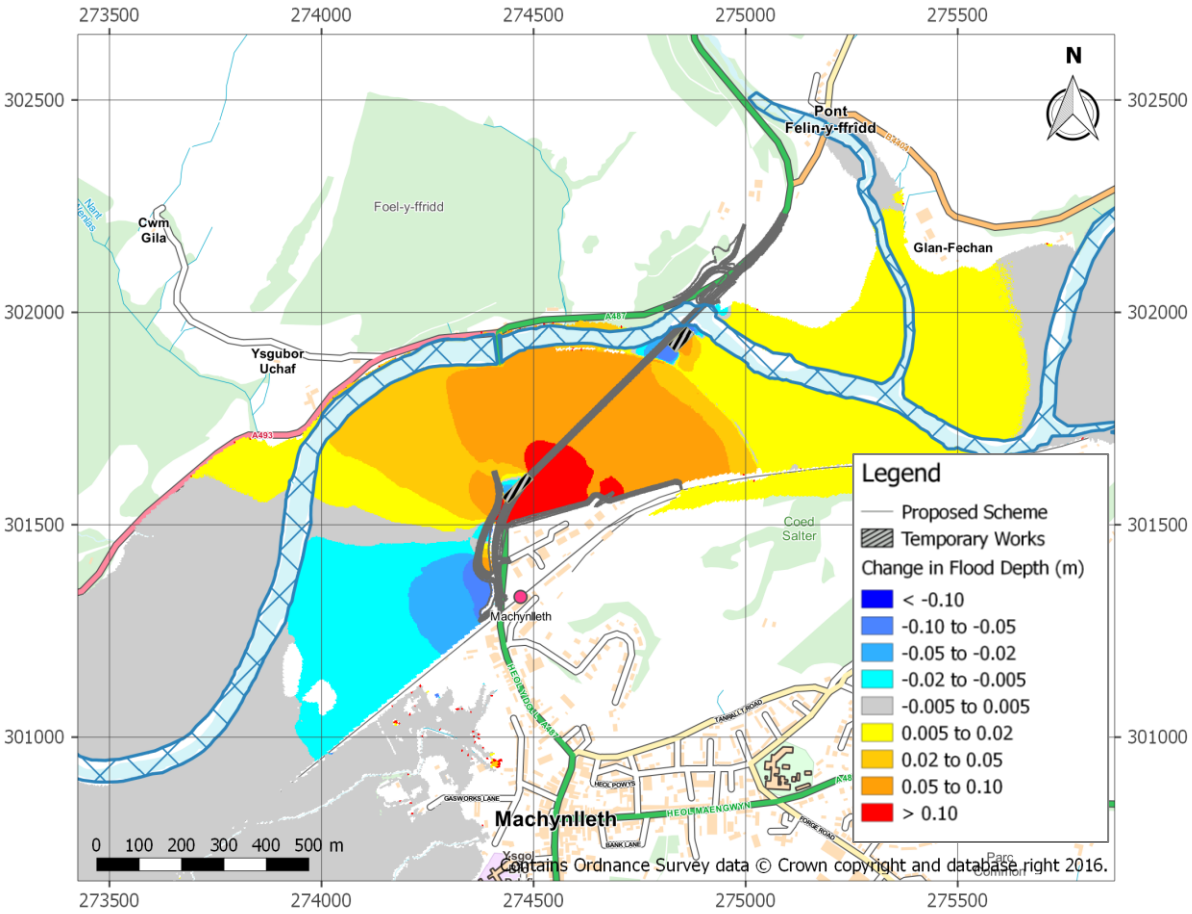


Figure 24 - Impact of Temporary Works and the Proposed Scheme during the 1 in 100 year flood event

Appendix A. Hydrology

Appendix B. River Survey

Appendix C. Flood Maps

Appendix D. Proposed Scheme

Appendix E. FLC Sensitivity Test Results

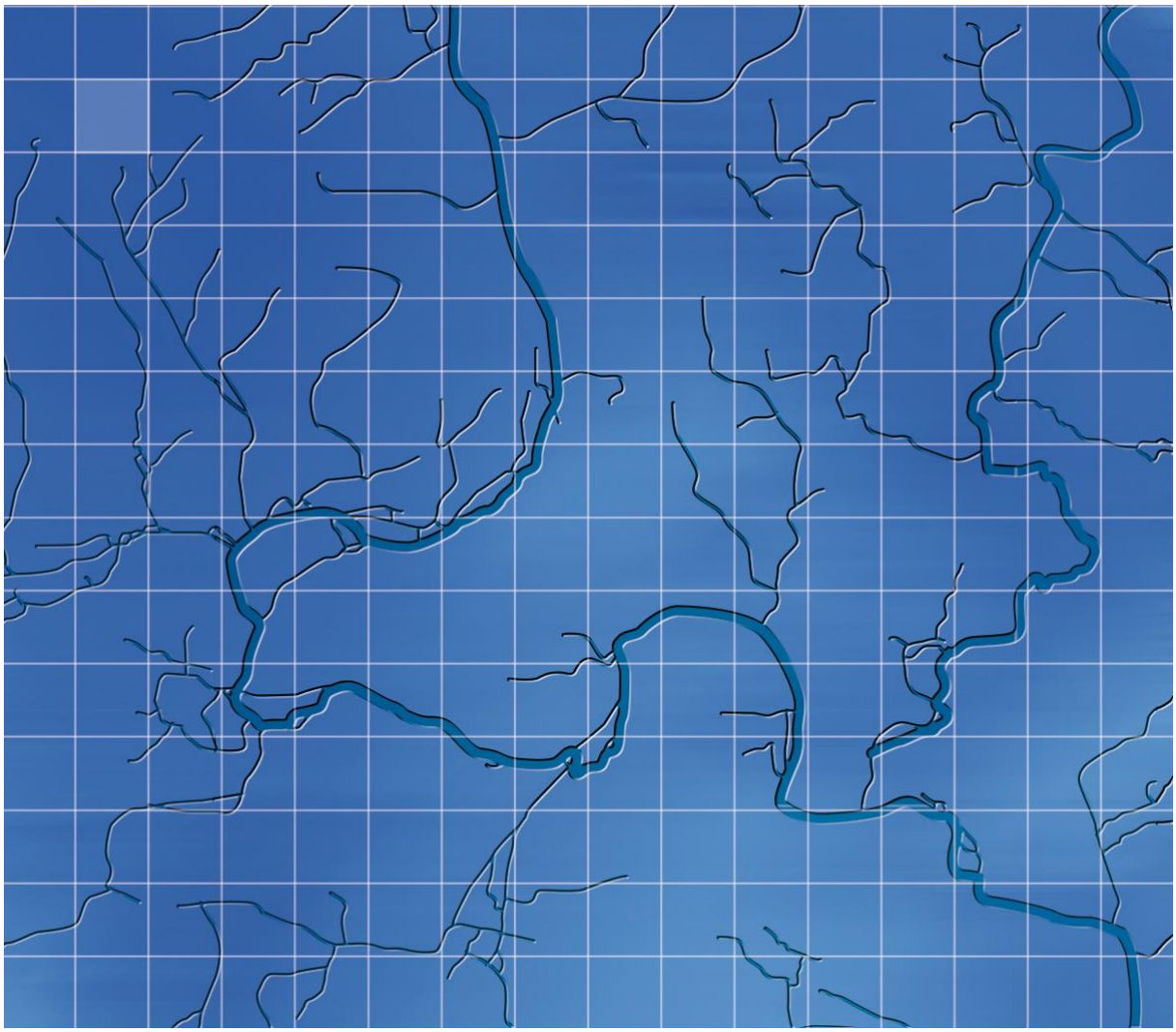
Appendix E

A487 New Dyfi Bridge
Hydrological Analysis Report

Arup

November 2015

A487 New Dyfi Bridge Hydrological Analysis



Wallingford HydroSolutions Limited

Arup

A476 New Dyfi Bridge – Hydrological Analysis

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For and on behalf of Wallingford HydroSolutions Ltd.

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Approved by Dr Andrew Young
Position *Director*

Date **18/11/2016**

This report has been produced in accordance with the WHS Quality Management system which is certified as meeting the requirements of ISO 9001:2008 and ISO 14001:2004

Contents

1 Introduction

WHS has been commissioned to complete a Flood Consequences Assessment in accordance with TAN15 to support the construction of a proposed new highway bridge crossing of the River Dyfi near Machynlleth. An existing hydraulic model was developed as part of the Machynlleth Study, produced by Capita Symonds and approved by the Environment Agency Wales in 2011. The Environment Agency Wales has been superseded by the Natural Resources Wales (NRW). WHS assessed the hydrology outlined within the report and updated this to conform with current best practice methods for flood peak flow estimation. The hydraulic model was extended beyond the confluence with the Afon Dulas, the limit of the existing model, hence the hydrological assessment also considers several ungauged tributaries upstream.

2 Catchment Description

The bridge is situated across the Dyfi, close to the gauging station 64001 (Dyfi at Dyfi Bridge) as shown on

. The Dyfi is the main river through the catchment. Just upstream of the bridge are a number of confluences with two main tributaries; the Dulas (North) and, the Dulas (South). The topographic catchment boundaries for each of these catchments, as defined from the FEH CD ROM 3 which uses the 50m DTM, are presented in Figure 1. A summary of each catchment is presented in Table 1. The catchments can be classed as 'rural' with an URBEXT2000 less than 0.03. None are impacted heavily by the presence of lakes and all have a fairly high annual rainfall.

Table 1. Catchment Descriptors for each catchment

	64001 Dyfi at Dyfi Bridge	Dulas (Northern Tributary)	Afon Dyfi (Eastern)	Afon Dulas (South)
X	274500	275350	275700	275750
Y	301900	301850	301750	301700
Area	464.6	63.4	334.7	65.4
BFIHOST	0.478	0.474	0.468	0.53
DPLBAR	20.37	10.29	22.52	9.71
DPSBAR	269.8	314.6	265.8	249
FARL	0.995	0.997	0.997	0.982
SAAR	1835	2193	1796	1688
URBEXT2000	0.0007	0.0022	0.0004	0.0004

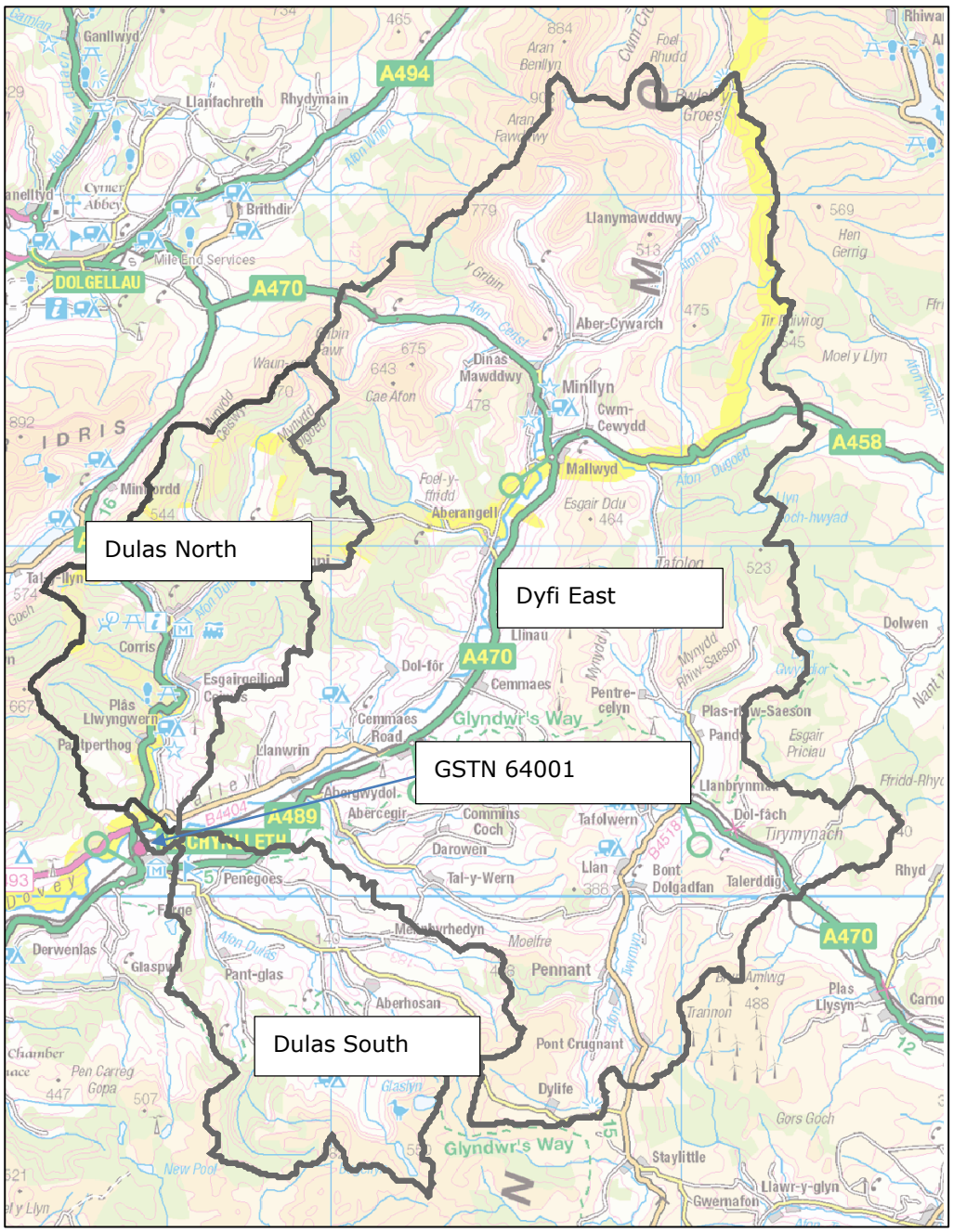

Figure 1. The location of each of the catchments used in the analysis. ***Contains OS data © Crown copyright and database right 2015***

3 Methodology

3.1 Assessment of previous hydrology

The Capita Symonds methodology relevant to the present study encompasses only the gauged site 64001, the Dyfi at Dyfi Bridge.

As part of the Capita Symonds study the annual maxima data were analysed and new ratings were derived to produce an improved Annual Maxima series. The FEH statistical methodology (using the software WINFAP v3) was applied using this data to produce both the QMED (the 1 in 2 year peak flow) and the flow frequency growth curve.

In addition, the Revitalised rainfall runoff (ReFH) model was calibrated against the data for specific events to identify catchment specific, calibrated parameters for the model. These catchment specific parameters were used within the ReFH model to derive flood hydrographs for the design scenarios. ReFH 1 was used for this analysis.

The growth curve factors from the fitted growth curves for the 1:100 year event for the catchments within the pooling group were reviewed within the Capita Symonds report. The report highlights that the growth curve factor for the gauged record for the Dyfi at Dyfi Bridge was low at a value of 1.82 EA guidance[1] suggests that a typical value is between 2.1 and 4.

The report states that there was more confidence in the design flows estimated using the REFH method as the parameters were calibrated from observed data. Confidence was placed on the QMED calculated from the gauged annual maxima but limited confidence was placed on statistical method derived growth curves as the 'very flat' growth curves were not considered representative of the site. The data within the final analysis at the gauging station therefore used the hydrograph shape and growth factors from ReFH (using the calibrated parameters) scaled to the QMED from the statistical method. The QMED from the statistical method was based on the annual maxima data from the new rating.

Both the statistical method and ReFH 1 were best practice methods recommended by the Environment Agency at the time of the analysis.

3.2 Approach to Methodology

Discussions with NRW (see Appendix) clarified that, as a general rule, NRW recommend estimating the peak flow using the FEH statistical method for flows up to and including the 1 in 100 year event, with a 'ratio' method used for higher return period events. The 'ratio' method involves scaling peak flow estimates from REFH to the 100 year statistical estimate. For example, the 1000yr peak flow = $Q100_{stat}$ * $Q1000_{REFH}$ / $Q100_{REFH}$.

Where: $Q100_{stat}$ is the peak flow calculated using the statistical method for the 100 year return period, $Q1000_{REFH}$ is the peak flow calculated using the ReFH methodology for the 1000 year return period and $Q100_{REFH}$ is the peak flow calculated using the ReFH methodology for the 100 year return period.

Since the Capital Symonds report there has been an update to the HiFlows dataset, used within the FEH statistical method. It is now managed by CEH and is called the Peak Flows dataset. The latest version of this is 3.3.4.

At the advice of NRW the statistical approach, using WINFAP 3, was used to generate the peak flows, which would then be used to rescale hydrographs from ReFH.

[1] Environment Agency, 2012. Flood estimation guideline, operational instruction 197_08.

Whilst the ReFH methodology has also been updated and has been incorporated within the ReFH 2 software this is not currently recommended for use by NRW. ReFH 1 was therefore used for the analysis.

For this assessment an alternative approach has been adopted to allow the incorporation of the local gauged data into the parameterisation of the ReFH 1 model. The ReFH 1 model was run with the design package estimates of design rainfall, model parameters and initial conditions to estimate QMED. The resultant model simulation was then subsequently calibrated to the gauged estimate of QMED by adjusting the value of the time to peak parameter, Tp.

4 Flood Estimates for Dyfi Bridge

4.1 Statistical Analysis at Dyfi Bridge

For the previous study, Capita Symonds used a revised rating, which was signed off by EA Wales, and hence annual maxima series for the station following additional analysis by EA Wales. The re-rating work utilised within the previous assessment had not been included within the update process of the Peak Flows dataset 3.3.4. Discussions with NRW (see Appendix) indicated that the re-rated annual maxima series is perceived to be an improvement over that held within the Peak Flows dataset 3.3.4 and therefore should be used for this assessment. These data were obtained from NRW for inclusion within the analysis.

The statistical approach was applied using the re-rated annual maxima series for 64001 to override the values for this station within the NRFA Peak Flows dataset 3.3.4.

Using these data the station was flagged as being suitable for pooling and QMED estimation. The revised annual series has 48 years of annual maxima. A summary of the QMED estimates derived using these data and the QMED estimation from the catchment descriptor equation are presented in Table 2. The observed QMED is almost 20% higher than the QMED estimated from catchment descriptors. The observed QMED is calculated as the median of the AMAX series. This will not be affected by the highest flows, for which there is some uncertainty due to the unknown influence of out of bank flow. It is probable that the catchment descriptor equation underestimates the QMED at this location.

Table 2 QMED values at gauging station 64001

	QMED (m^3/s)
Observed	332.2
Catchment descriptor	270.8

Figure 2 presents the fitted growth curves through the annual maxima dataset using the Generalised Logistic and Pearson III distributions. This indicates a negative L-Skewness value reflecting the fact that the growth curve is bounded i.e. the growth curve is such that as the return period increases the peak flows will not always increase.

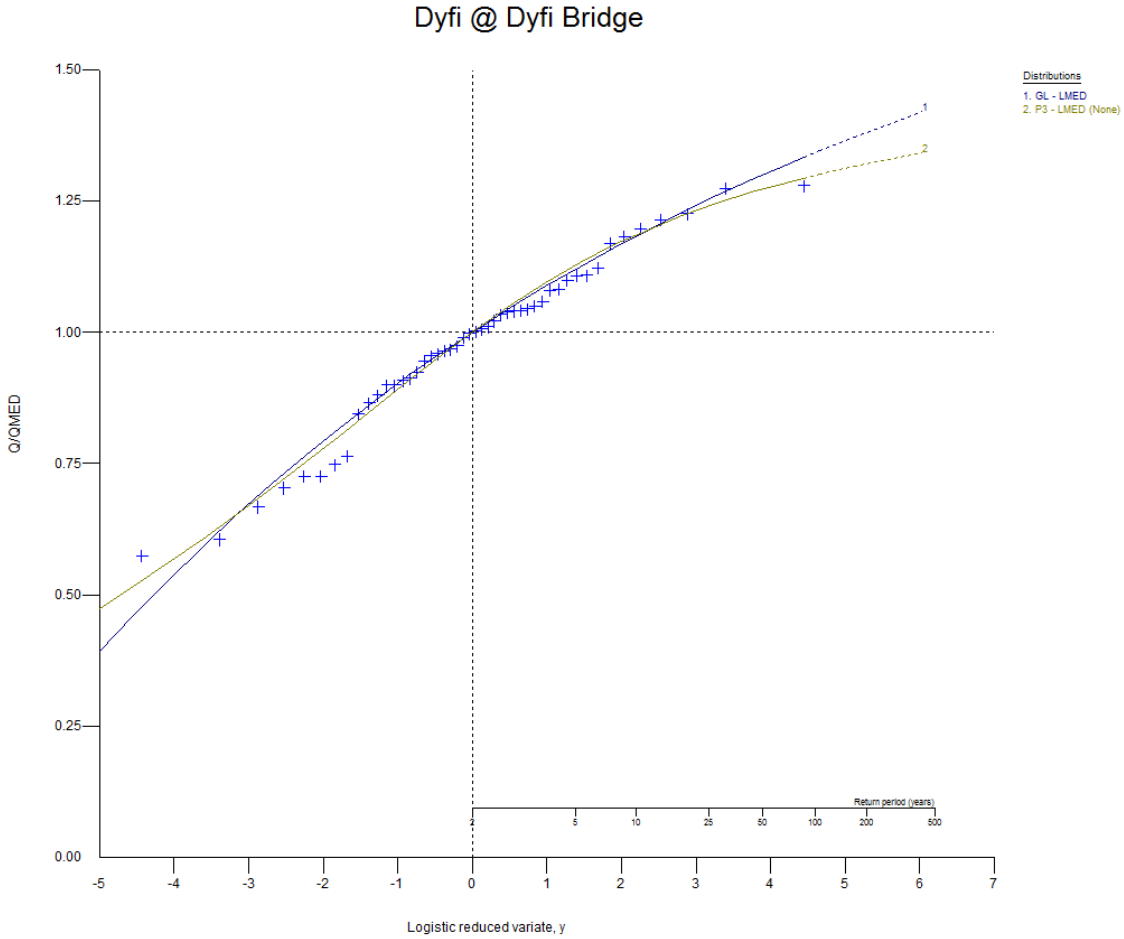

Figure 2. The flood frequency growth curve for the Dyfi at Dyfi Bridge with distributions fits for the Generalised Logistic and Pearson III distributions.

The station details from this gauge indicate that there is bypassing at the station, with the proportion not measured increasing with the overall flows rate. Within the Capita Symonds report it was noted that the new rating equations were an attempt to incorporate flood plain flow which had not been included previously to minimise the impact of this on the estimated peak flows. If there is bypassing then this would result in a reduction in the rate of change in the growth curve as events increase in size. This feature can still be viewed within the growth curve for the station, hence without further information it has been concluded that it is not appropriate to use the annual maxima data to produce the growth curve estimate for the catchment.

For these reasons the enhanced single site methodology was not used to derive the growth curve for the catchment, as is normally recommended for gauged sites.

A pooled data analysis was therefore completed to estimate the growth curve. Sites flagged as 'suitable for pooling' were utilised within the process. A total of 11 gauged catchments with 526 years of data were used within the pooling group. These are presented within Table 4.

The recommended distribution, based on the z value, is the Pearson III growth curve. In general this produces a less steep growth curve than that obtained using the Generalised Logistic distribution which is often utilised. The growth curve and peak flows are presented in Table 3.

Table 3 Growth curve for the Dyfi at Dyfi.

Return Period	Growth Curve	Peak Flow (m^3/s)
2	1.00	332.22
5	1.28	425.27
10	1.45	482.35
30	1.69	562.62
50	1.80	597.31
75	1.88	623.99
100	1.93	642.53
1000	2.36	782.60

The growth curve factor for the 1 in 100 year event is smaller than 2.1, which is quoted as 'typical' within the EA guidance. The AMAX series and the fitted growth curves for each station in the pooling group were assessed and considered to be acceptable in each case. Whilst the 1:100 growth factor is low it is within the range of outcomes that might be expected for a catchment of this type based on a comparison of gauged records within the NRFA Peak Flows dataset.

Table 4 Pooling group selection and reasons for retaining or removing from final pooling group.

Station	Distance SDM	AREA	SAAR	FARL	URBEXT 2000	Decision	Reasoning
79006 (Nith @ Drumlanrig)	0.426	468.87	1485	0.99	0.002	Retain	
56004 (Usk @ Llandetty)	0.497	545.59	1478	0.974	0.004	Retain	
77002 (Esk @ Canonbie)	0.498	495.37	1423	0.994	0.001	Retain	
27043 (Wharfe @ Addingham)	0.567	429.98	1385	0.975	0.004	Retain	
45002 (Exe @ Stoodleigh)	0.602	420.71	1361	0.979	0.002	Retain	
27034 (Ure @ Kilgram Bridge)	0.644	510.9	1338	0.99	0.004	Retain	
81002 (Cree @ Newton Stewart)	0.694	366.25	1757	0.932	0.002	Retain	
60002 (Cothi @ Felin Mynachdy)	0.697	298.73	1551	0.997	0.001	Retain	
3003 (Oykel @ Easter Turnaig)	0.728	331.64	1896	0.915	0	Retain	
21007 (Ettrick Water @ Lindean)	0.791	502.73	1306	0.928	0.002	Retain	
23006 (South Tyne @ Featherstone)	0.797	322.97	1331	0.995	0.002	Retain	
7001 (Findhorn @ Shenachie)	0.812	415.59	1217	0.982	0	Retain	

4.2 Derivation of Hydrographs

As recommended by NRW at present (November, 2015) the ReFH 1 methodology was used to produce the hydrographs for input to the hydraulic model.

The Capita Symonds work included calibration of the ReFH parameters. However, there was some concern as to the validity of the calibrated parameter set as the B_L value was high in relation to the ReFH calibration dataset. The calibrated B_L had a value of 210.67 hours whereas the highest calibrated value in the ReFH 1 calibration dataset for England and Wales is 109 hours. In calibration B_L is estimated subjectively from stream flow recession and has been estimated incorrectly in this case. This incorrect estimation invalidates the remainder of the calibration process.

For this assessment ReFH 1 was calibrated using the methodology described within Section 3.2. This involves calibration of the Tp parameter.

The parameters from the Capita Symonds calibration and calibration of Tp are presented in Table 5. Peak flow estimates for a selection of return periods are presented in Table 6. These indicate that the peak flow estimates obtained using the approach to calibration adopted for this assessment are higher than those from the Capita Symonds calibration. Both are higher than the statistical methodology.

Table 5. ReFH parameters

Parameter	Capita Symonds calibration	Tp calibration
CMAX	410.1	327
Tp	5.18	5.35
BL	210.67	42.2
BR	2.36	1.45

Table 6. ReFH peak flow estimates

Return Period	Capita Symonds calibration Peak Flow (m^3/s)	Tp calibration Peak Flow (m^3/s)
2	326.4	331.98
100	728.9	810.1
1000	1223.1	1434.5

4.3 Final Hydrographs

As described in Section 3.2 the hydrographs from the ReFH 1 methodology were rescaled by the statistical peak flows for events with a return period of 1 in 100 or less. For the 1 in 1000 year event

the ReFH 1 growth factor from the 1 in 1000 to 1 in 100 event was used to rescale the statistical 1 in 100 year event.

The final peak flows are presented in Table 7.

Table 7. Final peak flows at the Dyfi gauging station.

Return Period	**Peak Flow (m^3/s)**
2	332.2
5	425.3
10	482.3
30	562.63
50	597.33
75	624.0
100	642.5
1000	1137.0

5 Flood Estimates for the Tributaries

Flood hydrographs are required for input to the hydraulic model for each of the tributaries upstream. It is necessary that a water balance is closed across the hydraulic model. The sum of the input flow hydrographs for each of the sub catchments above the closing section of the hydraulic model must equal the flow hydrograph for the downstream section at the gauging station.

5.1 Methodology

The QMED values for each sub-catchment were calculated using the statistical method donor adjustment procedure. The donor catchment in each case was 64001, the Dyfi at Dyfi. The gauging station was not the closest in terms of catchment centroid distance for the Afon Dulas (south) but as the 64001 gauging station is downstream it was still used in preference as the donor station.

The flood frequency curve from the closing section was attributed to each of the three sub-catchments by rescaling it by the ratio of a QMED estimate for the sub-catchment concerned to the sum of the QMED estimates for the three tributaries such that the sum of the QMED values equalled the QMED value at the gauging station.

This approach ensures that the sum of the flood frequency curves equates to the flood frequency curve for the closing section, thus ensuring mass is conserved. The alternative approach would have been to estimate flood frequency curves for each of the tributaries and sum these to give an estimate of the flood frequency curve for the closing section. As the purpose of the study is to assess the flood risk issues associated with the bridge development on the closing section the first approach is preferable as this direct estimate is the best estimation of the flood frequency curve for this location.

The hydrographs were also developed such that the peak flows for a given return period sum to give the corresponding estimate of peak flow for the closing section. ReFH 1 was calibrated by adjusting the Tp parameter as described within Section 3.2. To develop the final hydrograph the timestep and

event duration (1 hour and 15 hours respectively) from the application of ReFH 1 to the closing section were retained for the individual subcatchments.

The hydrographs were estimated using the same rescaling approach as adopted for the combined catchment to the closing section.

The peak flow estimates are presented in Table 8.

Table 8. Peak Flows estimates for tributaries

Return Period	Dulas (Northern Tributary)	Afon Dyfi (Eastern Tributary)	Afon Dulas (South)
2	63.6	228.5	40.1
5	81.4	292.4	51.4
10	92.4	331.7	58.3
30	107.8	386.9	68.0
50	114.4	410.7	72.2
75	119.5	429.1	75.4
100	123.1	441.8	77.6
1000	217.8	781.8	137.4

5.2 Independent flood estimate for the Dulas (Northern Tributary)

One property within the network is perceived to be vulnerable to flooding. This is located close to the Dulas (North) road bridge in the vicinity of Pont Felin y Ffridd. An independent hydrological assessment will therefore be completed on this tributary at the request of NRW.

The peak flows and hydrographs were generated independently for the Dulas (Northern Tributary). The location of the property at risk (SH7519302434) indicates that it is appropriate to use the contributing catchment area previously used for this catchment.

5.2.1 Statistical Methodology

5.2.1.1 QMED estimation.

The QMED was that estimated using catchment descriptors and donor transfer (64001) without the adjustment step to ensure that QMED estimates sum to the estimate for the closing section. The QMED flow estimates with and without donor transfer are presented in Table 9.

Table 9. QMED Peak Flows Estimates

	QMED (m^3/s)
Catchment descriptor	59.9
Donor transfer	65.0

5.2.1.2 Growth Curve Estimate

The growth curve estimate was the unadjusted growth curve estimated for this catchment using the pooled data analysis reported in the previous section. Sites flagged as 'suitable for pooling' were utilised within the process. A total of 14 gauged catchments with 521 years of data were used within the pooling group. These are presented within Table 10.

Table 10. Pooling group selection and reasons for retaining or removing from final pooling group.

Station	Distance SDM	AREA	SAAR	FARL	URBEXT 2000	Decision	Reasoning
58006 (Mellte @ Pontneddfechan)	0.258	65.35	1981	0.975	0	Accept	
55004 (Irfon @ Abernant)	0.393	73.06	1845	1	0.003	Accept	
58012 (Afan @ Marcroft Weir)	0.503	89.42	2038	1	0.02	Accept	
74001 (Duddon @ Duddon Hall)	0.516	86.01	2261	0.985	0	Accept	
46007 (West Dart @ Dunnabridge)	0.539	47.49	1987	1	0.003	Accept	
90003 (Nevis @ Claggan)	0.575	69.21	2913	0.998	0.001	Accept	
16003 (Ruchill Water @ Cultybraggan)	0.686	98.48	1900	1	0	Accept	
47014 (Walkham @ Horrabridge)	0.728	44.31	1664	1	0.008	Accept	
73011 (Mint @ Mint Bridge)	0.752	65.59	1599	0.993	0.001	Accept	
84020 (Glazert Water @ Milton of Campsie)	0.787	51.9	1561	0.991	0.01	Accept	
21017 (Ettrick Water @ Brockhoperig)	0.831	38.59	1740	1	0	Accept	
96004 (Strathmore @ Allnabad)	0.858	105.31	2456	0.938	0	Accept	
78004 (Kinnel Water @ Redhall)	0.915	76.17	1466	0.999	0	Accept	
21019 (Manor Water @ Cademuir)	0.945	59.98	1344	0.997	0	Accept	
85003 (Falloch @ Glen Falloch)	0.599	79.62	2848	0.988	0	Remove	Bounded distribution
76014 (Eden @ Kirkby Stephen)	0.745	66.84	1492	1	0.005	Remove	Bounded distribution

Station	Distance SDM	AREA	SAAR	FARL	URBEXT 2000	Decision	Reasoning
73017 (Kent @ Bowston)	0.605	70.61	1919	0.948	0.002	Remove	Relatively short record, 13 years only. Analysis of AMAX data indicates it is not a good fit to the distribution. Also, high discordancy.
21030 (Megget Water @ Henderland)	0.569	55.97	1670	1	0	Remove	Relatively short record, 13 years only. Analysis of AMAX data indicates it is not a good fit to the distribution.
89004 (Strae @ Glen Strae)	0.906	37.38	2766	0.995	0	Remove	Bounded distribution

The recommended distribution, based on the z value, was the Generalised Extreme Value distribution. The growth curve and final peak flows are presented in Table 11. The peak flows are between 2 and 7% higher than used for the catchment wide hydraulic model.

Table 11.The flood growth curve and statistical peak flows for the Dulas North (independent estimate)

Return Period	Growth Curve	Peak Flows (m^3/s)
2	1	65.0
5	1.28	83.4
10	1.47	95.4
30	1.74	113.3
50	1.87	121.5
75	1.97	127.8
100	20.4	132.3
1000	2.57	167.2

5.2.2 Final Peak Flows Estimates

The ReFH model utilised within the original assessment, which was calibrated to the QMED as described in the previous section was used to produce hydrographs. The hydrographs were rescaled using the same approach as described within Section 3.2. The final peak flows are presented in Table 12.

Table 12. Final Peak Flows for the Dulas North Tributary

Return Period	Peak Flows (m^3/s)
2	65
5	83.4
10	95.4
30	113.3
50	121.5
75	127.8
100	132.3
1000	243.6

6 Appendix

Relevant Communication with NRW

There were a number of phone conversation and emails between WHS and Rob Bissel and Emyr Gareth from NRW. The below are a selection of the most relevant.

Email 12th November 2015. Relevant to the independent modelling of the Northern Tributary.

Hi all,

Apologies for my lateness in responding.

With regard to Rob's query, as mentioned previously, flooding of property is a potential issue on the Dulas north (in the vicinity of Pont Felin y Ffridd – approx. SH7519302434), although the exact source of flooding is not well understood. It would therefore be useful if the model could explore the potential for the new bridge to impact flood levels here. I presume that to do this, it would be necessary to model this tributary separately from the main Dyfi?

Regards,

Emyr

Emyr Gareth

Arbenigwr Technegol Datblygiad a Risg Llifogydd / Development and Flood Risk Technical Specialist
Cyfoeth Naturiol Cymru / Natural Resources Wales
Llwyn Brain
Parc Menai
Bangor
Gwynedd
LL57 4DE

Emails between Tracey Haxton and Rob Bissell on the general modelling approach.

Email 30th October 2015.

Hi Tracey,

Thanks for your email. I can confirm that the approach you've described is as we've discussed and agreed. But I should point out that we don't formally agree detailed methodologies/approaches with consultants simply because it's not until you undertake the analysis that it becomes clear which approach is most appropriate. Happy to offer advice though!

Just one thing re: the modelling of the smaller tributaries – I was under the impression that Emyr Gareth (Development & Flood Risk Engineer, NRW) wanted to see the flood risk from those separately (as well as in-combination) from the main river flows. Emyr – can you confirm if this is the case?

Hope this helps,

Rob

Rob Bissell
Hydroleg a Rheoli Adnoddau Dwr / Hydrology & Water Resources Management
Cyfoeth Naturiol Cymru / Natural Resources Wales
Ffôn / Phone: 03000 653902
Ffôn symudol / Mobile: 07468 742442
Gwefan / Website: www.cyfoethnaturiolcymru.gov.uk / www.naturalresourceswales.gov.uk

From: Tracey Haxton [mailto:tracey.haxton@hydrosolutions.co.uk]
Sent: 26 October 2015 16:14
To: Bissell, Robert <Robert.Bissell@cyfoethnaturiolcymru.gov.uk>
Cc: Paul Blackman <paul.blackman@hydrosolutions.co.uk>
Subject: Dyfi 487 WHS hydrology

Rob,

Many thanks for your guidance on our approach to the Hydrology for the Dyfi A487 scheme.

Further to our telephone conversation following your email from the 29th September, we have now completed the updated hydrology for the model along the lines discussed as summarised below:

We have used the NRW preferred approach to peak flow estimation in Wales which is to use the FEH statistical method for flows up to and including the 1 in 100 year event, with a 'ratio' method used for higher return period events. The 'ratio' method involves scaling peak flow estimates from REFH to the 100 year statistical estimate. For example, to estimate the 1000yr peak flow = Q100stat * Q1000REFH / Q100REFH.

This follows your email where you suggested the use of the statistical method at the site. The previous report had concerns about the statistical method due to the shallow growth curves when using the Dyfi gauging station. We agreed that it was not appropriate to use this gauging station as part of the methodology for estimating the growth curves due to concerns about the quality of the data which might have resulted in a shallow growth curve (in fact it has a bounded distribution). We did however agree that the re-rated data should be used for the estimation of the QMED. Within the original report the statistical method was not used due to concerns about the shallowness of the growth curve - the pooled growth curve is less shallow than the enhanced single site analysis growth curve, but is still lower than the 'norm' as quoted by the EA. However, as long as satisfactory analysis of the pooling group has been undertaken, a shallow growth curve is not reason enough in itself to say that this is not legitimate.

In combination with this is the uncertainty associated with the ReFH 1 calibration parameters, where the BL parameter is twice that within any station in the dataset used as part of the ReFH 1 development. This raises concerns with using these parameters and possibly negates the perceived improvement in using the ReFH method with local data, over the statistical method. The peak flow ratio of the 1 in 1000 to 1 in 100 is still used to estimate the 1 in 1000 event.

For both these reasons it is considered to be best practice to use the preferred approach recommended by NRW.

In terms of producing the hydrographs, these were produced using ReFH 1, calibrated at Q2 to the QMED through adjustment of the Tp value. Once rescaled to the QMED value, or other peak flows there is little difference between these hydrographs and those produced using the locally calibrated ReFH parameters.

For the tributaries upstream, the QMED values are estimated using the donor station approach from the Dyfi Gauge. ReFH 1 was then calibrated to these QMED values, using the same duration event. The hydrographs produced were then rescaled proportionally such that the addition of each of the individual hydrographs would result in the peak as calculated at the gauging station - the incremental area which is not accounted for by the tributaries is small in comparison with the total area considered.

I will write up the hydrology section of the modelling report on the above basis.

If you could confirm the above I would appreciate it,

Regards,

Tracey
--

Tracey Haxton
Senior Consultant

Please note I work part time, Monday, Tuesday, Thursday and Friday.

Wallingford Hydrosolutions Ltd
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Direct Tel : +44 1491 692452
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Email : tracey.haxton@hydrosolutions.co.uk

www.hydrosolutions.co.uk

From: Bissell, Robert [mailto:Robert.Bissell@cyfoethnaturiolcymru.gov.uk]
Sent: 24 September 2015 16:51
To: Tracey Haxton <tracey.haxton@hydrosolutions.co.uk>
Subject: RE: Afon Dyfi Hydrology

No worries.

Yes I'd prefer the re-rated data be used please – I've also found emails from a number of internal colleagues who reviewed the Cap Symonds rating work and OK'd the upper limb of the rating for implementation. I've now asked our National Hydrometry team to implement this upper limb in our hydrometric archive, so it should find its way in to the NRFA dataset at the next update.

I think given our reservations about the Cap Symonds REFH optimisation process, it would be worth trying different selection points to see what effect that has on the parameters before reverting to use of catchment descriptors, which should always be a last resort.

Thanks,
Rob

From: Bissell, Robert [mailto:Robert.Bissell@cyfoethnaturiolcymru.gov.uk]
Sent: 23 September 2015 11:37
To: Haxton, Tracey H. <tracey.haxton@hydrosolutions.co.uk>
Cc: Gareth, Emyr <Emyr.Gareth@cyfoethnaturiolcymru.gov.uk>
Subject: Afon Dyfi Hydrology

Hi Tracey,

Sorry I missed you yesterday. It's probably easier to put my thoughts in an email and discuss later, if necessary, once you've had time to read through it.

Generally speaking, our preferred approach to peak flow estimation in Wales is to use the FEH statistical method for flows up to and including the 1 in 100 year event, with a 'ratio' method used for higher return period events. The 'ratio' method involves scaling peak flow estimates from REFH to the 100 year statistical estimate. For example, to estimate the 1000yr peak flow = $Q100_{stat}$ * $Q1000_{REFH}$ / $Q100_{REFH}$.

However, we acknowledge there will be times when the statistical method isn't appropriate. It's often difficult to give advice to consultants regarding what a preferred approach might be on a case-by-case basis, as it's not until you start your analysis that it becomes clear what the issues & limitations are. As such, our advice is usually to adhere to the flood estimation guidelines and provide justification for the decisions and choices made throughout the analysis.

In this instance, the Capita Symonds report already exists and you've indicated you want to follow a similar approach for the assessment points on the main river – using REFH growth curves scaled to QMED from gauged data. Having looked through the Capita Symonds report I think the approach make sense (including optimisation of REFH parameters where possible), given the shallow statistical growth curve and uncertainties associated with significant floodplain storage. There are however some aspects of the Capita Symonds report that I think are lacking and require further explanation, which I'd expect to be considered if you were to follow the same approach:

QMED. You mentioned you couldn't replicate Capita Symonds estimate of QMED. Could this be due to the re-rating work they did, which was then applied to the AMAX time-series?

The Dyfi Bridge flood growth curve is very shallow compared to other stations within the pooling group, but there's little suggestion as to why this might be e.g significant floodplain storage. It's

also not clear whether the inclusion of Dyfi bridge in the pooling group utilised updated .cd3 files with the re-rated flow data. Would this result in a steeper growth curve?

You indicated REFH would be used without parameter optimisation for (*I think*) BL, BR and Cmax . The optimised values for BR and Cmax don't look abnormal in the context of optimised values from other gauging stations, but I agree the high BL value is something worth investigating. Capita Symonds used the optimised BL in their calculations. Could the high value be a result of a poor optimisation exercise? For example, there's no info as to how a catchment average rainfall input was derived from the 3 sets of raingauge data, nor any comment about how this would be subject to a lot of uncertainty due to the size of the catchment and high variability in rainfall across it. Their plots showing the optimisation process also appear to have the "start point" of the baseflow recession too high up the recession limb of the hydrograph – could that be a reason for the high BL value?

Capita Symonds used different storm durations for the main river assessment points than those on the tributaries. Strictly speaking, a single critical storm duration should be used, although I appreciate that for the smaller tribs using a longer storm duration could result in unrealistic overall volumes of water. Emyr Gareth (Flood Risk Analysis) has also indicated that there is flood risk to a property from the upstream Dulas tribs alone, so applying separate storm durations may be better in assessing the flood risk in that sense. If you adopt this approach all I'd ask is you mention its limitations.

I hope this helps, feel free to give me a call to discuss further.

Thanks,

Rob

Rob Bissell

Hydroleg a Rheoli Adnoddau Dwr / Hydrology & Water Resources Management

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Ffôn / Phone: 03000 653902

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Appendix F

Baseline Model Outputs

Project :

A487 New Dyfi Bridge

Client :

GRIFFITHS civil engineering and construction

ARUP

Legend :

Maximum Flood Depth (m)

- 0.00-0.50
- 0.50-1.00
- 1.00-1.50
- 1.50-2.00
- >2.00

Scale :

0 200 400 m

Title :

Maximum Flood Depth (m)
Baseline Scenario
1 in 2 year Flood Event

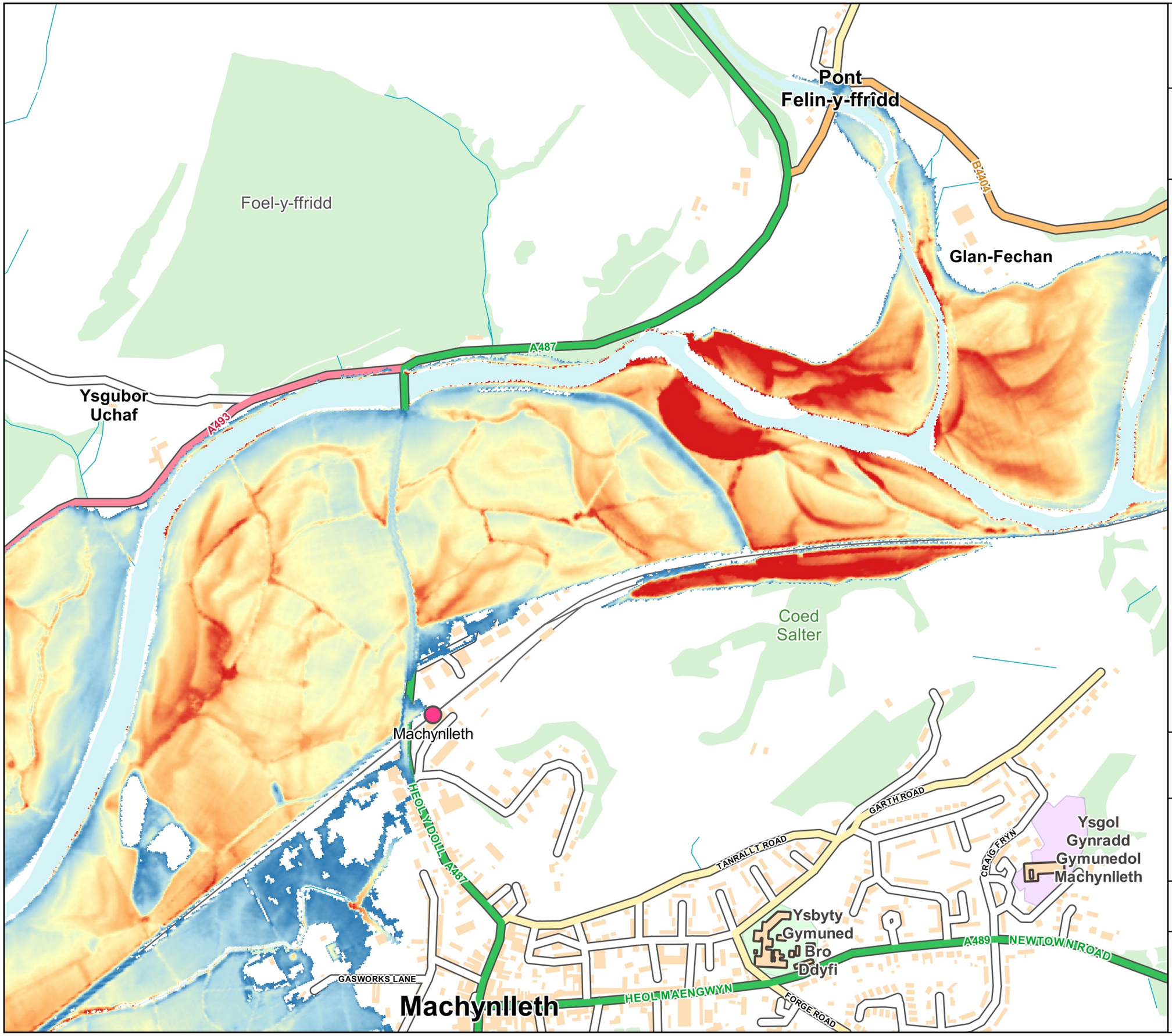
Drawing :

WHS1345-F10-0011

Rev :

1

WHS



Project :

A487 New Dyfi Bridge

Client :

GRIFFITHS civil engineering and construction

ARUP

Legend :

Maximum Flood Depth (m)

- 0.00-0.50
- 0.50-1.00
- 1.00-1.50
- 1.50-2.00
- >2.00

Scale :

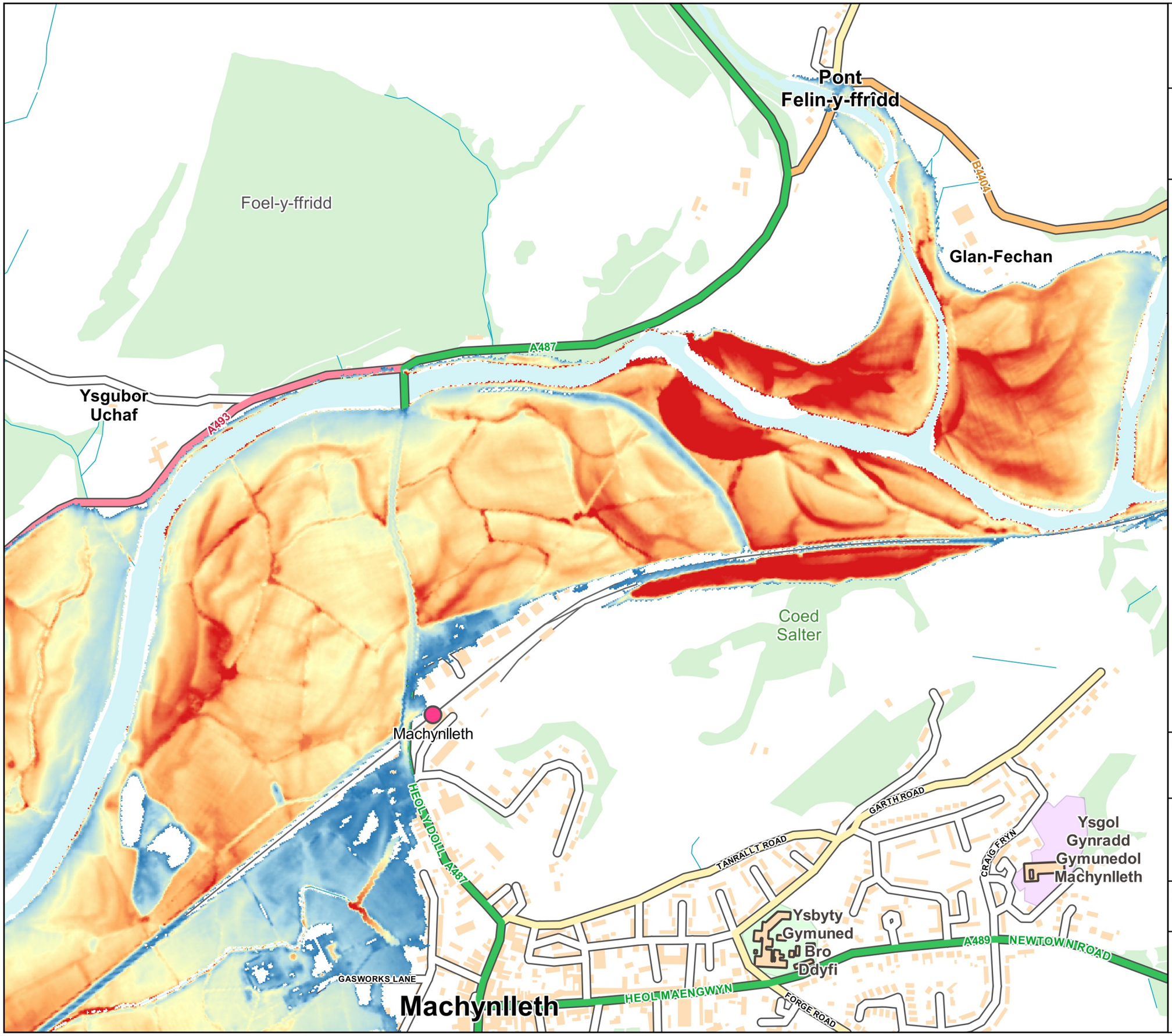
0 200 400 m

Title :

Maximum Flood Depth (m)
Baseline Scenario
1 in 100 year Flood Event

Drawing :	Rev :
WHS1345-F10-0012	1

WHS



Project :

A487 New Dyfi Bridge

Client :

GRIFFITHS civil engineering and construction

ARUP

Legend :

Maximum Flood Depth (m)

- 0.00-0.50
- 0.50-1.00
- 1.00-1.50
- 1.50-2.00
- >2.00

Scale :

0 200 400 m

Title :

Maximum Flood Depth (m)
Baseline Scenario
1 in 100 year + climate change Flood Event

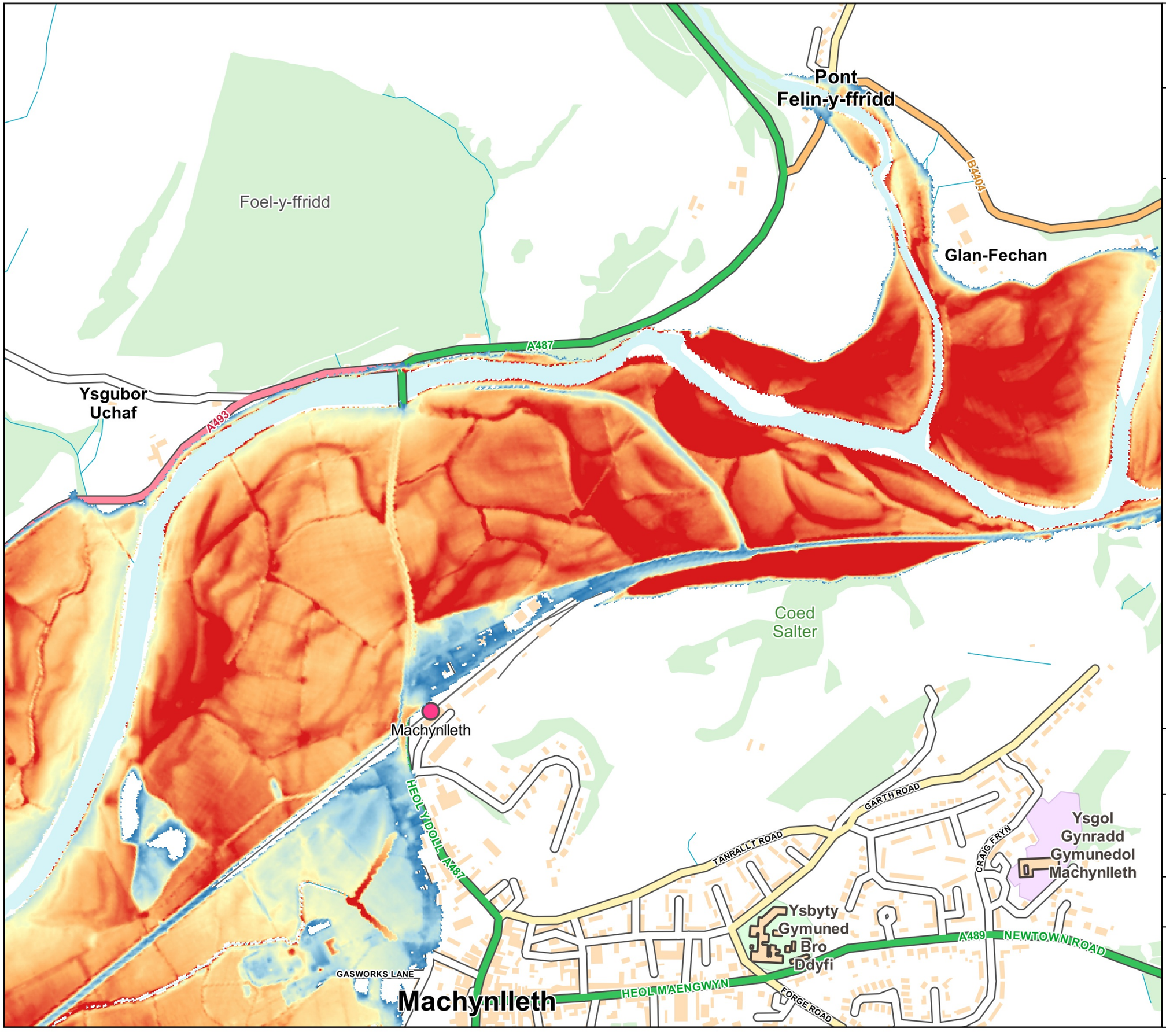
Drawing :

WHS1345-F10-0013

Rev :

1

WHS



Project :

A487 New Dyfi Bridge

Client :

GRIFFITHS civil engineering and construction

ARUP

Legend :

Maximum Flood Depth (m)

- 0.00-0.50
- 0.50-1.00
- 1.00-1.50
- 1.50-2.00
- >2.00

Scale :

0 200 400 m

Title :

Maximum Flood Depth (m)
Baseline Scenario
1 in 1000 year Flood Event

Drawing :

WHS1345-F10-0014

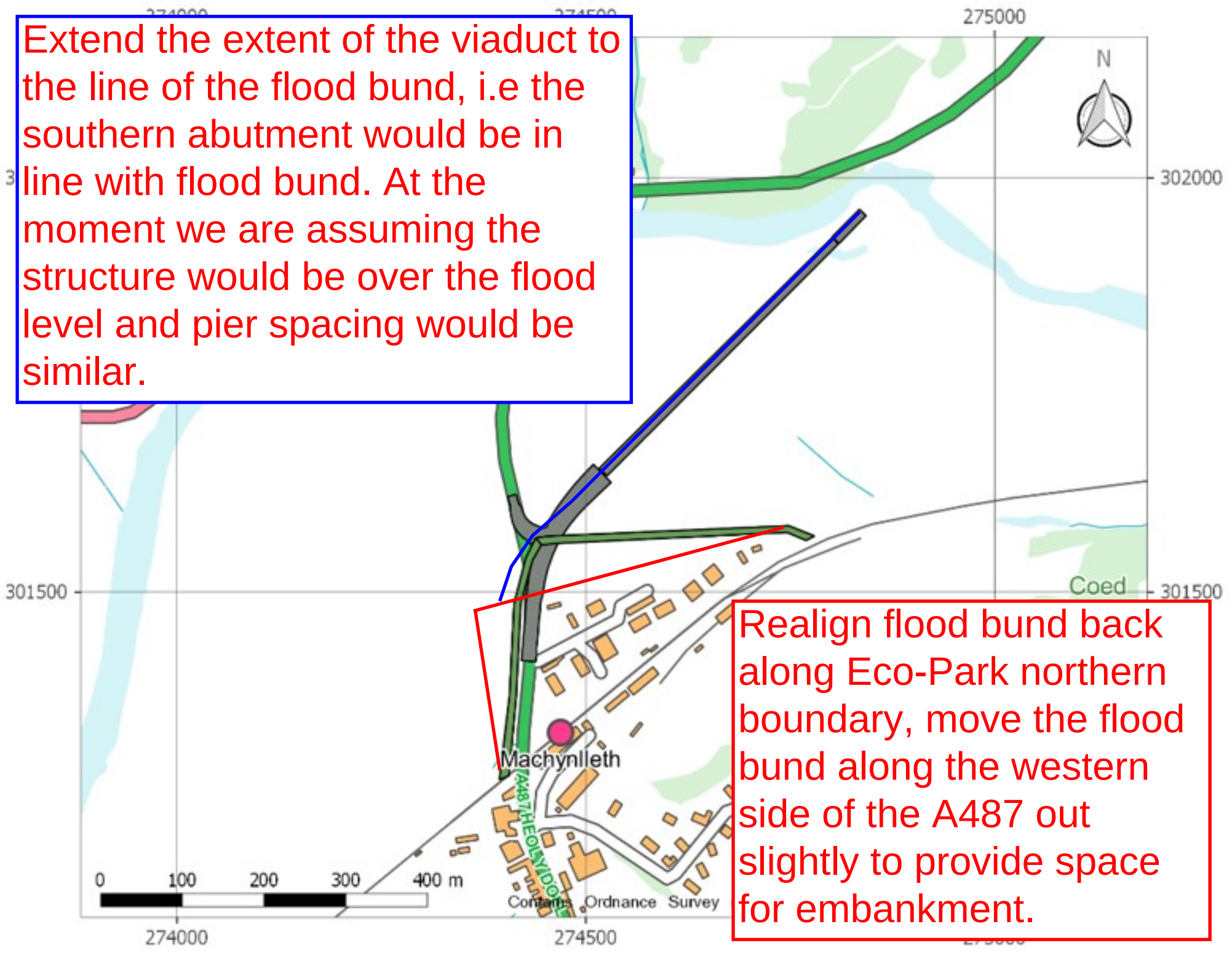
Rev :

1

WHS

Appendix G

Initial Proposed Scheme


Extend the extent of the viaduct to the line of the flood bund, i.e the southern abutment would be in line with flood bund. At the moment we are assuming the structure would be over the flood level and pier spacing would be similar.
Realign flood bund back along Eco-Park northern boundary, move the flood bund along the western side of the A487 out slightly to provide space for embankment.
275000
302000
301500
N
Coed
Machynlleth
A487 HEOL Y DOC
0
100
200
300
400 m
Contains Ordnance Survey
274000
274500

Appendix H

A487 New Dyfi Bridge Flood Options Report

Llywodraeth Cymru / Welsh Government

A487 New Dyfi Bridge

Scheme Layout Flood Options Report

900237-ARP-ZZ-XX-RP-CX-00005

P02.3 | 8 March 2017

This report takes into account the particular instructions and requirements of our client.

It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

Job number 244562

Ove Arup & Partners Ltd
The Arup Campus
Blythe Gate
Blythe Valley Park
Solihull B90 8AE
United Kingdom
www.arup.com

Document Verification

ARUP

Job title		A487 New Dyfi Bridge			**Job number** 244562
Document title		Scheme Layout Flood Options Report			**File reference**
Document ref		900237-ARP-ZZ-XX-RP-CX-00005			
Revision	**Date**	**Filename**	900237-ARP-ZZ-XX-RP-CX-00005.docx		
P01	30 May 2016	**Description**	First issue for comment		
			Prepared by	Checked by	Approved by
		Name	James Reeder	Steve Henry	Chris Furneaux
		Signature			
P01.2	23 Oct 2016	**Filename**	900237-ARP-ZZ-XX-RP-CX-00005.docx		
		Description	Updated for EA comments		
			Prepared by	Checked by	Approved by
		Name	Chris Furneaux	Steve Henry	Chris Furneaux
		Signature			
P02.1	15 Jan 2017	**Filename**	900237-ARP-ZZ-XX-RP-CX-00005.docx		
		Description	Issue - updated to clarify 20% climate change allowance.		
			Prepared by	Checked by	Approved by
		Name	Chris Furneaux	Steve Henry	Chris Furneaux
		Signature			
P02.2	8 Mar 2017	**Filename**	900237-ARP-ZZ-XX-RP-CX-00005.docx		
		Description	Updated for EA Comments		
			Prepared by	Checked by	Approved by
		Name	Chris Furneaux	Steve Henry	Chris Furneaux
		Signature			
				Issue Document Verification with Document	✓

Document Verification

Job title		A487 New Dyfi Bridge			**Job number** 244562
Document title		Scheme Layout Flood Options Report			**File reference**
Document ref		900237-ARP-ZZ-XX-RP-CX-00005			
Revision	**Date**	**Filename**	900237-ARP-ZZ-XX-RP-CX-00005.docx		
P02.3	8 Mar 2017	**Description**	Flood Map Key added to Section 3.4		
			Prepared by	Checked by	Approved by
		Name	Chris Furneaux	Steve Henry	Chris Furneaux
		Signature			
		Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Signature			
		Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Signature			
		Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Signature			
				Issue Document Verification with Document	✓

Contents

Appendices

Appendix A

Flood Options Matrix

Executive Summary

The conceptual design for the A487 New Dyfi Bridge scheme proposed building a 550m long straight section of viaduct with 170m of curved embankment (on the south side). Initial flood modelling of the conceptual scheme highlighted the following key benefits/impacts on flooding:

- Protection from overland river flooding of the existing railway bridge and properties to the south of the railway bridge in the 100yr+20% Climate Change (CC) event.
- Protection of the Eco Park and existing A487 (south of the scheme) from flooding in the 100yr+20%CC.
- Increase in flood levels of approximately 600m on agricultural land immediately to the north of the Eco Park in the 100yr+20%CC event.
- Increase in flood levels of approximately 200mm immediately upstream of Pont-ar-Ddyfi in the 100yr+20%CC event.
- Early onset of flooding and increase in levels, of up to 250mm, for residential properties adjacent to Pont-ar-Ddyfi in the 100yr+20%CC event.

This report considers the flood issues in more detail and compares the conceptual design with other options which have been assessed to have less flood impacts on the existing Pont-ar-Ddyfi, residential properties and agricultural land.

The more detailed analysis of the flooding impacts concluded:

- There are no noticeable impacts on the onset of flooding of the agricultural land or the period the land is flooded. The impact on agricultural business is therefore considered to be minimal, however the smaller the increase in flood levels the simpler it will be to explain and justify to landowners.
- The impact of flood level increases on the existing Pont-ar-Ddyfi has been assessed not to have a significant impact. However, scheme layout options which minimise the increase in upstream flood levels, and do not change the velocity of water through the structure, will best serve to maintain the integrity of the bridge by not reducing the factor of safety or increasing the scour risk.
- Flood impacts on the residential properties that increase flood levels and the onset of flooding is unacceptable (not TAN15 compliant) unless mitigated. The form of the mitigation will vary depending on the increase in flood level, but would range from threshold works for smaller increases to flood barriers/walls for the greater increases.

A range of options for the overall scheme layout, and flood mitigation, have been considered against the key objectives for transport associated around Economy, Environment and Social Impacts, and the scheme Transport Planning Objectives

(TPOs). An initial sift of the options identified two options for further consideration; Option 1 the conceptual design with significant flood mitigation works, or Option 2 an extended viaduct option with minimal flood mitigation threshold works.

In summary, the extended viaduct solution on balance has been assessed to be the best and most suitable option. The extended viaduct, despite the increased construction costs, greatly reduces the impact of flooding, and need for mitigation for the residential properties and existing Pont-ar-Ddyfi. It also reduces the increase in flood levels on the agricultural land, reduces severance, slightly improves the highway alignment and removes the need for any in river works. The key flooding benefits/impacts of this option are:

- Protection from overland river flooding of the existing railway bridge and properties to the south of the railway bridge in the 100yr+20%CC event.
- Protection of the Eco Park and existing A487 (south of the scheme) from flooding in the 100yr+20%CC.
- Increase in flood levels of approximately 140m on agricultural land immediately to the north of the Eco Park (no mitigation proposed/required) in the 100yr+20%CC event.
- Increase in flood levels of approximately 50mm immediately upstream of Pont-ar-Ddyfi (no mitigation proposed/required) in the 100yr+20%CC event.
- Early onset of flooding and increase in levels, of up to 50mm, for residential properties adjacent to Pont-ar-Ddyfi in the 100yr+20%CC event. (Localised works or threshold works to remove any impact).

1 Introduction

1.1 Purpose of this Report

The purpose of this report is to review the options for the layout of the scheme in relation to impacts on flood levels and frequency. The current proposal of building a 550m long straight section of viaduct with 170m of curved embankment (on the south side) will be compared to other options which have been assessed to have less flood impacts on the existing Pont-ar-Ddyfi, residential properties and agricultural land. The benefits and disadvantages of the options will be considered in this report and a recommendation made of what should form the basis of the design going forward.

Unless stated otherwise the flood levels stated in this report relate to the 100yr+20% Climate Change (CC) flood event.

1.2 Project Objectives

The current proposal and alternative layout options have been assessed against the Government's criteria as set out in WelTAG (Welsh Transport Appraisal Guidance). This approach considers the key objectives for transport associated around Economy, Environment and Social Impacts.

The following Transport Planning Objectives (TPOs) for the scheme were developed during the WelTAG Planning Stage and reported in the WelTAG Planning Stage Report (April 2012). The key objectives related to these layout options are highlighted in bold.

TP01	To improve reliability of crossing the Afon Dyfi for people, freight and emergency vehicles on the A487 strategic corridor.
TP02	To improve efficient and reliable accessibility to key services including employment opportunities, healthcare and education.
TP03	To maintain the role of Machynlleth as a vibrant and sustainable local centre.
TP04	**To preserve the long-term integrity of the Dyfi Bridge**
TP05	To reduce the number of severity of collisions and causalities on the A487 in the study area.
TP06	**To ensure that flood risk to third parties is not increased.**
TP07	**To minimise the impact of transport improvements on the landscape, biodiversity, water resources and heritage.**
TP08	To increase the opportunity for efficient, safe and reliable travel by walking and cycling on the A487 corridor within the study area.

1.3 Background

1.3.1 Description of Area

The existing A487 runs from the centre of Machynlleth passing under the Cambrian Coast Railway line, and then across floodplains to Pont-ar-Ddyfi in the north as shown on Figure 1.1. North of the railway line there is an Eco Park (Business Park) with an access road tying-in to the eastern side of the A487.

The floodplains on either side of the road, between the Eco Park and Pont-ar-Ddyfi, are agricultural land. Immediately north of Pont-ar-Ddyfi are several residential properties. The key properties considered in relation to flooding are the two properties located upstream of the existing bridge between the river and existing A487, and the six terrace properties located on the north side of the A493 downstream of the existing bridge.

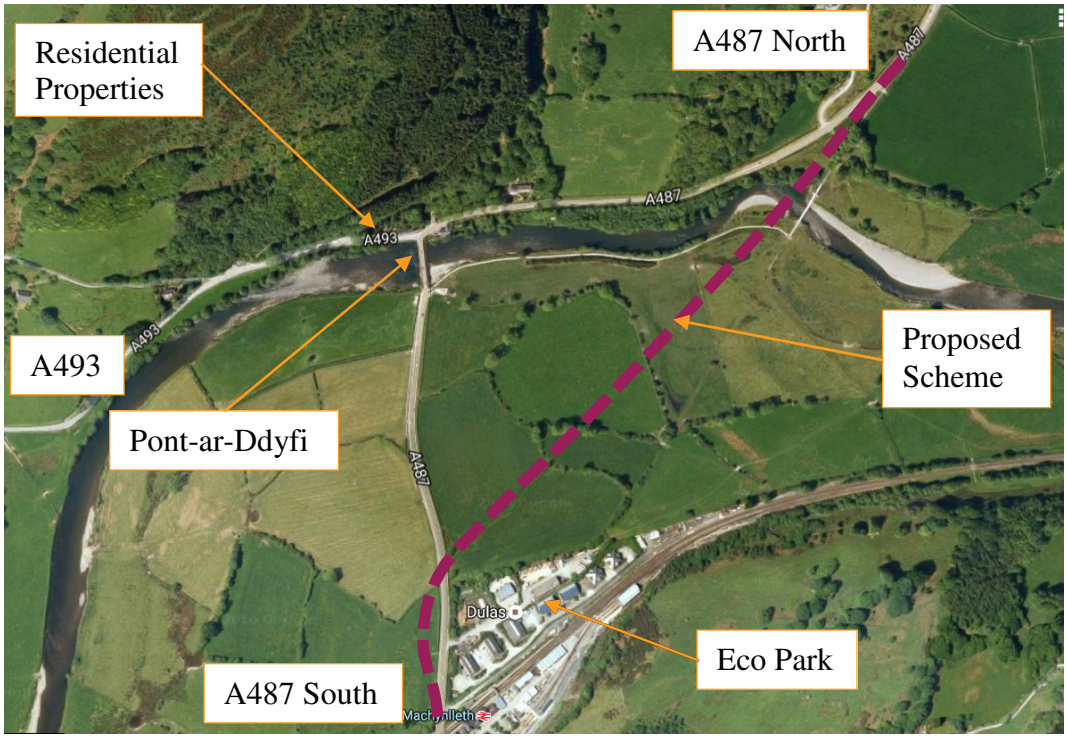


Figure 1.1: Location Plan

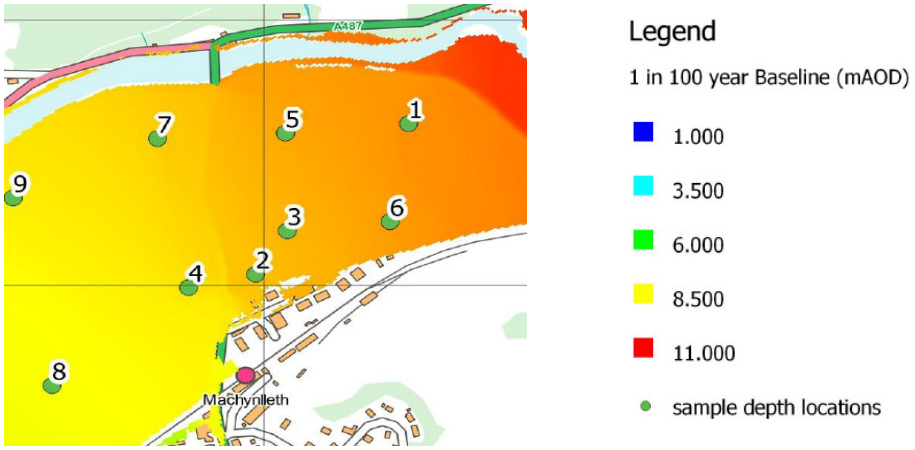
1.3.2 Existing Flooding Conditions

The extent of the 1 in 100 year plus climate change allowance (100yr+20%CC) is shown on Figure 1.2 below. Key aspects to the existing flood situation are:

- The existing A487 between the Eco Park and Pont-ar-Ddyfi is flooded in the 100yr+20%CC event (the model shows this to be the case in the 1 in 2 year flood event).
- Agricultural land is protected in the early part of flood event by an existing informal upstream curved flood bund.

- Residential properties adjacent to Pont-ar-Ddyfi are situated within the extent of the 100yr+20%CC event.
- River floodwater encroaches under the existing A487 railway bridge to flood residential and commercial properties to the south of the railway line.
- Northern parts of the Eco Park are situated within the extent of the 100yr+20%CC event.

Figure 1.2: Baseline 1 in 100 yr plus 20% climate change flood map.



1.3.3 Conceptual Scheme Proposal

The intention in the conceptual design, and as presented at the Public Information Exhibition (October 2015), is a new structure to cross the River Dyfi approximately 480m upstream of the existing bridge. The proposed scheme would commence from the northern boundary of the Eco Park on a 170m long embankment. The scheme would then move onto a multi-span viaduct across the floodplain, before two larger structural spans adjacent to and over the Afon Dyfi. The combined length of viaduct and bridge structure would be approximately 550m. The scheme finishes at a junction on the A487 to the north of the river.

Although not presented at the Public Information Exhibition the intention in the conceptual design was also to provide a flood bund along the northern and western sides of the Eco Park, connecting with the railway embankment. This would serve to protect the properties and existing A487 from flooding.

Initial flood modelling of the conceptual scheme highlighted the following key benefits/impacts on flooding:

- Protection from overland river flooding of the existing railway bridge and properties to the south of the railway bridge in the 100yr+20%CC event.
- Protection of the Eco Park and existing A487 (south of the scheme) from flooding in the 100yr+20%CC.
- Increase in flood levels of approximately 600m on agricultural land immediately to the north of the Eco Park.

- Increase in flood levels of approximately 200mm immediately upstream of Pont-ar-Ddyfi.
- Early onset of flooding and increase in levels, of up to 250mm, for residential properties adjacent to Pont-ar-Ddyfi.

2 Conceptual Design Key Flood Impacts

Based on the results of the flood modelling of the conceptual design, further consideration of the impact of the changes in flood patterns has been undertaken to inform the overall options considered, and is presented in the following sections.

2.1 Agricultural Land

As outlined in Section 1.3.2 an existing informal curved flood bund is located upstream of Pont-ar-Ddyfi. This means the onset of flooding of the agricultural land is currently related to the overtopping of this bund. This has been demonstrated in the flood model, and validated by observations on site, to occur from the north (immediately upstream of Pont-ar-Ddyfi) and via flow through a field access gate (which is a low point in the bund).

The construction of the proposed scheme is predominantly within the area enclosed by this bund, only the final two piers before the river crossing are outside of the bund. The flood modelling has therefore shown the scheme has no noticeable impact on the onset of flooding of the agricultural land (ie. the point at which the bund is overtopped).

However, the construction of the proposed embankment, and the protection of the Eco Park and southern section of the A487, effectively narrows the width of the flood plain. There is therefore less width for the floodwater to pass through, resulting in the associated depth of floodwater increasing. In the conceptual design this equates to approximately 600mm increase in flood depth immediately adjacent to the Eco Park in the 100yr+20%CC event compared to the existing.

Further analysis of flood events has shown the duration of flood is not significantly changed.

In conclusion, and in relation to TPO 6 *"To ensure that flood risk to third parties is not increased"* the impact of the agricultural land is limited to the depth of flood waters. There are no noticeable impacts on the onset of flooding or the period the land is flooded. The impact on agricultural business is therefore considered to be minimal, however the smaller the increase in flood levels the simpler it will be to explain and justify to landowners.

2.2 Pont-ar-Ddyfi

The flood modelling of the conceptual design highlighted an increase in floodwater level upstream of Pont-ar-Ddyfi. To fully understand the impacts on the existing Grade II* listed and Scheduled Ancient Monument bridge, a structural assessment was undertaken.

The structural assessment considered the impacts on the existing bridge for a number of scenarios with incremental increases in upstream flood levels in the 100yr+20%CC event (10mm, 40mm, 110mm and 200mm). It also considered the

impacts of an option which had no increase in upstream flood levels, but changed the water velocity through the structure.

The structural assessment concluded that the overall failure of Pont-ar-Ddyfi is unlikely to occur in any of the scenarios considered as a direct consequence of hydrostatic or hydrodynamic loading from flood waters or debris impact. However, the greater the increase in flood level the greater the reduction in factor of safety from 2.6 (100yr+20%CC baseline) to 2.2 (200mm upstream flood level increase).

Scour to foundations is the single greatest cause of masonry arch bridge failure in the UK. Calculations for Pont-ar-Ddyfi show that the existing scour protection measures are adequate for a 1-in-100 year flood including allowances for climate change in both the existing and proposed arrangements. However, increases in water velocity through the structure are considered to represent a small, but increased risk.

In conclusion, and in relation to TPO 04 "*To preserve the long-term integrity of the Dyfi Bridge"* the impact of the scheme has been assessed not to have a significant impact on the structure. However, scheme layout options which minimise the increase in upstream flood levels, and do not change the velocity of water through the structure, will best serve to maintain the integrity of the bridge by not reducing the factor of safety or increasing the scour risk.

2.3 Residential Properties

A detailed analysis of the flood risk to the residential properties was undertaken to fully understand the current flood risk. This involved an analysis of the point of onset of flooding based on the threshold levels from the topographical survey. This concluded the following flood risks:

- No. 1 Pont-ar-Ddyfi – approx. 1 in 5 year flood event
- No. 2 Pont-ar-Ddyfi – approx. 1 in 5 year flood event
- No. 3 Pont-ar-Ddyfi – approx. 1 in 10 year flood event
- No. 4 Pont-ar-Ddyfi – approx. 1 in 100 year flood event plus climate change.
- No. 7 Pont-ar-Ddyfi – approx. 1 in 5 year flood event.

Properties No. 5, 6 and 8 have threshold levels above the 1 in 100 year event and therefore have not been considered further. The location of the majority of the residential properties is on the northern side of the A493, with limited space between the carriageway and the buildings. No. 2, 3 and 4 have a small wall and gate alongside the road, No. 1 has no physical separation (wall or kerb) between the carriageway and building). A number of the properties are Grade II listed buildings.

In the conceptual design there are flood level increases of approximately 200m (varies depending on property location). This increase in flood level could only realistically be mitigated through the construction of flood defences remote from

the property (potentially via works to the existing retaining wall between the A493 and the river). However, smaller increases in the order of magnitude of approximately 50mm could potentially be mitigated through threshold works.

In conclusion, and in relation to TPO 6 *"To ensure that flood risk to third parties is not increased"* the impact on the residential properties is related to both the onset of flooding and an increase in flood levels. The impact on the residential properties is considered to be unacceptable (not TAN15 compliant) unless mitigated. The form of the mitigation will vary depending on the increase in flood level, but would range from threshold works for smaller increases to flood barriers/walls for the greater increases.

3 Layout Options Considered

The conceptual design flood modelling and other options tested has highlighted the key impacts on flood levels are related to the reduction in the floodplain width.

The reductions in flood plain width primarily relate to the barrier created by the A487 embankment and flood bunds at the southern end of the scheme. The flood bunds provide protection to both the Eco Park and the A487. If flood bunds were not provided, flood protection of Eco Park would be removed, and continued flooding of A487 would need to be accepted.

The width of the existing 100yr +20%CC floodplain is approximately 530m (note the floodplain width is broadly perpendicular to the river, and does not relate to the structure length which crosses the flood plain at approximately 45°). The conceptual design effectively narrowed this to approximately 330m. Options that minimise this reduction have a lesser impact on flood levels.

The layout options that have been considered in relation to increasing the width of the flood plain, ie extend the scheme on some form of structure, can be summarised as:

- Various lengths of viaduct structure (conceptual length (Option 1) and options that increase the length by +85m, +170m and +235m (Options A, 2 and B respectively),
- Conceptual viaduct length with +85m or +170m of culverts in the southern approach embankment (Options D and C respectively), and
- Intermediate earthwork platform options, which effectively relocated sections of embankments from the southern end to part way along the viaduct (Options E and F).

The key impacts of the flood level increases are around Pont-ar-Ddyfi and the adjacent residential properties. Therefore various localised mitigation measures have been considered to locally reduce flood levels and impacts. These can be summarised as:

- Property threshold works and/or flood barriers (depending on increase in water level) (included in Options 1 and 2),
- Pont-ar-Ddyfi Bypass Channels (various layouts and sizes have been modelled both bypassing and downstream of the existing bridge) (Option I),
- Pier restriction to hold back flood waters behind the new viaduct, (Option II),
- Removal of the informal upstream flood bund (Option III),
- Removal of Pont-ar-Ddyfi (Option IV),
- Upstream Flood Channel/Area (Option V),

- Removal of the existing A487 (lowering back to field level) (Option VI), and
- Purchasing affected residential properties (Option VII).

The full range of options have been considered and assessed, the results of which are presented in a matrix in Appendix A. The two best performing options are described and assessed in more detail below, the other options and key reasons for rejecting them are provided in Section 3.3 and 3.4.

Unless stated otherwise the flood levels stated in this report related to the 100yr+20%CC flood event.

3.1 Option 1: 550m Viaduct with Residential Properties/Pont-ar-Ddyfi Mitigation

Option 1 provides the scheme layout with a 550m long viaduct and bridge as per the conceptual design (1 No. 22m, 12 No. 34m, 1 No. 50m and 1 No. 70m spans). However, to mitigate the impacts of increase in flood levels at Pont-ar-Ddyfi and the residential properties, the option includes either;

- Flood defences/barriers and Pont-ar-Dyfi strengthening, or
- Downstream flood channel and Pont-ar-Ddyfi scour works.

The option of flood defences/barriers would require works to the existing retaining wall between the A493 and the river. Records show undermining of this wall by the river, and therefore any works to use it as a formal flood defence are likely to require complex traffic management and in river works. The close proximity to Scheduled Ancient Monument Pont-ar-Ddyfi would add complexity of approval and specification of works. Flood defences/barriers would also only protect the properties, and therefore there would still be approximately 200mm of increase flood level (100yr+20%CC) on the upstream face of the Pont-ar-Ddyfi.

The option of a downstream flood channel would reduce flood levels slightly below the baseline (100yr+20%CC) immediately upstream and downstream of Pont-ar-Ddyfi, and therefore would provide flood benefits to the residential properties. However, a flood channel would require in river works to effectively form a benched overflow channel. This option would also increase water velocity through the existing bridge.

The 200mm of increase flood levels (with the defences) or the increase velocity of water (with the downstream channel) means allowances have been included for precautionary in river works to inspect and ensure the structural integrity of Pont-ar-Ddyfi.

Both of the mitigation approaches require in river works, have impacts on Pont-ar-Ddfyi, the surrounding property and landowners and the wider landscape. Therefore, the impacts of both options are considered comparable and the assessment in this note is based on either option.

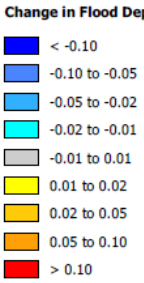
3.2 Option 2: 720m Viaduct with Residential Properties Threshold Works

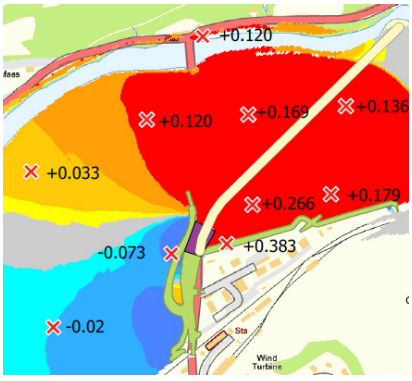
Option 2 would provide an extended 720m long viaduct (2 No. 27m, 16 No. 34m, 1 No. 50m and 1 No. 74m spans). The layout at the southern end of the scheme would change from conceptual design to provide sufficient freeboard above the flood levels at the northern boundary of the Eco Park. This change would extend the tie in of the scheme southwards to the existing railway bridge, with a diversion initially offline to the west.

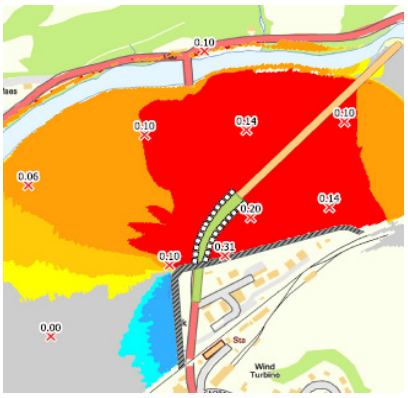
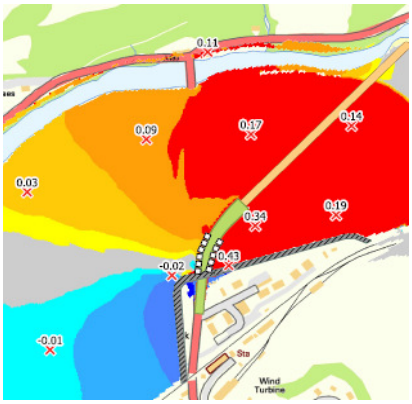
The flood level increases in the vicinity of Pont-ar-Ddyfi are relatively small with this layout (approx. 50mm). Therefore no works, other than inspections, are proposed to the existing bridge. Localised threshold or other minor works would be provided to ensure no change to the onset of flooding for the residential properties. Where practical works would look to reduce the frequency of flooding slightly, and provide other measures to benefit the properties.

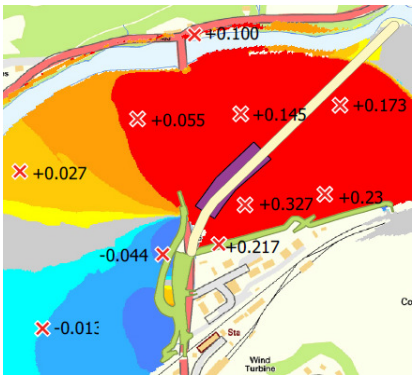
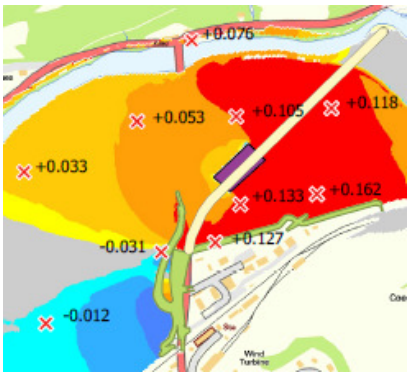
3.3 Layout Options Considered but Rejected

Flood Map Key



Option	Description and Key Reasons for Rejecting
A: 85m Viaduct Extension 	The layout at the southern end of the scheme would be altered to accommodate an 85m extension to the viaduct. This option would require the changes to the road layout, traffic management requirements and construction approach (as per Option 2 above). The increase in viaduct length would reduce the flood level increases to 120mm and 380mm at Pont-ar-Ddyfi and adjacent to the Eco Park respectively. However, this increase would still require flood barriers/walls, and in river works, to protect the residential properties. **This option has therefore been rejected because it does not provide sufficient reduction in flood levels to remove the costly and risky in river/flood defence works, and costs more than Option 1 (approx. +£4.0m).**

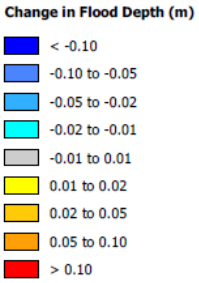
B: 235m Viaduct Extension 	The layout would be a further evolution of the layout proposed in Option 2. However, the vertical alignment of the new A487 would be even tighter, potentially with retaining walls, to provide sufficient freeboard to the flood waters. The 235m viaduct extension reduces the flood level increases to 9mm at both Pont-ar-Ddyfi and the Eco Park. **This option has been rejected because it requires a tighter vertical alignment, additional hard engineering adjacent to the Eco Park, although it is accepted it reduces flood level increases compared to Option 2, and costs more than Option 2 (approx.+£0.85m).**
C: 170m Culverts in Southern Approach Embankment, with 550m viaduct. 	This option would have a similar layout to the viaduct extension options, although the road alignment would be supported on multiple box culverts (assumed 5.4m * 2.0m). This option would reduce flood level increases to 100mm and 310mm at Pont-ar-Ddyfi and adjacent to the Eco Park. However, these increases in flood levels would still require flood barriers/walls. **This option was rejected because it introduces greater visual impact, results in culvert blockage flood risks, does not provide sufficient reduction in flood levels to remove the costly and risky in river/flood defence works, and costs more than Option 1 (approx. +£3.1m).**
D: 85m Culverts in Southern Approach Embankment, with 550m viaduct. 	This option has a similar layout to the other culvert, option C above, although with a shorter length of culverts. This option would result in flood level increases of 110mm and 430mm at Pont-ar-Ddyfi and adjacent to the Eco Park. However, these increase in flood levels would still require flood barriers/walls. **Although slighter cheaper than the other culvert option, this option would still cost more than Option 1 (approx. +£2.3m) and have other associated issues as outlined above for the culvert option.**

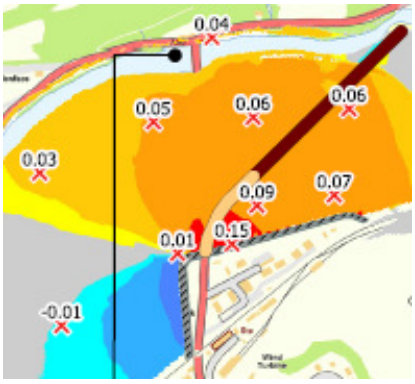
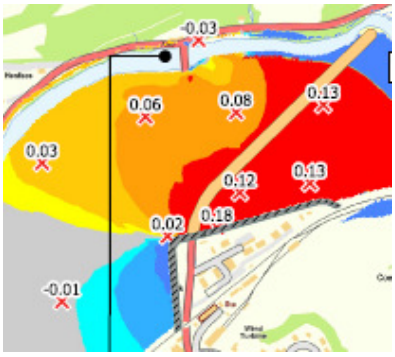
E: 170m Embankment part way along viaduct, with total 550m length of viaduct. 	This option has the same layout as the culvert and extended viaduct options and maintains the same total length of structure. However, it moves 85m of viaduct to immediately north of the Eco Park, with an intermediate embankment provided in between the two structures. The flood level increases of 100mm and 220mm at Pont-ar-Ddyfi and adjacent to the Eco Park are similar to the culvert options. **This option has been rejected because it does not provide the same reductions in flood level increases as Option 2, and is more expensive (approx. +£0.75m). It would also be complex to construct the large embankment which would have visual impacts across the floodplain.**
F: 85m Embankment part way along viaduct, with total 635m length of viaduct. 	This option has a similar layout to other embankment option (E), but increases the overall length of viaduct by +85m. The increase in structural length results in flood level increases of 75mm and 120mm at Pont-ar-Ddyfi and adjacent to the Eco Park respectively. **This option has similar flood level increases, and is slightly cheaper than Option 2 (approx. +£0.55m). However, it has been rejected because of the complexity of constructing a large embankment in the flood plain, the increased visual impact of the earthworks and the land severance it requires.**

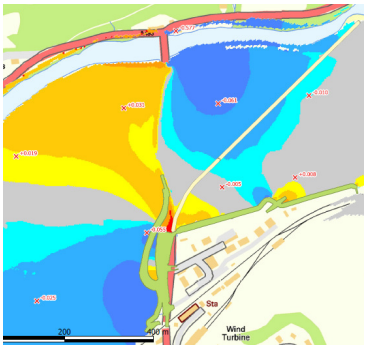
3.4 Pont-ar-Ddyfi Area Mitigation Options considered but rejected

Note these options would be included alongside a scheme layout as outlined above in order to potentially mitigate the increases in flood levels. All flood maps shown below show changes in flood levels when compared to Option 2.

Flood Map Key



Option	Description and Key Reasons for Rejecting
I: Pont-ar-Ddyfi Bypass Channels. 	A number of options for Pont-ar-Ddyfi bypass channels where modelled. They showed the ability to reduce flood level increases (produced by a particular scheme layout option above) of up to 100mm at Pont-ar-Ddyfi. The construction of a channel would have impacts on the river, landscape, agricultural operations, existing Pont-ar-Ddyfi southern abutment and utilities (BT). **This option has therefore been rejected when compared to the downstream flood channel and flood defences/barriers which can accommodate much greater increase in flood levels.**
II: Pier Restriction. 	An option was looked at to test whether increase the constriction provided by the bridge piers would help with flood levels at Pont-ar-Ddyfi. This showed the ability to reduce flood level increases (produced by a particular scheme layout option above) of up to 10mm at Pont-ar-Ddyfi. **This option was therefore rejected based on the relatively small flood benefits possible.**
III: Removal of Upstream Informal Flood Bund 	The removal of the upstream bund was tested within the flood model. This showed the ability to reduce flood level increases (produced by a particular scheme layout option above) of up to 80mm at Pont-ar-Ddyfi. **This option was rejected based on the significant changes in flood patterns for the agricultural land.**

IV: Removal of Pont-ar-Ddyfi 	The removal of the existing bridge was tested in the flood model. This showed the ability to reduce flood level increases (produced by a particular scheme layout option above) of up to 600mm at Pont-ar-Ddyfi. **This option was rejected based on the unacceptability in terms of moving the existing Scheduled/Listed bridge.**
V: Upstream Flood Channel/Area	**The relatively small flood changes in flood levels provided by a bypass channel means an upstream flood channel is not considered to be viable. Opportunities for large areas of flood compensation immediately upstream are limited by the railway line to the south, and the topography (steep slopes) and archaeological features to the north.**
VI: Removal of Existing A487 between Eco Park and Pont-ar-Ddyfi.	The removal of the existing A487, reducing it to surrounding ground level, was tested. This showed the ability to reduce flood level increases (produced by a particular scheme layout option above) of up to 10mm at Pont-ar-Ddyfi. **This option was therefore rejected based on the relatively small flood benefits possible and the cost of the works.**
VII: Purchase of Properties	Purchasing the properties immediately north of the Pont-ar-Ddyfi potentially would remove the need to mitigate the increase flood levels. However, several of these properties are listed buildings and therefore have protection. In addition, any increases in flood levels will also impact the A493 and traffic joining the A487 from the west. **The purchase of the properties which are currently occupied and listed buildings, to avoid the need to provide mitigation, has been rejected based on the future maintenance costs for Welsh Government to maintain the listed structures and the fact that it would not remove the increased flooding impact on the A493.**

4 Option 1: 550m Viaduct with Residential Properties/Pont-ar-Ddyfi Mitigation

4.1 Engineering Design

4.1.1 Geometry and Departures

There are several proposed and existing highway alignment Departures from Standards (DfS) associated with the highway layout. They have been summarised against the number within the Departures from Standards Report; 900237-ARP-ZZZZ-RP-CX-00001 which covers Option 2.

DP307 - A487 Combination Departure in Stopping Sight Distance (SSD), Horizontal Alignment (HA) and Transitions

DP308 - A487 Combination Departure in SSD, HA, Vertical Alignment (VA) and Transitions – ***Existing layout***

DP309 - A487 Approach to A487/ Eco Park Junction – ***Existing layout***

DP310 - A487 Approach to A487/ Old A487 Junction

DP311 - A487 Approach to A487/ Railway Access Junction – ***Existing layout***

DP312 - Eco Park Junction Visibility – ***Existing layout***

DP313 - Old A487 Junction Visibility

DP314 - Railway Access Junction Visibility – ***Existing layout***

DP401 - Old A487 Omission of Supereleveation (SE) and Transitions

DP402 - Old A487 Horizontal Alignment

DP403 - Eco Park Combination Departure in HA,VA and SE – ***Existing layout***

4.1.2 Structures

The proposed structure is multi span steel composite bridge carrying the A487 two lane single carriageway over the Dyfi River and its flood plain. The structure also spans the National Cycle Network Route 8. The straight alignment provides a constant cross section along the length of the structure and the proposed construction technique is to push launch the main viaduct from the southern abutment. The large bridge spans would be erected in situ.

4.1.3 Lighting and Signage

The section of A487 to the south of the southern abutment would be subject to a 30mph speed limit, and would have street lighting. The start of the 30mph zone

would closely replicate the existing situation, and provide a gateway entrance feature to Machynlleth which encourages drivers to slow down.

4.1.4 Utilities

Existing utilities in the area concerned include:

Utility	Effect of scheme
11kV overhead cables	To be diverted underground
33kV overhead cables	To be diverted underground
High Pressure 150mm gas main	To be locally protected under proposed 0.5m high new A487 embankment
180mm Water Main	Minimal/No impact
BT Ducting	Minimal impact

4.1.5 Community and Private Assets

The southern embankment encroaches into the north-west corner of the Garden Centre land parcel located within Dyfi Eco Park.

4.2 Economy

4.2.1 Construction Costs

The proposed scheme would be predominately as per the conceptual design. However, additional mitigation works would be required in the vicinity of Pont-ar-Ddyfi. These would be more complex in river works, to existing structures with more complex traffic management. The cost of these works, the risks associated with them for both the contractor and client, and the greater likelihood of a Public Inquiry means the scheme budget for Option 1 would be approximately £26.8m.

4.2.2 Transport/Traffic

The proposed layout is as per the conceptual design.

4.3 Environment

4.3.1 Noise (and Vibration)

There would be no significant change in noise and vibration, noise levels may increase slightly for some receptors at the southern end of the scheme due to road level increases.

Changes in noise levels at the northern end of the scheme, or in the proximity to Pont-ar-Ddyfi have not been considered in this assessments.

4.3.2 Air Quality

There would be no significant change in air quality.

4.3.3 Landscape

The southern embankment would protrude into the flood plain from the Eco Park. Although the slopes would be colonised with meadow seed, helping the scheme blend in with the landscape, the embankment would impact on the landscape. It would also require the removal of the existing vegetated boundary between the Eco Park and the A487, therefore increasing the visual impact on receptors with the Eco Park.

4.3.4 Bio-diversity (Nature Conservation & Ecology)

The proposed option will have an impact on the local bio-diversity by increasing the extent of inundation due to increased flood levels, and the requirement for in river works associated with the flood mitigation measures. The embankment footprint will require land-take, potentially encroaching into existing habitats.

4.3.5 Heritage

This increase in floodwater depth on the upstream face of the existing bridge may have a longer term impact on the integrity of Scheduled/Listed Pont-ar-Ddyfi, See Section 2.2. Flood mitigation measures in the vicinity of the existing bridge would also impact on the setting of the structure.

4.3.6 Soils

The southern embankment requires fill material excavated from the northern junction, and some additional imported fill.

4.3.7 Water Environment

The 550m long viaduct (Option 1) provides various flood benefits, but also several flood impacts.

- Protection from overland river flooding of the existing railway bridge and properties to the south of the railway bridge in the 100yr+20%CC event.
- Protection of the Eco Park and existing A487 (south of the scheme) from flooding in the 100yr+20%CC.
- Increase in flood levels of approximately 600m on agricultural land immediately to the north of the Eco Park (no mitigation proposed)
- Increase in flood levels of approximately 200mm immediately upstream of Pont-ar-Ddyfi (mitigation and/or strengthening proposed)

- Early onset of flooding and increase in levels, of up to 250mm, for residential properties adjacent to Pont-ar-Ddyfi. (mitigation and/or strengthening proposed to remove impact)

4.4 Social

4.4.1 Transport/Safety

The SSD on the A487 around the southern tie-in curve are below standard due to the relatively tight horizontal curve of 180m. However, the eastern verge has been widened to improve these values. The visibility from the Eco Park entrance is also below standard due to the 180m radius curve and the location of the junction on the inside of a bend.

4.4.2 Physical Fitness

There would be no significant effect on physical fitness because of the option.

4.5 Assessment Summary Table

Transport Planning Objectives	**TP01, 02, 03, 05 and 08:** Overall scheme meets objective. **TP04:** The proposed option would cause a significant increase in flood levels upstream of the bridge, exacerbating the lateral loading on the bridge during flood events. **TP06:** The proposed option would increase flood levels local to the A487 viaduct and Pont-ar-Ddyfi, mitigation would be provided to ensure no increase in risk to local residents. **TP07:** The proposed would impact the landscape, bio-diversity water resources and heritage due to the increase in flood levels,
Economy	**Construction Cost:** Approximately £26.8m, as per the scheme estimate with allowances for flood mitigation works. **Benefit cost ratio (BCR):** as per conceptual scheme with reduction for flood mitigation works.
Environment	**Noise:** There would be no significant change in noise. **Air Quality:** There would be no significant change in air quality. **Landscape:** The southern embankment would protrude into the flood plain, and require the removal of the existing vegetated boundary between the Eco Park and the A487. **Bio-diversity:** The increased flood levels and in river works will have an impact on the river bio-diversity. **Heritage:** The option will significantly increase flood levels and loading on the listed Pont-ar-Ddyfi structure.

	Water environment: Due to the embankment protruding out into and narrowing the floodplain there will be a significant increase in flood levels. Mitigation will be required to ensure no increased risk to residential properties along the A493. **Soils:** No effect
Social	**Transport Safety:** The southern A487 tie-in bend does not provide full SSD, however verge widening has improved this to be close to standard. Visibility from the Eco Park junction is below standard **Personal Security:** No effect. **Permeability:** No effect. **Physical Fitness:** No effect. **Social Inclusion:** The same provision is being provided. **Equality diversity and human rights:** No effect.

5 Option 2: 720m Viaduct with Residential Properties Threshold Works

5.1 Option Summary

This option involves extending the viaduct to a total length of 720m, formerly 550m, with an additional 170m long curved viaduct extension.

It is envisaged that this viaduct structure will be constructed insitu unlike the push launched straight section of viaduct. The viaduct spans will be approximately 34m. The open spans of the extended viaduct section allow flood water to flow more freely through the scheme and reduces flood water build-up behind the proposed viaduct.

5.2 Engineering Design

5.2.1 Geometry and Departures

The majority of the highway alignment DfS associated with Option 1 would be unchanged with this option. The key differences have been highlighted below:

DP307 - A487 Combination Departure in Stopping Sight Distance (SSD), Horizontal Alignment (HA) and Transitions – ***Reduced by increase in horizontal radius.***

DP308 - A487 Combination Departure in SSD, HA, Vertical Alignment (VA) and Transitions – ***Similar to existing layout***

DP309 - A487 Approach to A487/ Eco Park Junction – ***Similar to existing layout***

DP310 - A487 Approach to A487/ Old A487 Junction – ***No major difference to Option 1***

DP311 - A487 Approach to A487/ Railway Access Junction – ***Similar to existing layout***

DP312 - Eco Park Junction Visibility – ***Similar to existing layout***

DP313 - Old A487 Junction Visibility– ***No major difference to Option 1***

DP314 - Railway Access Junction Visibility – ***Similar to existing layout***

DP401 - Old A487 Omission of Supereleveation (SE) and Transitions – ***No major difference to Option 1***

DP402 - Old A487 Horizontal Alignment – ***No major difference to Option 1***

DP403 - Eco Park Combination Departure in HA,VA and SE – ***Similar to existing layout***

5.2.2 Structures

The proposed structure is multi span steel composite bridge carrying the A487 two lane single carriageway over the Dyfi River and its flood plain. The structure also spans the National Cycle Network Route 8. The extended viaduct would introduce a curved section with an over widened cross section before the straight section with a constant cross section. This would impact on the proposed construction technique, with the curve section constructed insitu and a temporary platform required for the push launch. The large bridge spans would be erected in situ.

5.2.3 Lighting and Signage

The section of A487 to the south of the southern abutment would be subject to a 30mph speed limit, and would have street lighting. The start of the 30mph zone would closely replicate the existing situation, and provide a gateway entrance feature to Machynlleth which encourages drivers to slow down.

5.2.4 Utilities

Existing utilities in the area concerned include:

Utility	Effect of scheme
11kV overhead cables	To be diverted underground
33kV overhead cables	Additional length to be diverted underground
High Pressure 150mm gas main	Extended viaduct to span over gas main.
180mm Water Main	To be diverted
BT Ducting	To be diverted

5.2.5 Community and Private Assets

Due to the extended length of tie-in to the existing A487, and the elevated A487, the Dyfi Eco Park entrance would require reconfiguring.

5.3 Economy

5.3.1 Construction Costs

There would be an increase in cost due to extending the viaduct. This extension would require major construction works with the majority of the cost being associated with: piling, pier construction, deck construction and road surfacing. Other works include additional diversion of utilities, additional works to existing A487, additional works to Eco Park entrance and additional land requirements to west of A487.

However, the flood level increases for the extended viaduct are significantly less and therefore only relatively minor threshold works are required to mitigate the impact on the residential properties. There would be no requirement for complex and risky in river works, and therefore the risk allocations are lower for the extended viaduct

The scheme budget for Option 2 would be approximately £28.0m, £1.2m higher than Option 1.

5.3.2 Transport/Traffic

The extended viaduct option lengthens the highway works, resulting in the Eco Park entrance coming within the limits of the scheme. However, the junctions have relatively low turning movements and can be accommodated via two simple T-junctions.

The change in scheme length of layout is unlikely to significantly change the journey times and overall benefits of the scheme.

5.4 Environment

5.4.1 Noise (and Vibration)

The extended viaduct will marginally increase noise and vibration due to the increased amount of piling and heavy civils works required in construction.

5.4.2 Air Quality

The alternative option would have no significant impact on air quality.

5.4.3 Landscape

Additional land take would be required to the west of A487, although the scheme would retaining the existing boundary and visual screen between the Eco Park and the A487. It would also provide less severance of agricultural land and field patterns within the flood plain.

5.4.4 Bio-diversity (Nature Conservation & Ecology)

The key differential between the options in terms of ecology is the removal of the in river works in Option 2. Therefore reducing the potential impact on ecology to those associated with the flood level increases.

5.4.5 Heritage

By reducing the flood levels upstream of the Pont-ar-Ddyfi, the extended viaduct option will help conserve the structural integrity of the Scheduled/Listed bridge.

5.4.6 Water Environment

The extended viaduct provides various flood benefits, but also several flood impacts.

- Protection from overland river flooding of the existing railway bridge and properties to the south of the railway bridge in the 100yr+20%CC event.
- Protection of the Eco Park and existing A487 (south of the scheme) from flooding in the 100yr+20%CC.
- Increase in flood levels of approximately 140m on agricultural land immediately to the north of the Eco Park (no mitigation proposed).
- Increase in flood levels of approximately 50mm immediately upstream of Pont-ar-Ddyfi (no mitigation proposed/required).
- Early onset of flooding and increase in levels, of up to 50mm, for residential properties adjacent to Pont-ar-Ddyfi. (localised works or threshold works to remove any impact).

5.4.7 Soils

New earthworks will be required for the viaduct structure extension however, these will be low in volume.

5.5 Social

5.5.1 Transport Safety

The A487 SSD has been improved by increasing the radius of the southern tie in bend to 255m as opposed to 180m radius for the current proposed design. The east verge on the extended viaduct section has also been widened to provide improved SSD, although would still remain below standard.

5.5.2 Physical Fitness

The alternative option would have no effect on physical fitness.

5.6 Assessment Summary Table

Transport Planning Objectives	**TP01, 02, 03, 05, and 08:** Overall scheme meets objective. **TP04:** The open viaduct structure will allow flood water to freely pass under it causing a marginal increase in flood level at Pont-ar-Ddyfi. **TP06:** There is only a marginal increase in flood water of 50mm at the houses north of the Pont-ar-Ddyfi. Localised mitigation or threshold works are proposed to remove any increase risk and potentially provide elements of betterment. **TP07:** The structure causes only marginal change in flood level across the scheme and this is likely to have little effect on water resources biodiversity and heritage.
Economy	**Construction Cost:** Approximately £28.0m, £1.2m higher than Option 1. **Benefit cost ratio (BCR):** reduced BCR as a result of the increased construction cost
Environment	**Noise:** There would be no significant impact on noise and vibration. **Air Quality:** There would be no significant impact on air quality. **Landscape:** The extended viaduct will have additional impacts on the local landscape by encroachment of the southern embankment into the land west of A487. However, it will retain the boundary along the west of the Eco Park and avoid the earthworks protruding into the flood plain. **Bio-diversity:** The viaduct extension will maintain the current bio-diversity allowing habitats to be used beneath the structure as well as minimising the flood level increase through the scheme. **Heritage:** There will be a marginal increase in flood levels at the existing bridge, but no works are required to it, or in the immediate vicinity of the bridge. **Water environment:** The extended viaduct will be more sympathetic to the local water environment, more closely reflecting the existing flooding patterns, and requiring less mitigation works. **Soils:** No effect.
Social	**Transport Safety:** There would be no significant effect, however SSD will be increased round the larger radius southern tie-in bend, and by widening of the eastern verge. **Personal Security:** No effect. **Permeability:** The same highway provision is provided. **Physical Fitness:** No effect. **Social Inclusion:** No effect. **Equality diversity and human rights:** No effect.

6 Conclusion

6.1 Comparison of Options Key Points

The Assessment Summary Tables in Sections 4.5 and 5.6 outline the performance of Option 1 (550m Viaduct with Residential Properties/Pont-ar-Ddyfi Mitigation) and Option 2 (720m Viaduct with Residential Properties Threshold Works). In a number of areas the two options perform similarly, however the bullet points below summarise the key differences between the options:

- Option 2 performs better than Option 1 on the three key TPOs (TPO 4, 6 and 7).
- The construction cost of Option 2 would be approximately £1.2m higher than Option 1, and therefore would have a lower BCR value.
- Option 2 would increase flood levels upstream of the existing listed Pont-ar-Ddyfi by only 50mm as opposed to 250mm for Option 1, in the 100yr+20%CC event. Therefore having less impact, and requiring less mitigation, on the residential properties and Pont-ar-Ddyfi.
- The mitigation works for Option 2 are localised works in the vicinity of the properties immediately north of Pont-ar-Ddyfi. Option 1 would require in river works, which would impact on both the landscape and the existing Scheduled/Listed Pont-ar-Ddyfi.
- Option 2 would increase flood levels on the agricultural land adjacent to the Eco Park by 140mm instead of 600mm with Option 1, in the 100yr+20%CC event.
- Option 2 would require more land, but provides less severance of land (animals and small vehicles would be able to cross beneath the extended section of viaduct).
- Option 2 would include a larger radius curve at the southern end of the scheme, improving visibility for road users, and therefore safety slightly.

6.2 Summary

In summary, Option 2 on balance is the best and most suitable option based on the justification and appraisal tables above. Option 2, despite the increased construction costs, greatly reduces the impact of flooding, and need for mitigation for the residential properties and existing Pont-ar-Ddyfi. It also reduces the increase in flood levels on the agricultural land, reduces severance, allows a slight improvement in the highway alignment and removes the need for any in river works.

Appendix A

Flood Options Matrix

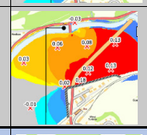
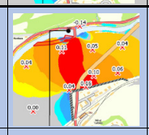
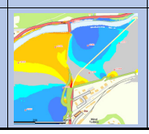
Scheme Layout Options

Option No.	Option Group	Option Name	Viaduct Length (m)	Bridge Length (m)	Culvert Details	Baseline Flood Map	Increase in height (Pr 2) adjacent to Eco ParK (m)	Increase in height at Pont-ar-Ddyfi and properties (m)	TPO4: To preserve the long-term integrity of the Dyfi Bridge	TPO5: To reduce the number of severity of collisions and casualties on the A487 in the study area.	TPO6: To ensure that flood risk to third parties is not increased.	TPO7: To minimise the impact of transport improvements on the landscape, biodiversity, water resources and heritage.	Economy - Total Cost (£m)	Economy - Total Cost including Flood Mitigation Works (£m)	Environment - Landscape	Environment - Bio-diversity	Environment - Heritage	Environment - Water Environment	Social - Transport Safety	Public Acceptability/Risk (General Public, Residential Properties and Landowners)	Buildability	Geometry
1	Works Information Requirements	Works Info	430	125	n/a		0.600	0.250	Baseline	Baseline	Baseline	Baseline	0	2.2	Baseline - Flood bund across field, severing natural pattern. Boundary along garden centre removed.	Baseline	Baseline	Baseline	Baseline	Baseline	Basline	Radius of 180m at southern end of viaduct, no overtaking opportunity.
1a		Works Info + Mitigation (culverts and removal of A487)	430	125	tbc		0.550	0.250	Minimal change to baseline levels	No change to baseline	Minimal change to baseline levels	Landscape impact of culverts and works to existing A487	0	0	Addition to baseline visual impact of culverts and removing A487.	Minimal change to baseline	Minimal change to baseline levels	Minimal change to baseline levels	No change to baseline	Minimal change to baseline levels	Minimal change to baseline	Layout as per Option 1.
All options below this point, with the exception of the Works Info, require a change to the scheme horizontal and vertical which																						
A	Viaduct Extension Options	Works Info + 85m viaduct extension	515	125	n/a		0.383	0.120	Reduction in flood levels at existing bridge to approx. 100mm increase	No change to baseline	Reduction in flood levels at existing bridge to approx. 100mm increase	Reductions in flood levels	1.8	4	Embankment interrupt field pattern, but GC boundary retained and bund along existing boundary	Minimal change to baseline	Reduction in flood levels at existing bridge to approx. 100mm increase	Reduction in flood levels at existing bridge to approx. 100mm increase	No change to baseline	Reduction in flood levels at existing bridge and EcoPark	More difficult TM phasing and construction approach for structure	Radius of 255m at southern end of viaduct, overtaking opportunity on viaduct
2		Works Info + 170m viaduct extension	595	125	n/a		0.140	0.050	Reduction in flood levels at existing bridge to less than 100mm increase	No change to baseline	Reduction in flood levels at existing bridge to less than 100mm increase	Reductions in flood levels	3.15	3.17	Embankment interrupt field pattern, but GC boundary retained and bund along existing boundary	Minimal change to baseline	Reduction in flood levels at existing bridge to less than 100mm increase	Reduction in flood levels at existing bridge to less than 100mm increase	No change to baseline	Reduction in flood levels at existing bridge and EcoPark, and less land severance	More difficult TM phasing and construction approach for structure	Layout as per Option 3
B		Works Info + 235m viaduct extension	660	125	n/a		0.009	0.009	Reduction in flood levels at existing bridge to less than 100mm increase	No change to baseline	Reduction in flood levels at existing bridge to less than 100mm increase	Reductions in flood levels but greater visual impact	4.5	4.52	Greater hard engineering at EcoPark, tight geometry	Minimal change to baseline	Reduction in flood levels at existing bridge to less than 100mm increase	Reduction in flood levels at existing bridge to less than 100mm increase	No change to baseline	Reduction in flood levels at existing bridge and EcoPark, less land severance, but impact on GC	More difficult TM phasing, construction approach for structure and constrained site	Tight vertical alignment from railway bridge
C	Culvert Extension Options	Works Info + 170m extension with culverts	430	125	30 No. (5.4m*2.0m)		0.310	0.100	Reduction in flood levels at existing bridge to approx. 100mm increase	No change to baseline	Reduction in flood levels at existing bridge to approx. 100mm increase	Minimal reduction in flood levels, greater visual impact of culverts	2.1	3.1	Hard engineering of box culverts and inconsistent structural form result in greater impact.	Minimal change to baseline	Reduction in flood levels at existing bridge to approx. 100mm increase	Reduction in flood levels at existing bridge to approx. 100mm increase	No change to baseline	Reduction in flood levels at existing bridge and EcoPark	More difficult TM phasing, and construction approach for structure/ culverts/ embankment	Layout as per Option 3
D		Works Info + 85m extension with culverts at Eco Park	430	125	15 No. (5.4m*2.0m)		0.430	0.110	Reduction in flood levels at existing bridge to approx. 100mm increase	No change to baseline	Reduction in flood levels at existing bridge to approx. 100mm increase	Minimal reduction in flood levels, greater visual impact of culverts	1.3	2.3	Hard engineering of box culverts and inconsistent structural form result in greater impact.	Minimal change to baseline	Reduction in flood levels at existing bridge to approx. 100mm increase	Reduction in flood levels at existing bridge to approx. 100mm increase	No change to baseline	Reduction in flood levels at existing bridge and EcoPark	More difficult TM phasing, and construction approach for structure/ culverts/ embankment	Layout as per Option 3
E	Earthwork Platforms	Works Info + 170m section of viaduct moved to Eco Park	430	125	n/a		0.217	0.100	Reduction in flood levels at existing bridge to approx. 100mm increase	No change to baseline	Reduction in flood levels at existing bridge to approx. 100mm increase	Minimal reduction in flood levels, greater visual impact of earthworks	2.9	3.9	Inconsistent structural form/support across flood plain. Limited opportunities to mitigate without making it look odd.	Minimal change to baseline	Reduction in flood levels at existing bridge to approx. 100mm increase	Reduction in flood levels at existing bridge to approx. 100mm increase	No change to baseline	Reduction in flood levels at existing bridge and EcoPark	More difficult TM phasing, construction approach for structure and settlement issues with embankment	Layout as per Option 3
F		Works Info + 85m viaduct extension at Eco Park	515	125	n/a		0.190	0.060	Reduction in flood levels at existing bridge to less than 100mm increase	No change to baseline	Reduction in flood levels at existing bridge to less than 100mm increase	Reductions in flood levels but greater visual impact	2.6	2.62	Inconsistent structural form/support across flood plain. Limited opportunities to mitigate without making it look odd.	Minimal change to baseline	Reduction in flood levels at existing bridge to less than 100mm increase	Reduction in flood levels at existing bridge to less than 100mm increase	No change to baseline	Reduction in flood levels at existing bridge and EcoPark	More difficult TM phasing, construction approach for structure and settlement issues with embankment	Layout as per Option 3
F		Works Info + 85m viaduct extension at Eco Park	515	125	n/a		0.127	0.076	Reduction in flood levels at existing bridge to less than 100mm increase	No change to baseline	Reduction in flood levels at existing bridge to less than 100mm increase	Reductions in flood levels but greater visual impact	2.6	2.62	Inconsistent structural form/support across flood plain. Limited opportunities to mitigate without making it look odd.	Minimal change to baseline	Reduction in flood levels at existing bridge to less than 100mm increase	Reduction in flood levels at existing bridge to less than 100mm increase	No change to baseline	Reduction in flood levels at existing bridge and EcoPark	More difficult TM phasing, construction approach for structure and settlement issues with embankment	Layout as per Option 3

Note: With the exception of Cost (including mitigation column) assessment does not consider impacts of flood mitigation work

- Moderate Positive
- Slight Positive
- Neutral
- Slight Adverse
- Moderate Adverse

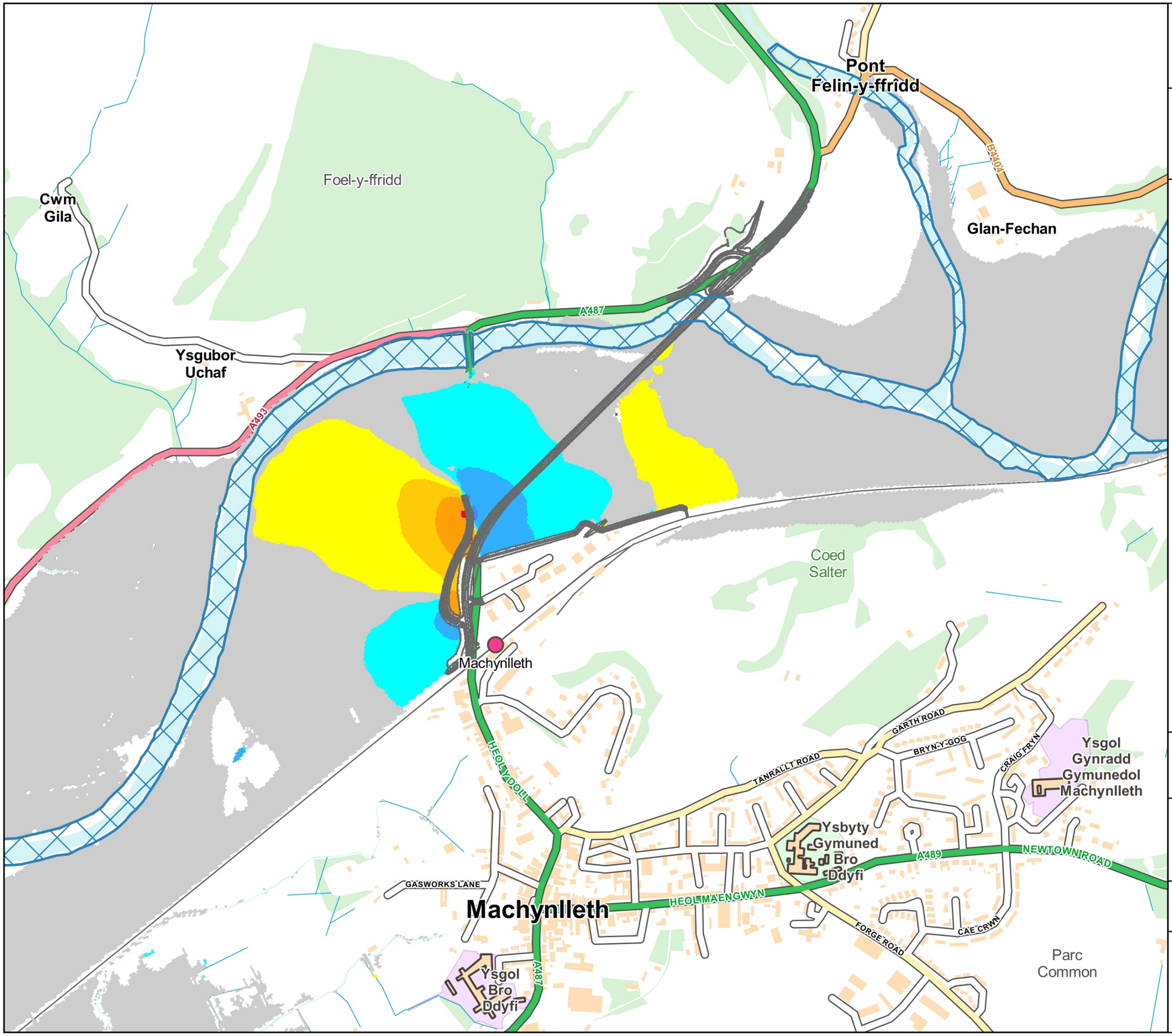
Pont-ar-Ddyfi Area Mitigation Options

Option No.		Option Name	Option Details		Increase in height at Pont-ar-Ddyfi and properties (m)	Reduction from baseline (m)	Benefits both upstream and downstream of Pont-ar-Ddyfi	TPO4- To preserve the long-term integrity of the Dyfi Bridge	TPO5- To reduce the number of severity of collisions and casualities on the A487 in the study area.	TPO6- To ensure that flood risk to third parties is not increased.	TPO7- To minimise the impact of transport improvements on the landscape, biodiversity, water resources and heritage.	Economy - Total Cost (£)	Environment - Landscape	Environment - Bio-diversity	Environment - Heritage	Environment - Water Environment	Social - Transport Safety	Public Acceptability/Risk (General Public, Residential Prop Landowners)	Buildability
n/a		Baseline	n/a		0.050	n/a	n/a	Baseline - no works adjacent to existing bridge	Basline	Basline	Basline		Baseline	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline
I	Options than can mitigate flood level increases Up to 50mm	Bypass Channel around Pont-ar-Ddyfi (Option 1)	tbc		0.040	0.010	NO	Works to the south of the bridge may impact on integrity	No change to baseline	Slight reduction in flood levels compared to basline, but still increase.	Summary of disciplines	Not priced - indicative cost £1m +	Significant amount of works, NMU routes changes, harder engineering, impact on field boundaries, etc	In river works required.	Works to the south of the bridge may impact on integrity and setting	In river works required.	No change to baseline	Works impact on agricultural land and setting of Dyfi valley	Works required to connect channel to river.
I		Bypass Channel around Pont-ar-Ddyfi (Option 3)	tbc		0.010	0.040	NO, upstream only	Works to the south of the bridge may impact on integrity	No change to baseline	Slight reduction in flood levels compared to basline, but still increase.	Summary of disciplines	Not priced - indicative cost £1m +	Significant amount of works, NMU routes changes, harder engineering, impact on field boundaries, etc	In river works required.	Works to the south of the bridge may impact on integrity and setting	In river works required.	No change to baseline	Works impact on agricultural land and setting of Dyfi valley	Works required to connect channel to river.
II		Increased constriction from new bridge	n/a		0.040	0.010	YES	No works around existing bridge	No change to baseline	Slight reduction in flood levels compared to basline, but still increase.	Summary of disciplines	Not priced limited benefit	We currently have elegant structure, changes to pier spacings wouldn't look sensible	No change to baseline	No works around existing bridge	No change to baseline	No change to baseline	No major change to baseline	No change to baseline
Option 2		Flood barrier for residential properties	n/a	Localised works to thresholds	n/a	upto 50mm	NO	Localised works with little impact on existing bridge	Only minor changes around existing road.	Protection to properties	Summary of disciplines	£20,000.00	Limit visual impact	Localised works, outside of river channel	Very minor works with limited impact on setting of bridge.	Localised works, outside of river channel	Only minor changes around existing road.	Minor works which will provide flood protection to properties.	Minor works, relatively straight forward to complete
I		Bypass Channel around Pont-ar-Ddyfi (Option 2)	15m wide, 1.5m deep		-0.040	0.090	NO, upstream only	Works to the south of the bridge may impact on integrity	No change to baseline	Reduction in flood levels at properties	Summary of disciplines	Not priced - indicative cost £1m +	Tightly constraint channel with hard engineering, close to bridge and within setting.	In river works required.	Works to the south of the bridge may impact on integrity and setting	In river works required.	No change to baseline	Works impact on agricultural land and setting of Dyfi valley	Works required in constrained location potentially while bridge in operation
III		Removal of existing upstream flood bund	n/a		-0.030	0.080	NO, Upstream only (in 1in100+cc)	No works around existing bridge	No change to baseline	Reduction in flood levels at properties but major change to flood of agricutural land	Summary of disciplines	Not priced, not considered viable.	Limited visual and landscape impact	Mainly works in agricultural land	No works around existing bridge	Change in flood patterns for agricultural land	No change to baseline	Major change to flooding pattern of agricultural land	Earthworks operation across agricultural land not directly linked to scheme,
Option 1A	Options than can mitigate flood level increases greater than 100	Downstream flood channel	24m wide, 1.5m deep		-0.140	0.190	YES	Increase in velocity of water through the bridge impacting on scour risks	No change to baseline	Reduction in flood levels at properties	Summary of disciplines	£2,200,000.00	Impact on landscape, sensitive design could incorporate into landscape	In river works required.	Increase in velocity of water through the bridge impacting on scour risks	In river works required.	No change to baseline	Works impact on agricultural land and setting of Dyfi valley	Works required to connect channel to river.
Option 1B		Flood barrier for residential properties	n/a	Approx 50m long * 0.5m high	n/a	upto 400mm	NO	Localised works with little impact on existing bridge	Only minor changes around existing road.	Protection to properties	Summary of disciplines	£2,200,000.00	Limit visual impact	Potentially some in river works required to existing retaining wall;	Localised works which would impact on setting of bridge.	Potentially some in river works required to existing retaining wall;	Only minor changes around existing road.	Flood protection provide to properties but will involve more signficant works, potential in river	More works required in constraint location with house, road and river.
IV		Removal/relocation of existing Pont-ar-Dyfi	n/a		-0.557	0.607	NO, upstream only	Removal of existing bridge from current setting.	No change to baseline	Reduction in flood levels at properties	Summary of disciplines	Not priced, not considered viable.	Historic landscape character impact	In river works required.	Removal of existing bridge from current setting.	In river works required.	No change to baseline	Moving the existing bridge is unlikely to be acceptably to wider public and stakeholders	In river works to carefully dismantle existing structure.

- Moderate Positive
- Slight Positive
- Neutral
- Slight Adverse
- Moderate Adverse

Appendix I

Proposed Model Outputs



Project :

A487 New Dyfi Bridge

Client :

GRIFFITHS civil engineering and construction

ARUP

Legend :

- River Dyfi and Tributries
- Proposed Scheme

Change in Flood Depth (m)

- < -0.10
- -0.10 to -0.05
- -0.05 to -0.02
- -0.02 to -0.005
- -0.005 to 0.005
- 0.005 to 0.02
- 0.02 to 0.05
- 0.05 to 0.10
- > 0.10

Scale :

0 200 400 m

Title :

Impact of Proposed Development
1 in 2 year flood event

Drawing :

WHS1345-F01-0001

Rev :

4

WHS

Project :

A487 New Dyfi Bridge

Client :

GRIFFITHS civil engineering and construction

ARUP

Legend :

River Dyfi and Tributries

Proposed Scheme

Change in Flood Depth (m)

- < -0.10
- -0.10 to -0.05
- -0.05 to -0.02
- -0.02 to -0.005
- -0.005 to 0.005
- 0.005 to 0.02
- 0.02 to 0.05
- 0.05 to 0.10
- > 0.10

Scale :

0 200 400 m

Title :

Impact of Proposed Development
1 in 5 year flood event

Drawing :

WHS1345-F01-0002

Rev :

4

WHS

Pont Felin-y-ffridd

Foel-y-ffridd

Cwm Gila

Glan-Fechan

B4404

A487

Ysgubor Uchaf

A493

Coed Salter

Machynlleth

HEOL Y DOLL

TANRALLT ROAD

GARTH ROAD

BRYN-Y-GOG

CRAIG FRYN

Ysgol Gynradd Gymunedol Machynlleth

Ysbyty Gymuned Bro Ddyfi

A489

NEWTOWN ROAD

HEOL MAENGWYN

GASWORKS LANE

Machynlleth

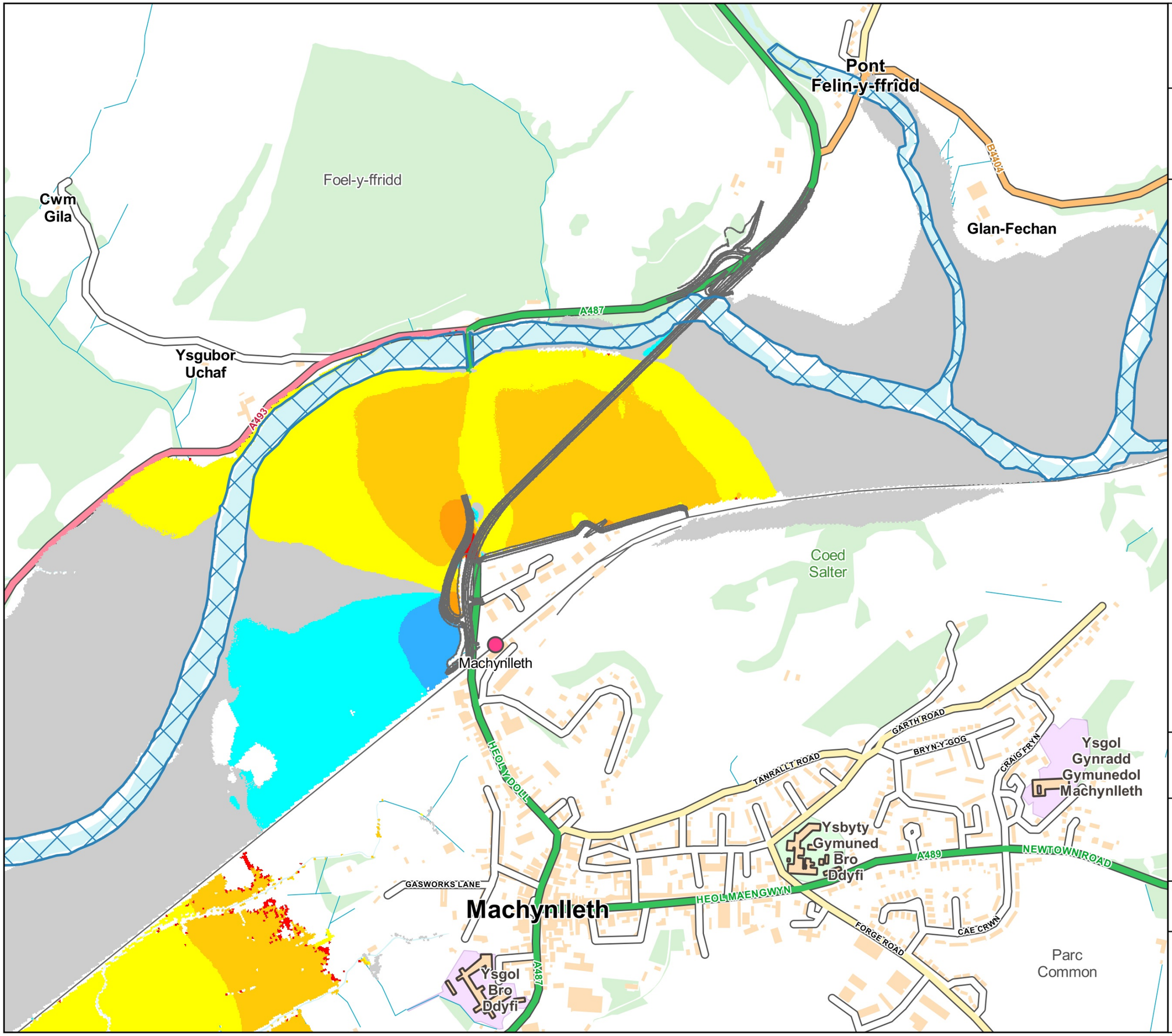
FORGE ROAD

CAE CRWN

Ysgol Bro Ddyfi

A487

Parc Common



Project :

A487 New Dyfi Bridge

Client :

GRIFFITHS civil engineering and construction

ARUP

Legend :

- River Dyfi and Tributries
- Proposed Scheme

Change in Flood Depth (m)

- < -0.10
- -0.10 to -0.05
- -0.05 to -0.02
- -0.02 to -0.005
- -0.005 to 0.005
- 0.005 to 0.02
- 0.02 to 0.05
- 0.05 to 0.10
- > 0.10

Scale :

0 200 400 m

Title :

Impact of Proposed Development
1 in 10 year flood event

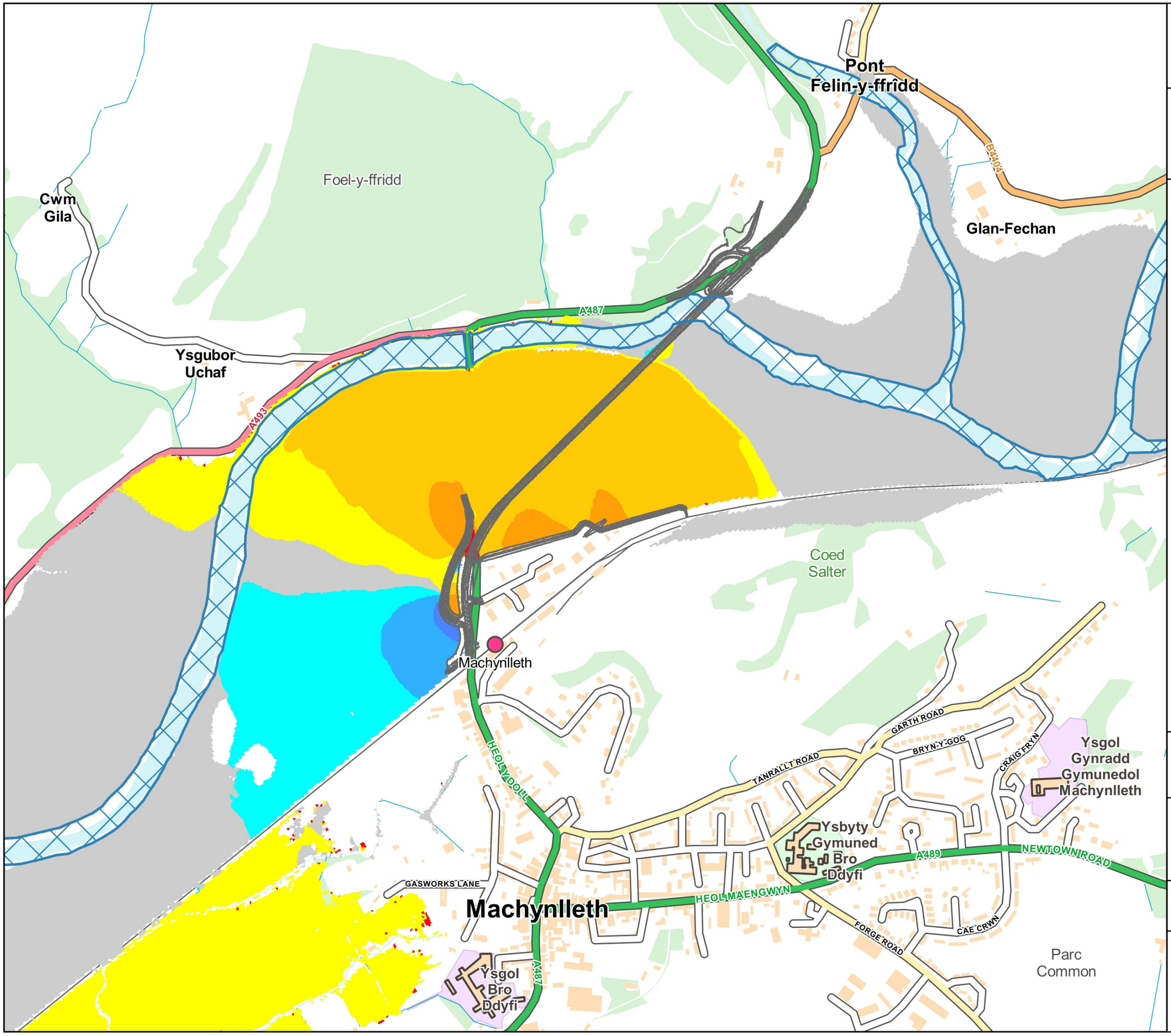
Drawing :

WHS1345-F01-0003

Rev :

4

WHS



Project :

A487 New Dyfi Bridge

Client :

GRIFFITHS civil engineering and construction

ARUP

Legend :

- River Dyfi and Tributries
- Proposed Scheme

Change in Flood Depth (m)

- < -0.10
- -0.10 to -0.05
- -0.05 to -0.02
- -0.02 to -0.005
- -0.005 to 0.005
- 0.005 to 0.02
- 0.02 to 0.05
- 0.05 to 0.10
- > 0.10

Scale :

0 200 400 m

Title :

Impact of Proposed Development
1 in 30 year flood event

Drawing :

WHS1345-F01-0004

Rev :

4

WHS

Project :

A487 New Dyfi Bridge

Client :

GRIFFITHS civil engineering and construction

ARUP

Legend :

River Dyfi and Tributries

Proposed Scheme

Change in Flood Depth (m)

- < -0.10
- -0.10 to -0.05
- -0.05 to -0.02
- -0.02 to -0.005
- -0.005 to 0.005
- 0.005 to 0.02
- 0.02 to 0.05
- 0.05 to 0.10
- > 0.10

Scale :

0 200 400 m

Title :

Impact of Proposed Development
1 in 50 year flood event

Drawing : WHS1345-F01-0005

Rev : 4

WHS

Pont Felin-y-ffridd

Glan-Fechan

Foel-y-ffridd

Cwm Gila

Ysgubor Uchaf

A487

A493

B4404

Coed Salter

Machynlleth

HEOL Y DOLL

GARTH ROAD

TANRALLT ROAD

BRYN-Y-GOG

CRAIG FRYN

Ysgol Gynradd Gymunedol Machynlleth

Ysbyty Gymuned Bro Ddyfi

A489

NEWTOWN ROAD

HEOL MAENGWYN

GASWORKS LANE

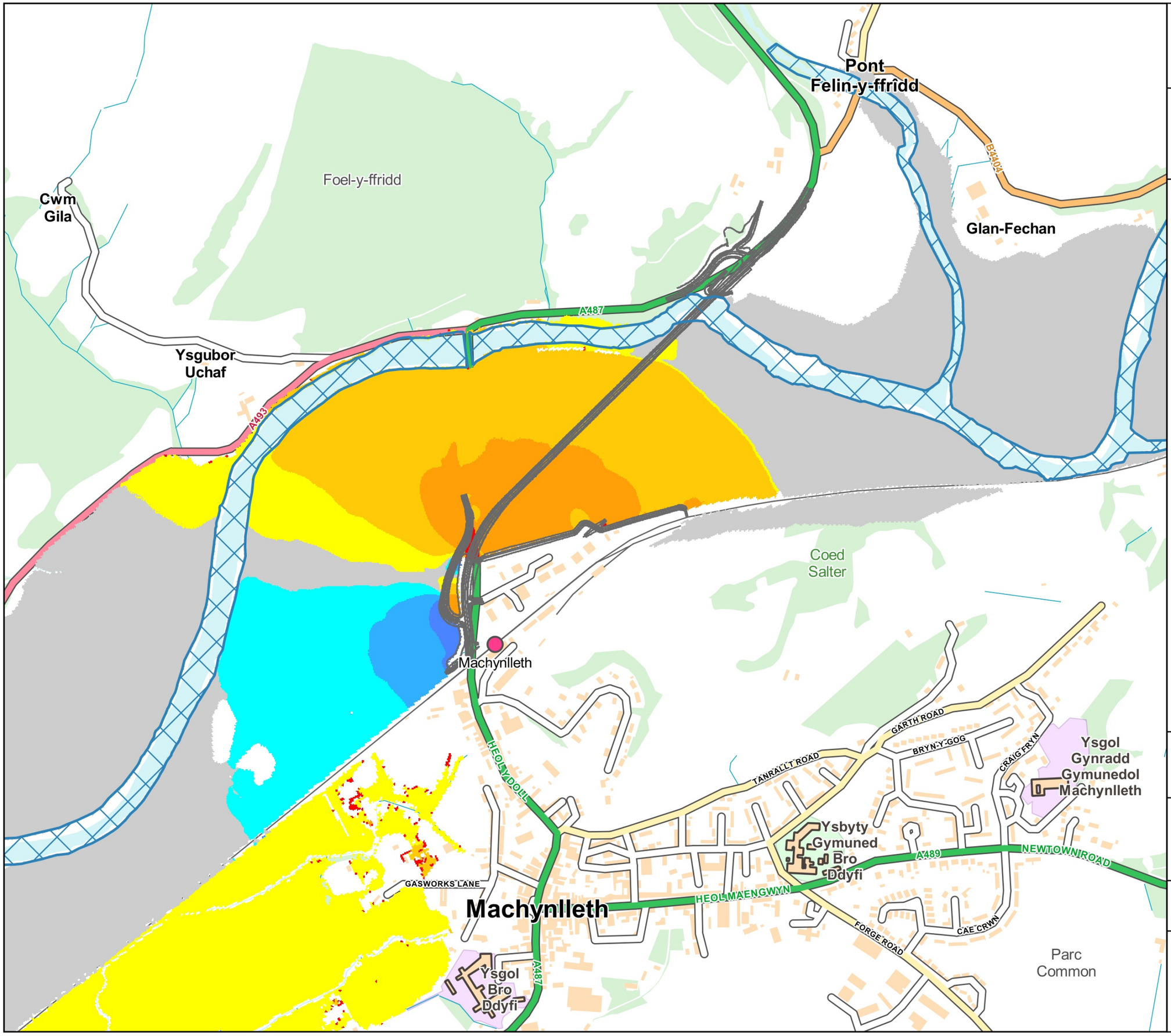
FORGE ROAD

CAE CRWN

Machynlleth

Ysgol Bro Ddyfi

Parc Common



Project :

A487 New Dyfi Bridge

Client :

GRIFFITHS civil engineering and construction

ARUP

Legend :

- River Dyfi and Tributries
- Proposed Scheme

Change in Flood Depth (m)

- < -0.10
- -0.10 to -0.05
- -0.05 to -0.02
- -0.02 to -0.005
- -0.005 to 0.005
- 0.005 to 0.02
- 0.02 to 0.05
- 0.05 to 0.10
- > 0.10

Scale :

0 200 400 m

Title :

Impact of Proposed Development
1 in 75 year flood event

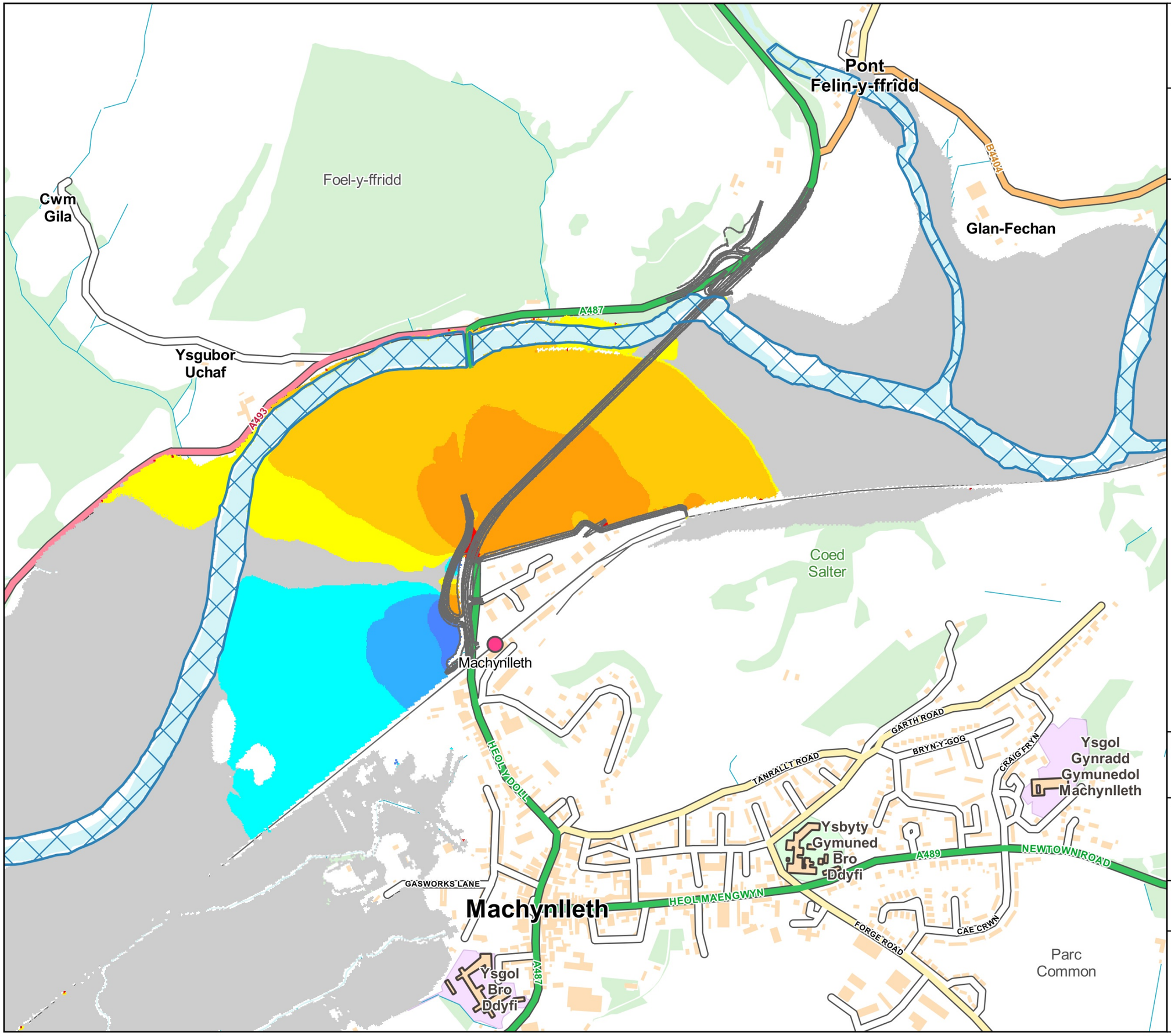
Drawing :

WHS1345-F01-0006

Rev :

4

WHS



Project :

A487 New Dyfi Bridge

Client :

GRIFFITHS civil engineering and construction

ARUP

Legend :

- River Dyfi and Tributries
- Proposed Scheme

Change in Flood Depth (m)

- < -0.10
- -0.10 to -0.05
- -0.05 to -0.02
- -0.02 to -0.005
- -0.005 to 0.005
- 0.005 to 0.02
- 0.02 to 0.05
- 0.05 to 0.10
- > 0.10

Scale :

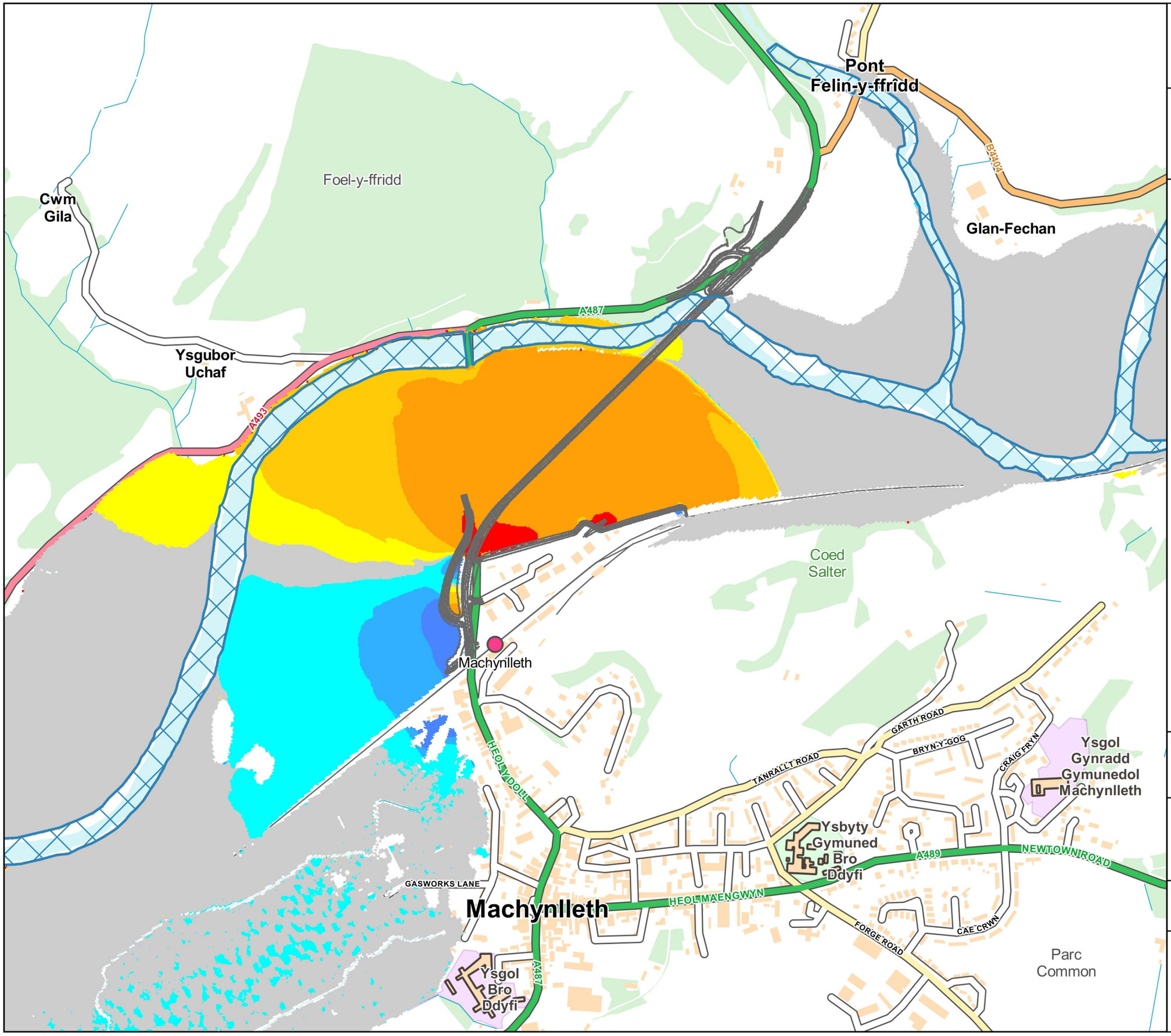
0 200 400 m

Title :

Impact of Proposed Development
1 in 100 year flood event

Drawing :	Rev :
WHS1345-F01-0007	4

WHS



Project :

A487 New Dyfi Bridge

Client :

GRIFFITHS civil engineering and construction

ARUP

Legend :

- River Dyfi and Tributries
- Proposed Scheme

Change in Flood Depth (m)

- < -0.10
- -0.10 to -0.05
- -0.05 to -0.02
- -0.02 to -0.005
- -0.005 to 0.005
- 0.005 to 0.02
- 0.02 to 0.05
- 0.05 to 0.10
- > 0.10

Scale :

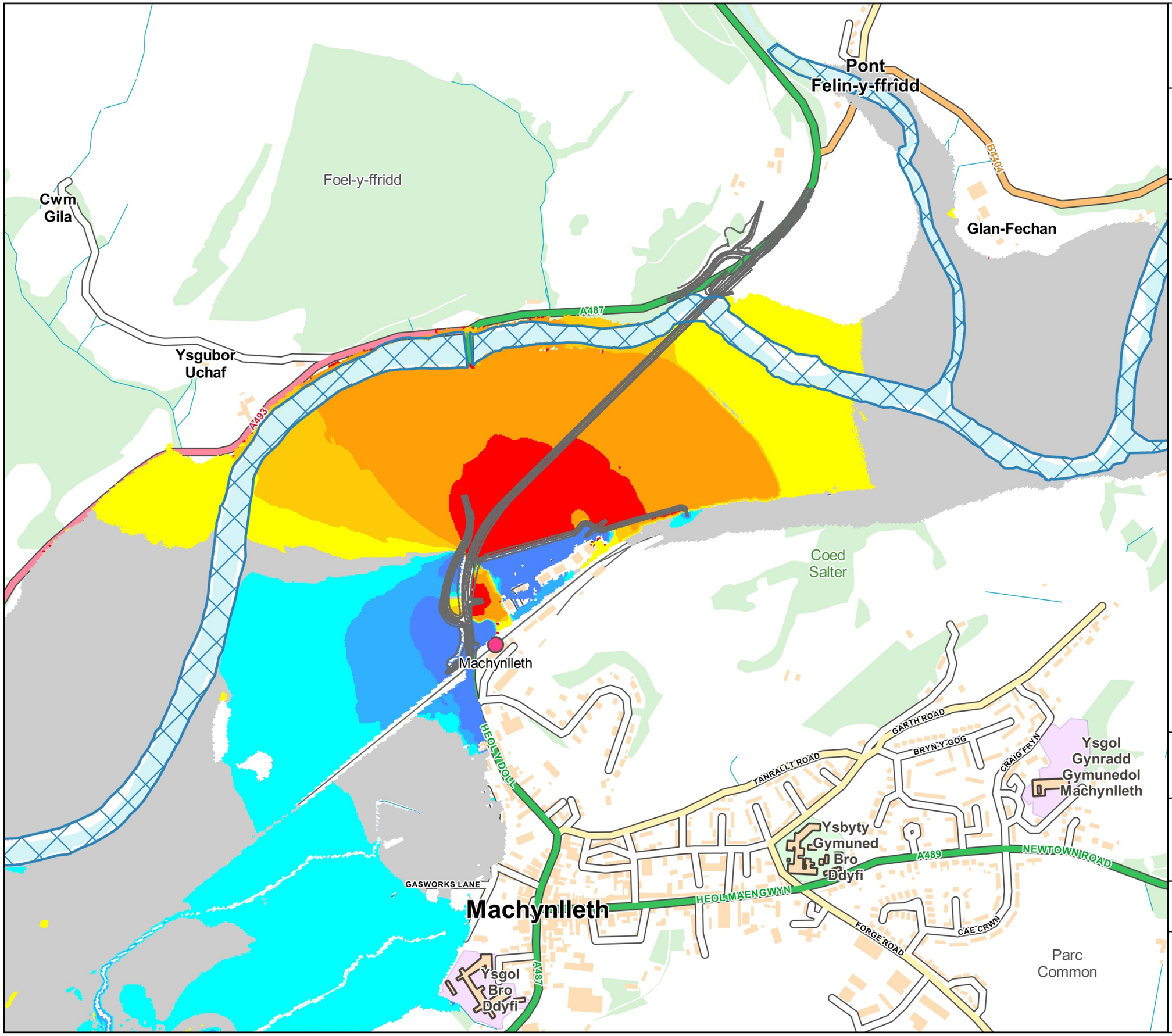
0 200 400 m

Title :

Impact of Proposed Development
1 in 100 year flood event + Climate Change

Drawing :	Rev :
WHS1345-F01-0008	4

WHS



Project :

A487 New Dyfi Bridge

Client :

GRIFFITHS civil engineering and construction

ARUP

Legend :

- River Dyfi and Tributries
- Proposed Scheme

Change in Flood Depth (m)

- < -0.10
- -0.10 to -0.05
- -0.05 to -0.02
- -0.02 to -0.005
- -0.005 to 0.005
- 0.005 to 0.02
- 0.02 to 0.05
- 0.05 to 0.10
- > 0.10

Scale :

0 200 400 m

Title :

Impact of Proposed Development
1 in 1000 year flood event

Drawing :

WHS1345-F01-0009

Rev :

4

WHS

Project :

A487 New Dyfi Bridge

Client :

GRIFFITHS civil engineering and construction

ARUP

Legend :

River Dyfi and Tributries

Propose Scheme

Change in Flood Depth (m)

- < -0.10
- -0.10 to -0.05
- -0.05 to -0.02
- -0.02 to -0.005
- -0.005 to 0.005
- 0.005 to 0.02
- 0.02 to 0.05
- 0.05 to 0.10
- > 0.10

Scale :

0 200 400 m

Title :

Impact of Proposed Development
1 in 100 year flood event + 2016 Climate Change updates (30%)

Drawing :	Rev :
WHS1345-F01-0011	2

WHS

Pont Felin-y-ffridd

Glan-Fechan

B4404

Foel-y-ffridd

Cwm Gila

Ysgubor Uchaf

A487

A493

Coed Salter

Machynlleth

HEOL Y DOLL

GASWORKS LANE

TANRALLT ROAD

GARTH ROAD

BRYN-Y-GOG

CRAIG FRYN

Ysgol Gynradd Gymunedol Machynlleth

Ysbyty Gymuned Bro Ddyfi

A489

NEWTOWN ROAD

HEOL MAENGWYN

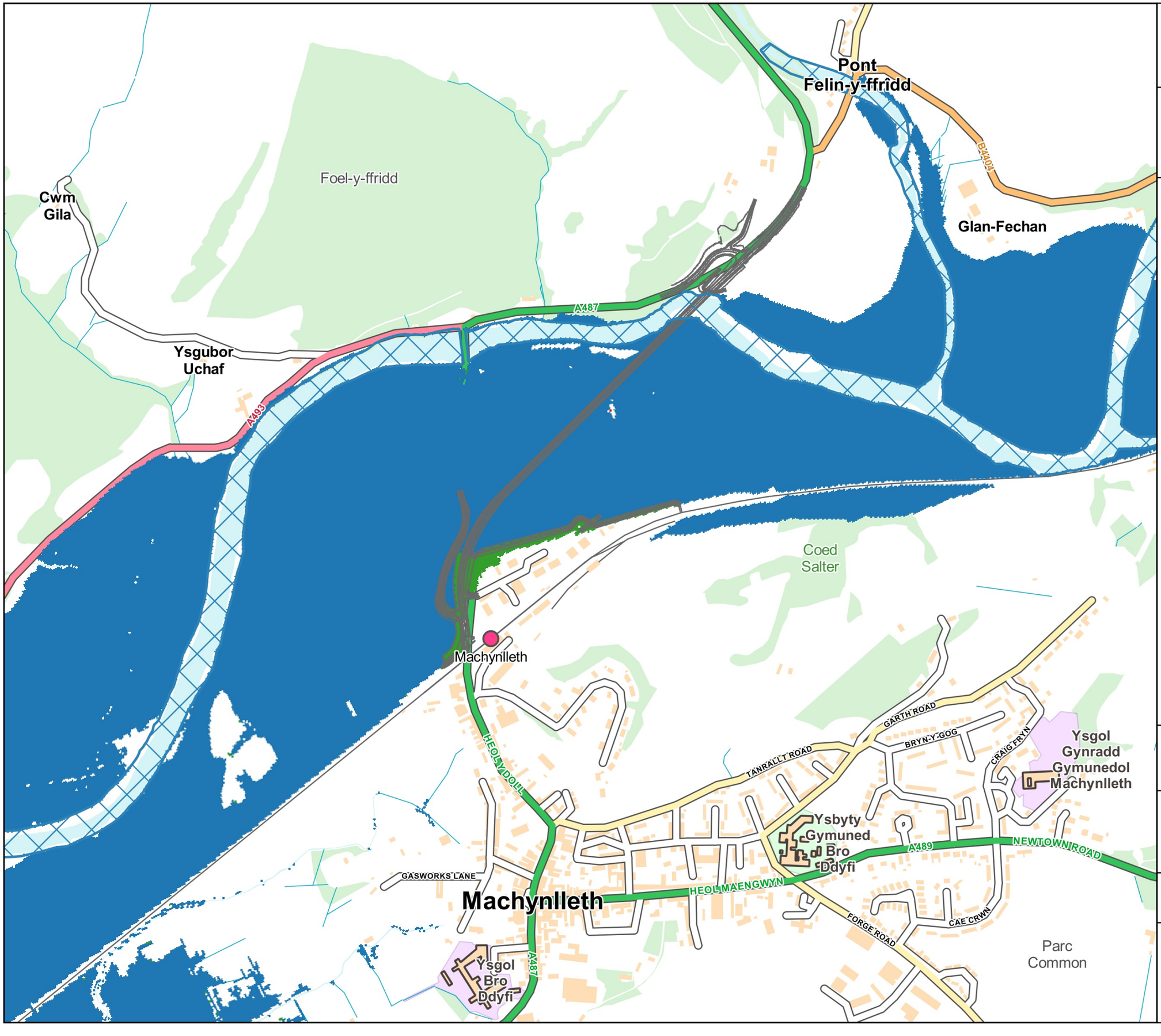
FORGE ROAD

CAE CRWN

Machynlleth

Ysgol Bro Ddyfi

Parc Common



Project :

A487 New Dyfi Bridge

Client :

GRIFFITHS civil engineering and construction

ARUP

Legend :

- River Dyfi and Tributries
- Propose Scheme

Flood Extent Change

- Decreased Extent
- No Change
- Increased Extent

Scale :

0 200 400 m

Title :

Impact of Proposed Development
Flood Extent Change
1 in 2 year event

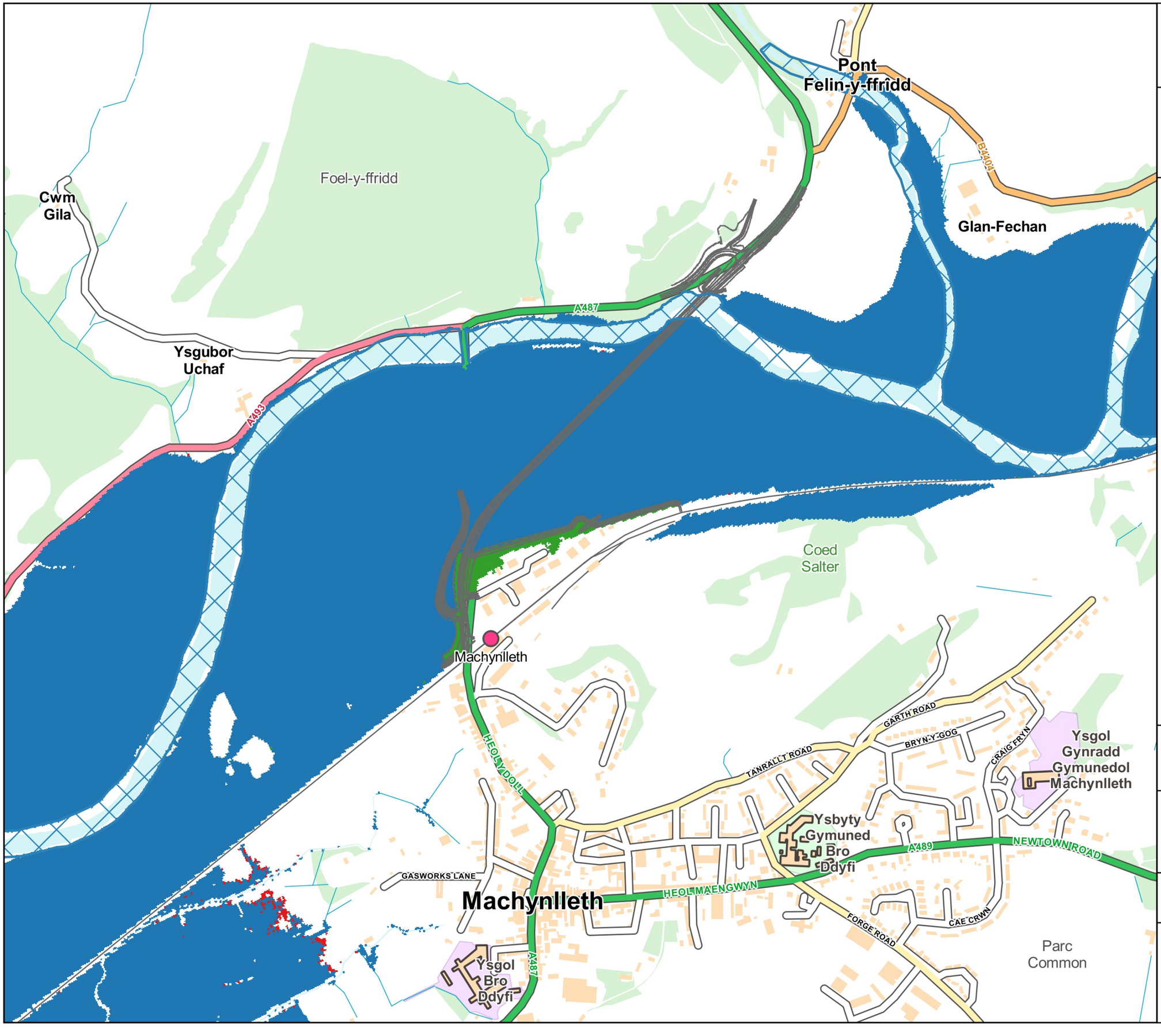
Drawing :

WHS1345-F01-0012

Rev :

2

WHS



Project :

A487 New Dyfi Bridge

Client :

GRIFFITHS civil engineering and construction

ARUP

Legend :

- River Dyfi and Tributries
- Propose Scheme

Flood Extent Change

- Decreased Extent
- No Change
- Increased Extent

Scale :

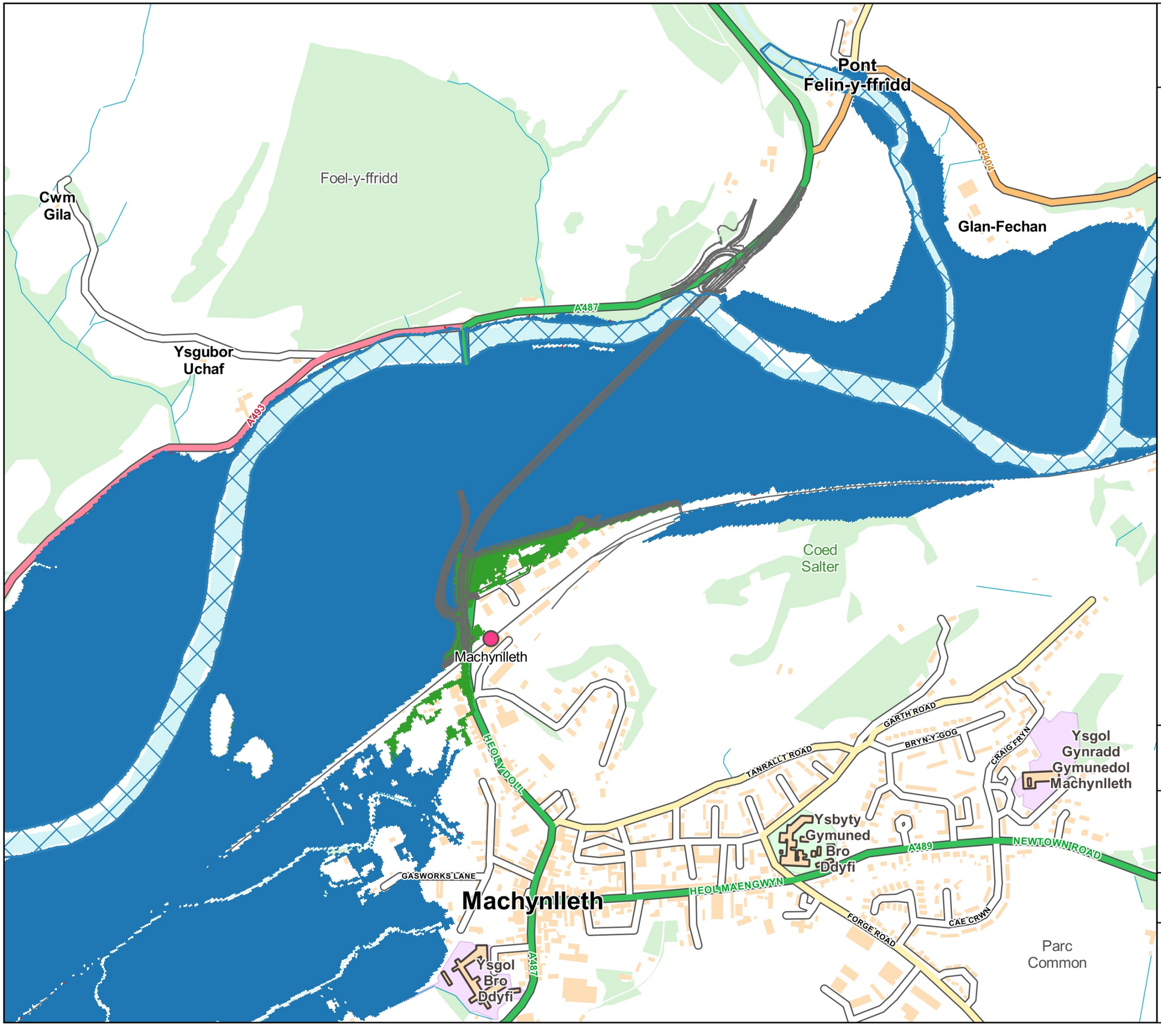
0 200 400 m

Title :

Impact of Proposed Development
Flood Extent Change
1 in 10 year event

Drawing :	Rev :
WHS1345-F01-0013	1

WHS



Project :

A487 New Dyfi Bridge

Client :

GRIFFITHS civil engineering and construction

ARUP

Legend :

- River Dyfi and Tributries
- Propose Scheme

Flood Extent Change

- Decreased Extent
- No Change
- Increased Extent

Scale :

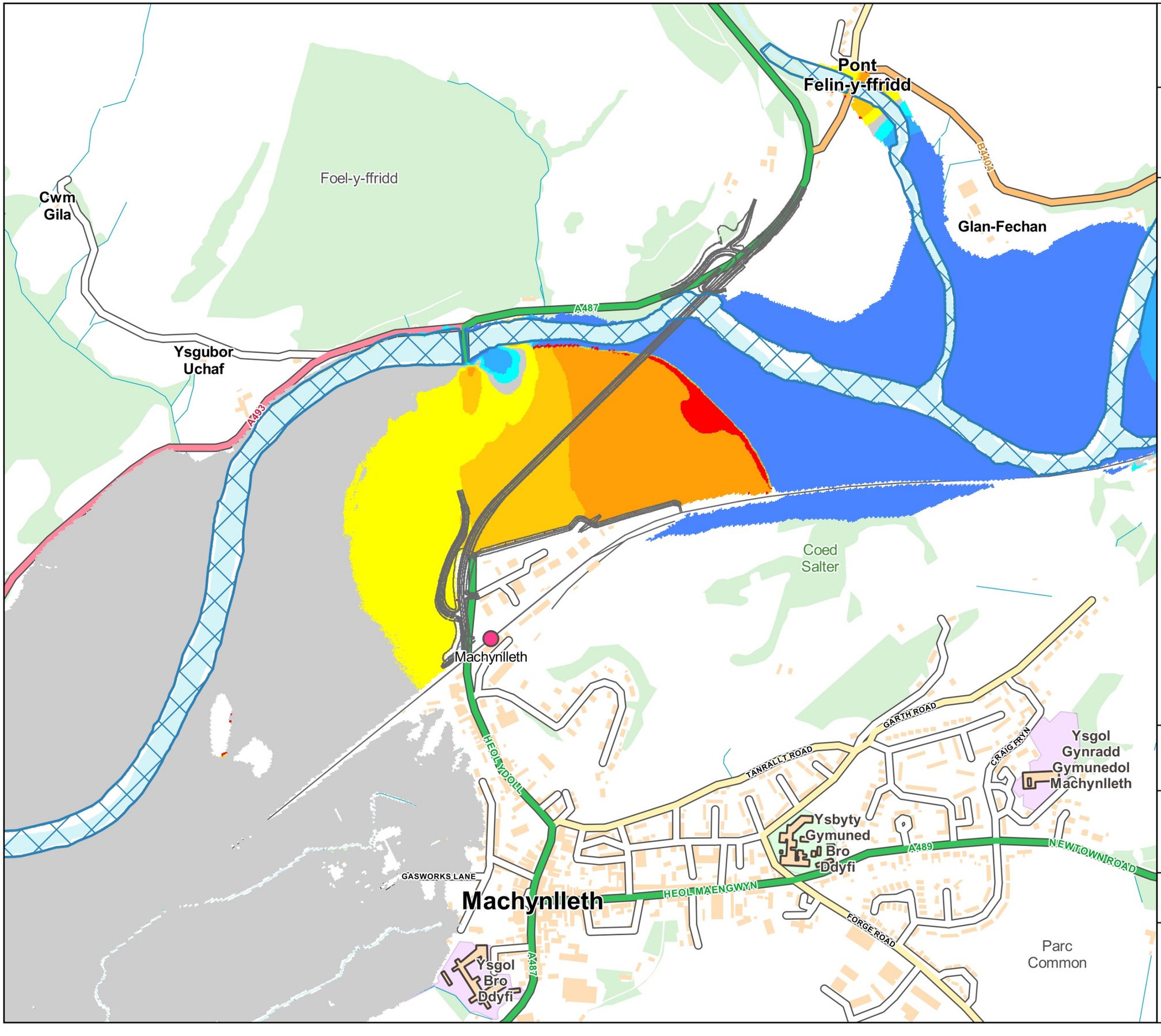
0 200 400 m

Title :

Impact of Proposed Development
Flood Extent Change
1 in 100 year event

Drawing :	Rev :
WHS1345-F01-0014	1

WHS



Project :

A487 New Dyfi Bridge

Client :

GRIFFITHS civil engineering and construction

ARUP

Legend :

- River Dyfi and Tributries
- Propose Scheme

Change in Flood Depth (m)

- < -0.10
- -0.10 to -0.05
- -0.05 to -0.02
- -0.02 to -0.005
- -0.005 to 0.005
- 0.005 to 0.02
- 0.02 to 0.05
- 0.05 to 0.10
- > 0.10

Scale :

0 200 400 m

Title :

Impact of Removal of the Infomal Bund
SEN_3b
1 in 100 year flood event + Climate Change

Drawing :

WHS1345-F10-0010

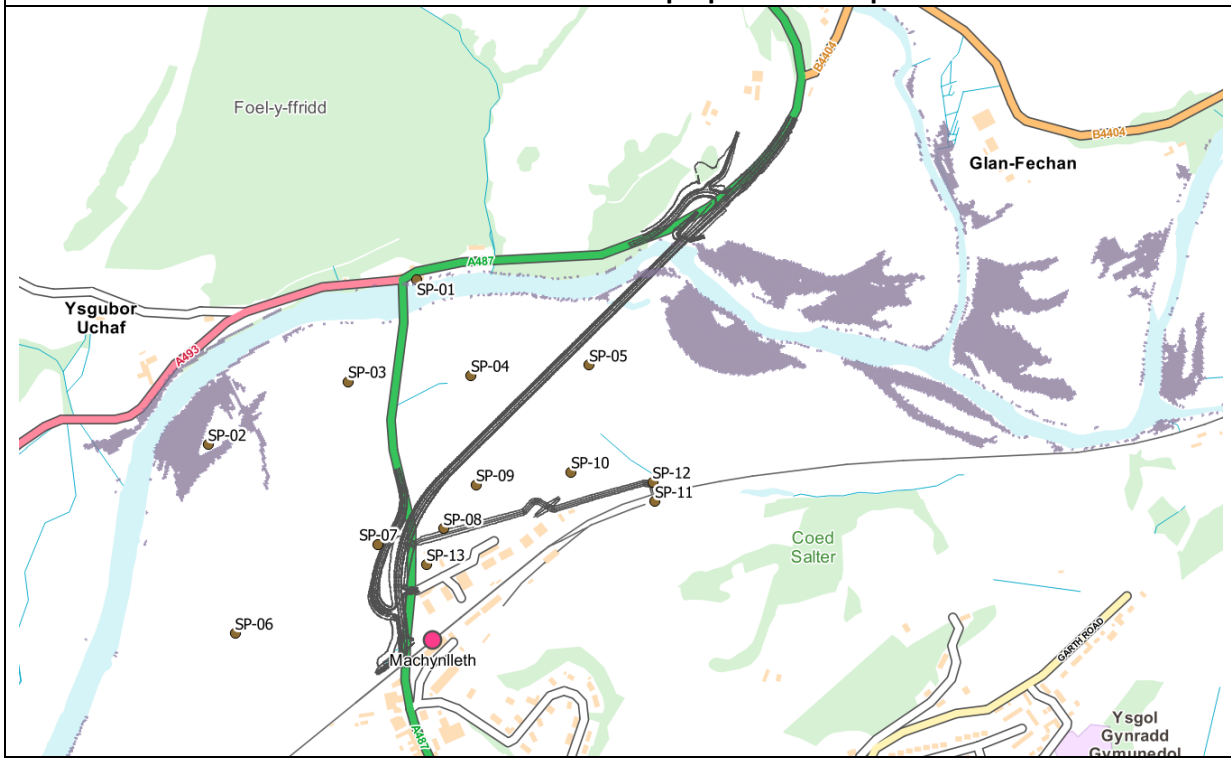
Rev :

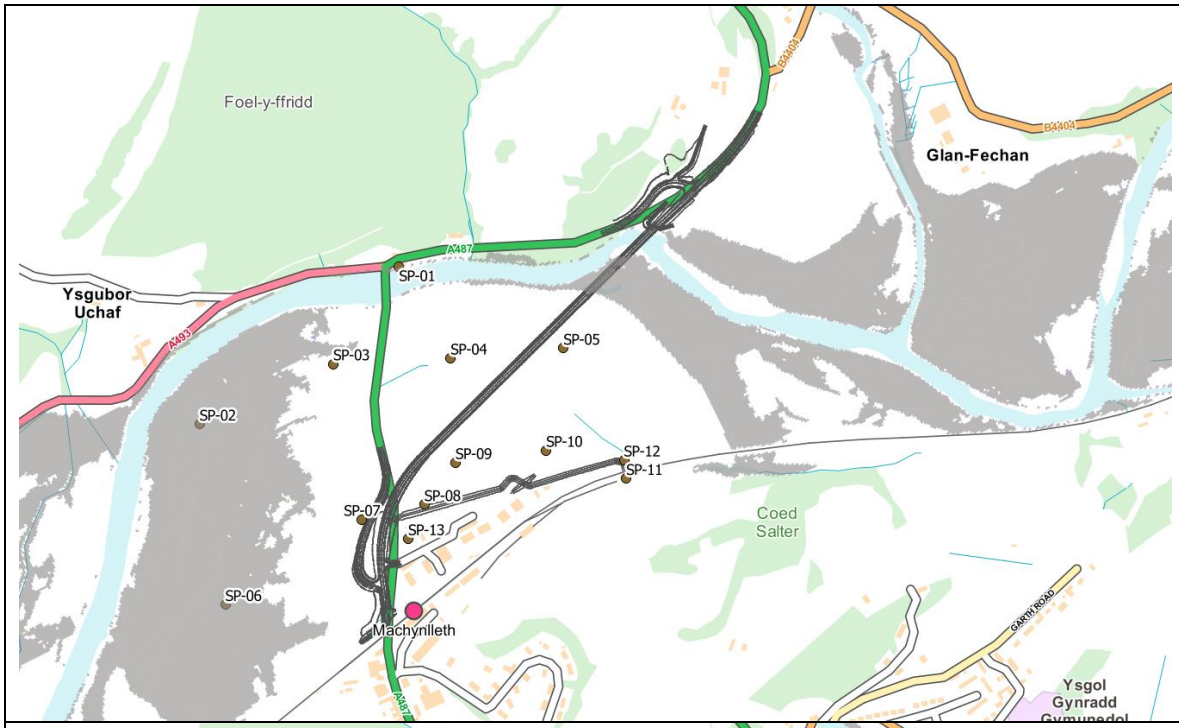
3

WHS

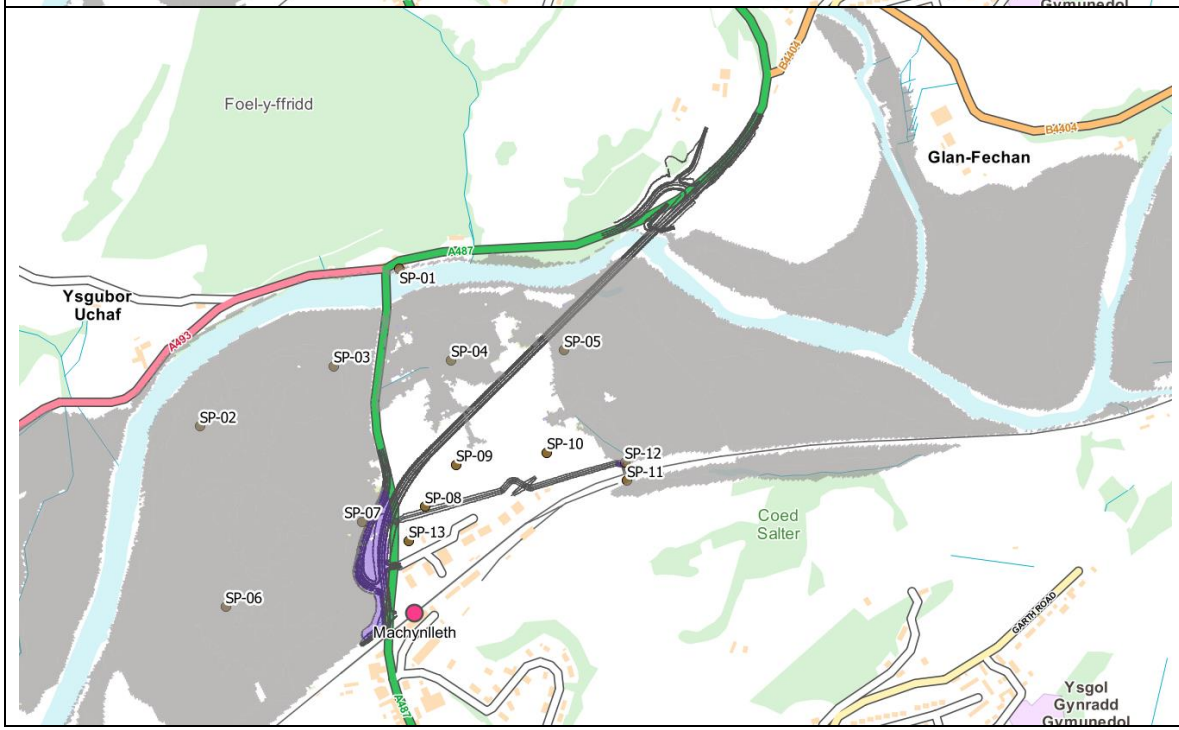
Appendix J

Proposed Model Outputs –
Extents at Hourly Intervals

Model outputs for the 1 in 1000 year flood event at hourly intervals, beginning at Time 7 hours when floodwaters initially spill over the left bank. **The baseline (green) and proposed (purple) model outputs are overlaid, with a transparency setting of 60%. This produces a grey extent, with any purple colours indicating where the flood extent is reduced as a result of the proposed development, and any green colours indicating where the flood extent is increased as a result of the proposed development.**	**Time (hours)**
	**<u>T7 HOURS</u>**

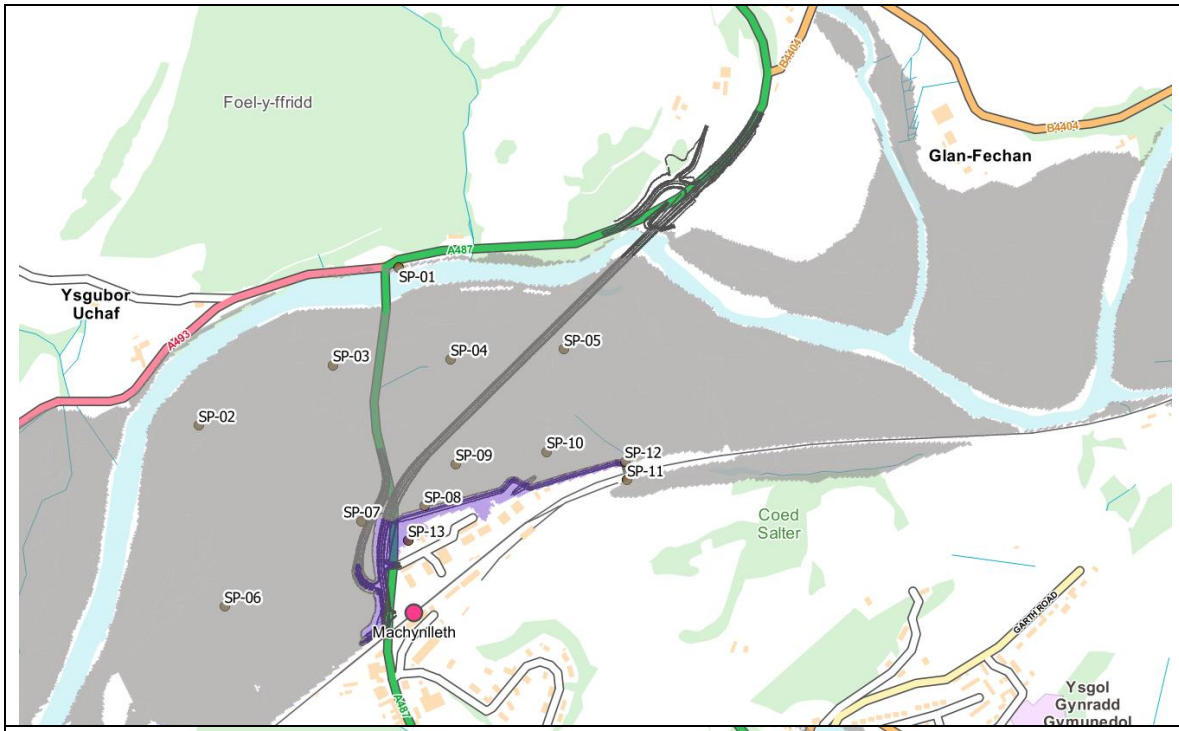


T8 HOURS



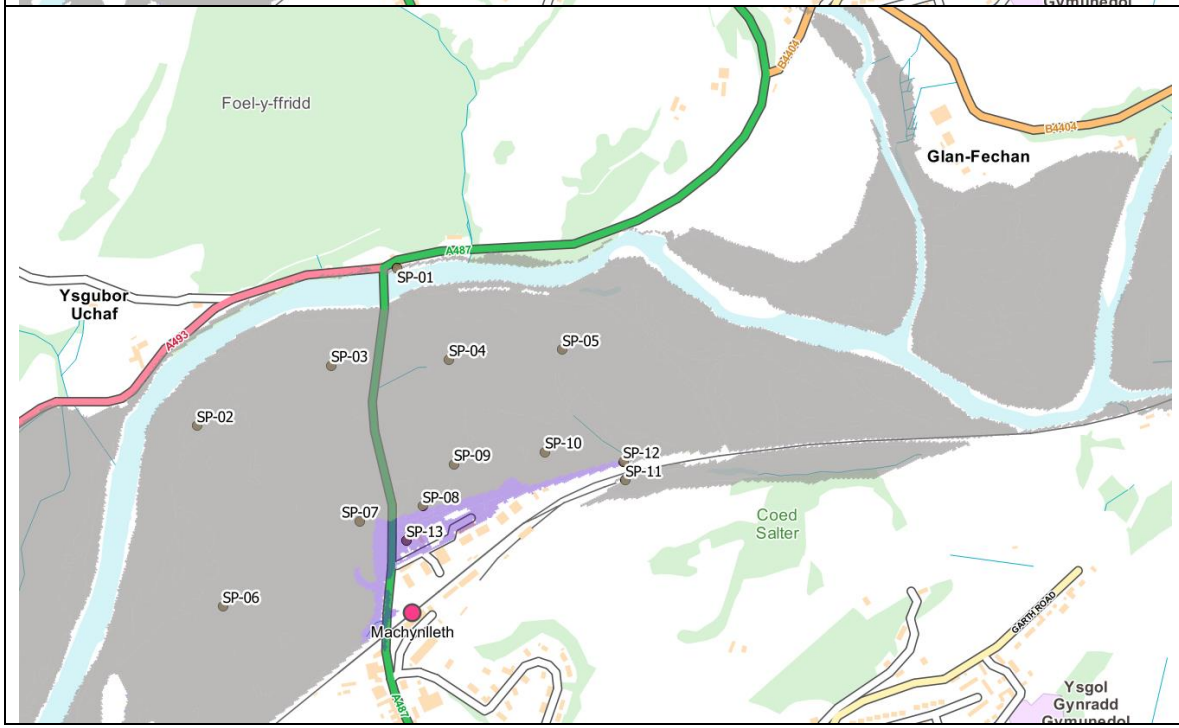
T9 HOURS

The purple colours indicate areas where the onset of flooding is delayed in the proposed scenario compared to the baseline scenario.

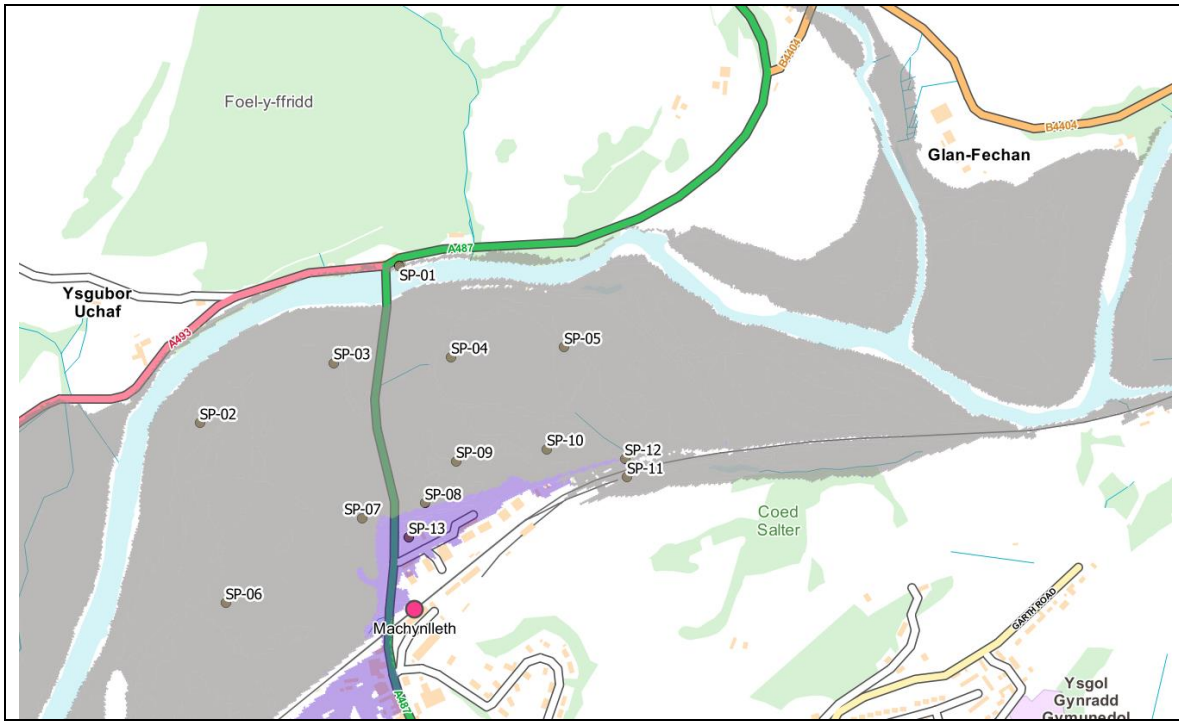


T10 HOURS

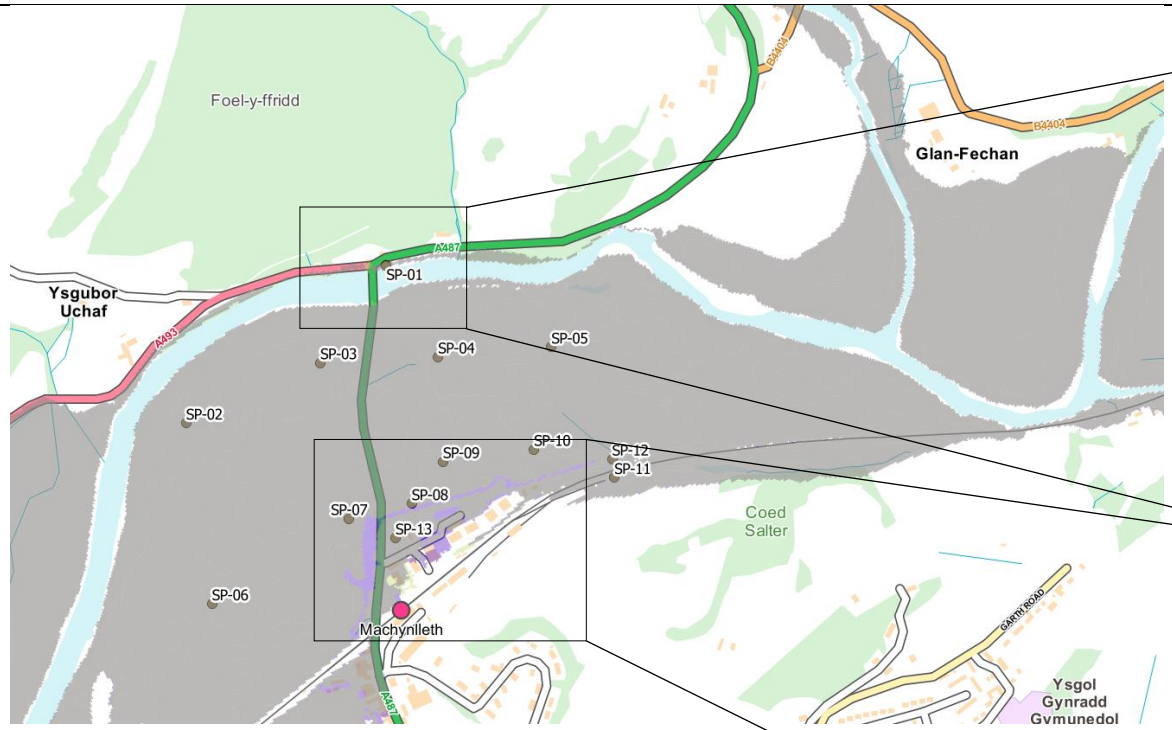
The purple colours indicate areas where the onset of flooding is delayed in the proposed scenario compared to the baseline scenario. It can be seen that the areas within the Dyfi Eco Park that are protected by the raised embankment benefit from a delayed onset of flooding in the proposed scenario.
There are no areas which experience earlier onset of flooding.



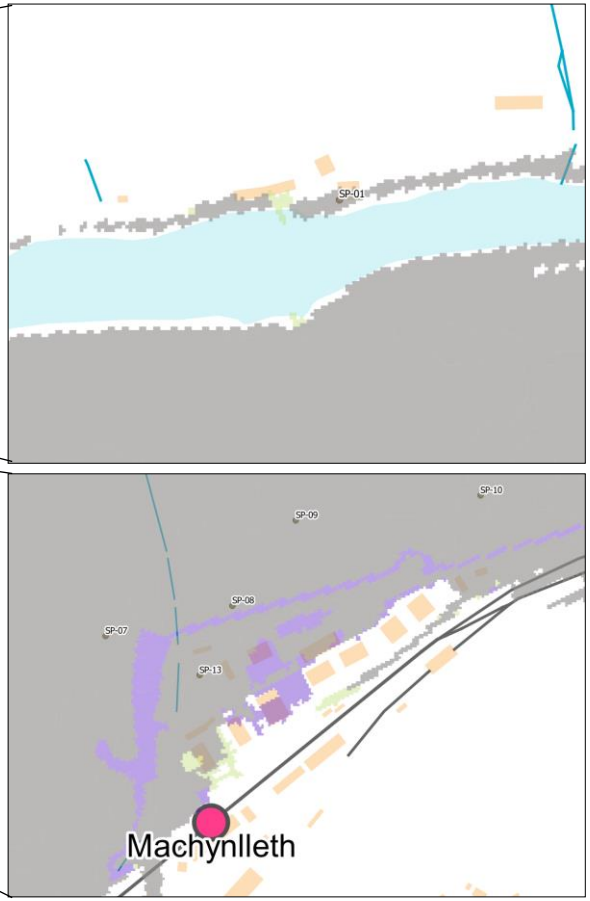
T11 HOURS


Foel-y-ffridd
B4404
Glan-Fechan
A487
SP-01
Ysgubor
Uchaf
A493
SP-03
SP-04
SP-05
SP-02
SP-09
SP-10
SP-12
SP-11
SP-08
SP-07
SP-13
Coed
Salter
SP-06
Machynlleth
GARTH ROAD
Ysgol
Gynradd

T12 HOURS

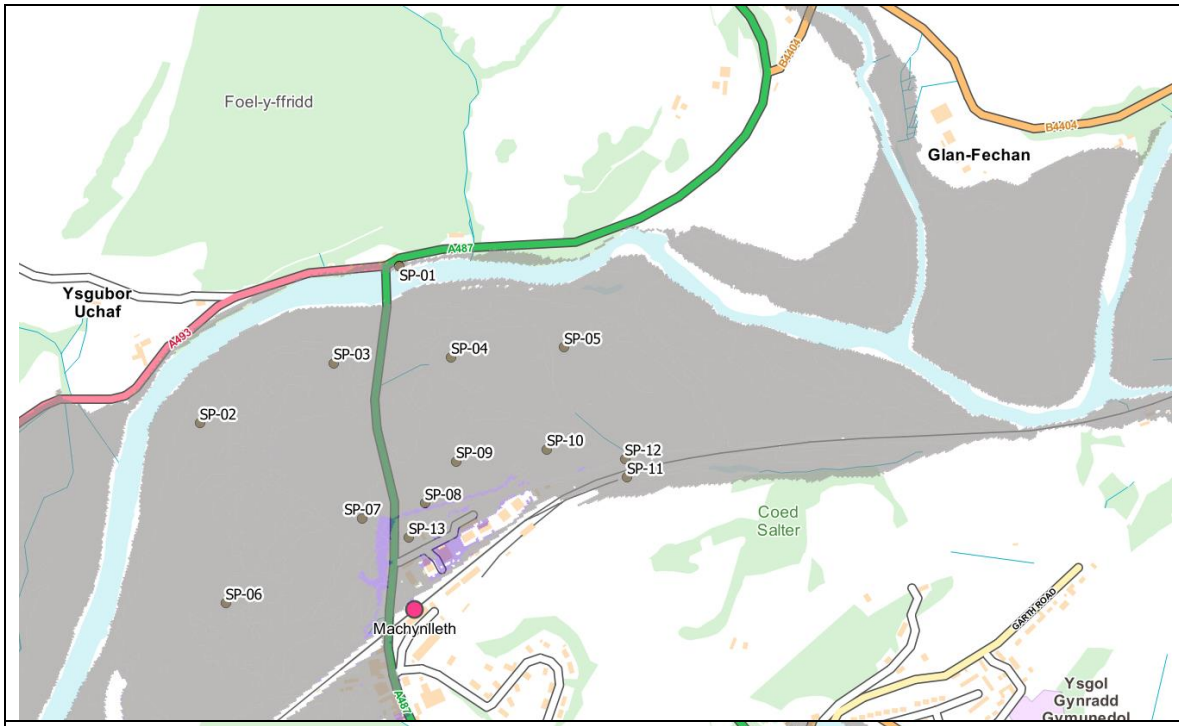


T13 HOURS

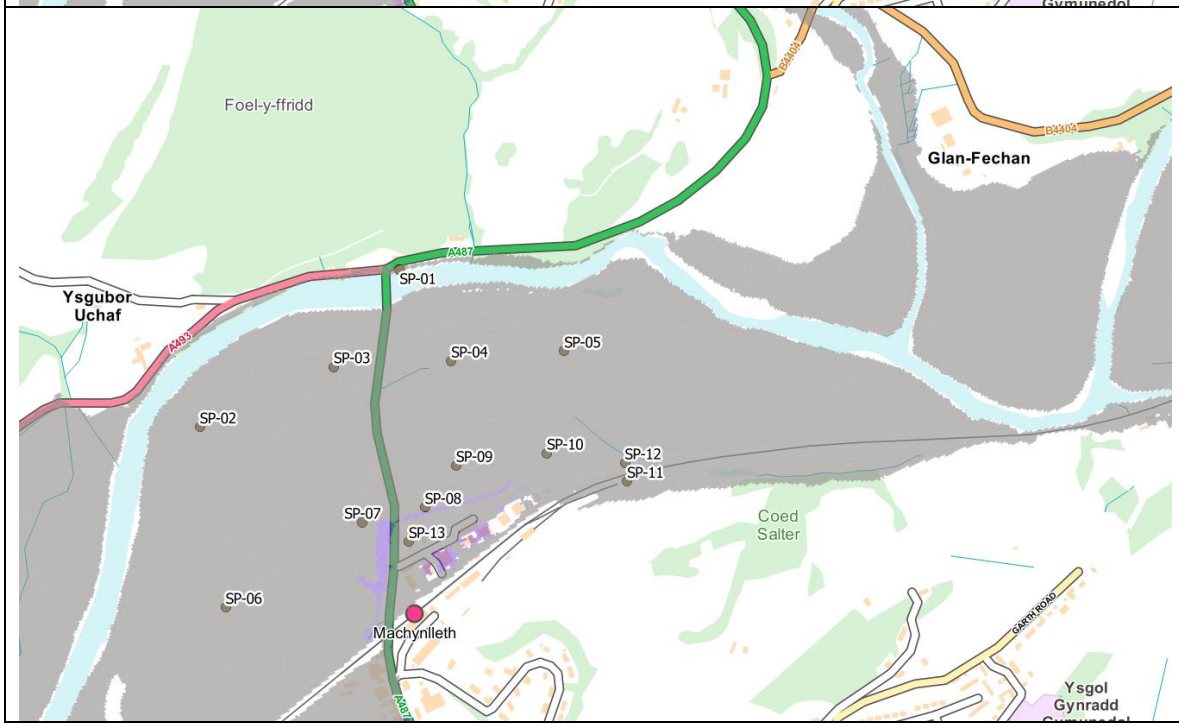


At 13 hours, the earth embankment at the Dyfi Eco Park is breached and flood waters flow into the area, albeit at lesser depths and to a lesser extent when compared to the existing scenario.

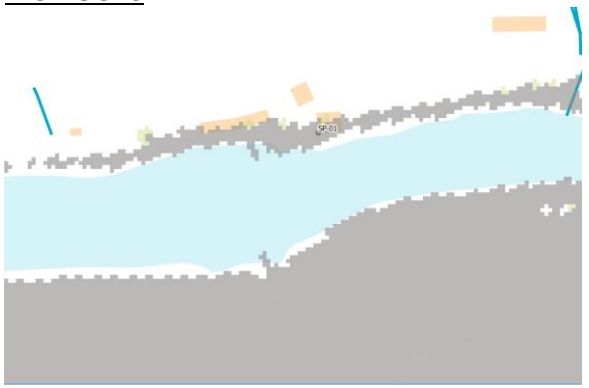
At the properties immediately downstream of the existing Dyfi Bridge, a very minor area is predicted to experience earlier onset of flooding, as shown by the green colours above. The base mapping is removed from this zoomed-in image to display this area more clearly.



T14 HOURS



T15 HOURS



15 hours marks the approximate peak of the flood event. It can be seen in the image above that there is a very minor area where additional flooding is predicted, as shown by the green colours.

Appendix K

Proposed Highway Drainage

A1

N

EMERGENCY PUMP STATION

PROPOSED CATCHMENT 1
Impermeable Area = 0.81 Ha
Permeable Area = 0.62
Outfall to River Dyfi via Petrol Interceptor & Isolation Device

Petrol Interceptor & Pollution Isolation Device

PROPOSED CATCHMENT 3
Impermeable Area = 1.26 Ha
Permeable Area = 2.37 Ha
Outfall via Poltion Interceptor,ditch and isolation device to River Dyfi

Pollution Isolation Device

Ditch to provide treatment and storage

PROPOSED CATCHMENT 2
Impermeable Area = 0.20 Ha
Permeable Area = 0.29 Ha
Outfall to existing stone culvert (size tbc) under Railway via swale and isolation device

Petrol Interceptor

Swale to provide treatment and storage

Pollution Isolation Device

EMERGENCY PUMP STATION

0 10 20 30 40 50 100 Metres
Scale 1:2500

P01.1	---	---	---	---	
DRAFT 3					
Issue	Date	By	Chkd	Appd	

ARUP GRIFFITHS civil engineering and construction WHS
Blythe Gate Blythe Valley Park
Solihull B90 8AE
Tel +44 121 213 3000 Fax +44 121 213 3001
www.arup.com

Client
Llywodraeth Cymru
Welsh Government

Project Title
A487 New Dyfi Bridge

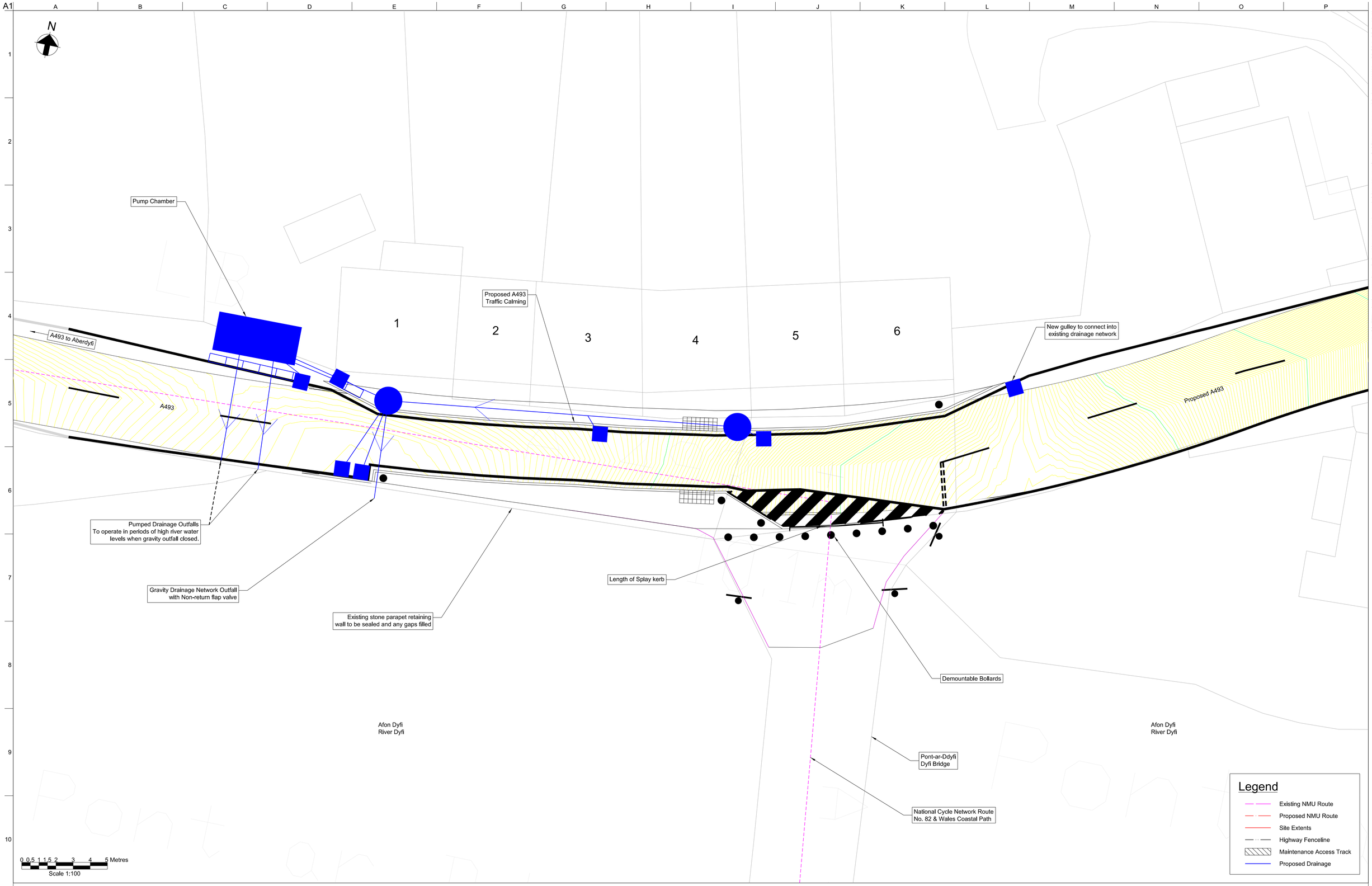
Drawing Title
A487 New Dyfi Bridge
Proposed Highways Drainage Catch

Scale at A1 1:2500
Role Civil Engineer - Drainage
Suitability S0 - Initial non-contractual
Arup Job No 244562-00
Rev P01.1
Name 900237-ARP-ZZ-ZZ-DR-CD-00002

Do not scale

Appendix L

Proposed A493 Pumped Drainage



Notes:

Issue	Date	By	Chkd	Appd
P01.2	---	---	---	---

ARUP GRIFFITHS civil engineering and construction WHS
Blythe Gate Blythe Valley Park
Solihull B90 8AE
Tel +44 121 213 3000 Fax +44 121 213 3001
www.arup.com

Client
Llywodraeth Cymru
Welsh Government

Project Title
A487 New Dyfi Bridge

Drawing Title
A493
General Arrangement

Scale at A1 1:100
Role Civil - Highways
Suitability S0 - Initial non-contractual
Arup Job No **244562-00**
Rev **P01.2**
Name **900237-ARP-OB-05-DR-CH-00102**

S1.002

S1.003

Pont ar Ddyfi

Pont arDdyfi

Ford

Pog Sta

11.9m

Existing Network Details for Storm

PN	Length (m)	Fall (m)	Slope (1:X)	I.Area (ha)	T.E. (mins)	Base Flow (l/s)	k (mm)	HYD SECT	DIA (mm)
S1.000	23.062	0.550	41.9	0.070	4.00	0.0	0.600	o	450
S1.001	5.426	0.073	74.3	0.311	0.00	0.0	0.600	o	450
S1.002	5.818	-2.073	-2.8	0.000	0.00	0.0	0.600	o	450
S1.003	32.466	0.081	400.8	0.000	0.00	0.0	0.600	2 _/	300

Network Results Table

PN	US/IL (m)	Σ I.Area (ha)	Σ Base Flow (l/s)	Vel (m/s)	Cap (l/s)
S1.000	8.050	0.070	0.0	3.15	500.5
S1.001	7.500	0.381	0.0	2.36	375.4
S1.002	7.427	0.381	0.0	0.00	0.0
S1.003	7.412	0.381	0.0	5.21	139749.0

Area Summary for Storm

Pipe Number	PIMP Type	PIMP Name	PIMP (%)	Gross Area (ha)	Imp. Area (ha)	Pipe Total (ha)
1.000	User	-	95	0.074	0.070	0.070
1.001	User	-	95	0.039	0.037	0.037
	User	-	20	1.372	0.274	0.311
1.002	-	-	100	0.000	0.000	0.000
1.003	-	-	100	0.000	0.000	0.000
				Total	Total	Total
				1.484	0.381	0.381

Simulation Criteria for Storm

Volumetric Runoff Coeff	0.750	Additional Flow - % of Total Flow	30.000
Areal Reduction Factor	1.000	MADD Factor * 10m³/ha Storage	2.000
Hot Start (mins)	0	Inlet Coeffiecient	0.800
Hot Start Level (mm)	0	Flow per Person per Day (l/per/day)	0.000
Manhole Headloss Coeff (Global)	0.500	Run Time (mins)	60
Foul Sewage per hectare (l/s)	0.000	Output Interval (mins)	1

Number of Input Hydrographs	0	Number of Storage Structures	0
Number of Online Controls	1	Number of Time/Area Diagrams	0
Number of Offline Controls	0	Number of Real Time Controls	0

Synthetic Rainfall Details

Rainfall Model	FSR	Profile Type	Summer
Return Period (years)	100	Cv (Summer)	0.750
Region	England and Wales	Cv (Winter)	0.840
M5-60 (mm)	18.000	Storm Duration (mins)	15
Ratio R	0.200		

Online Controls for Storm

Level Controlled Pump Manhole: S3, DS/PN: S1.002, Volume (m³): 4.7

Invert Level (m) 7.427 Cut In Height (m) 1.500 Cut Out Height (m) 0.100

Depth (m)	Outflow (l/s)	Depth (m)	Outflow (l/s)	Depth (m)	Outflow (l/s)
0.100	150.0000	1.100	150.0000	2.100	150.0000
0.200	150.0000	1.200	150.0000	2.200	150.0000
0.300	150.0000	1.300	150.0000	2.300	150.0000
0.400	150.0000	1.400	150.0000	2.400	150.0000
0.500	150.0000	1.500	150.0000	2.500	150.0000
0.600	150.0000	1.600	150.0000	2.600	150.0000
0.700	150.0000	1.700	150.0000	2.700	150.0000
0.800	150.0000	1.800	150.0000	2.800	150.0000
0.900	150.0000	1.900	150.0000	2.900	150.0000
1.000	150.0000	2.000	150.0000	3.000	150.0000

Summary of Results for 15 minute 100 year Summer (Storm)

Margin for Flood Risk Warning (mm) 300.0 DVD Status OFF
Analysis Timestep Fine Inertia Status OFF
DTS Status ON

PN	US/MH Name	Water Level (m)	Surcharged Depth (m)	Flooded Volume (m³)	Flow / Cap.	Overflow (l/s)	Pipe Flow (l/s)	Status
S1.000	S1	9.012	0.512	0.000	0.08		31.2	SURCHARGED
S1.001	S2	9.001	1.051	0.000	0.90		151.9	FLOOD RISK
S1.002	S3	8.966	1.089	0.000	1.34		150.0	SURCHARGED
S1.003	S4	7.718	-3.282	0.000	0.00		150.0	OK

Summary of Results for 30 minute 100 year Summer (Storm)

Margin for Flood Risk Warning (mm) 300.0 DVD Status OFF
Analysis Timestep Fine Inertia Status OFF
DTS Status ON

PN	US/MH Name	Water Level (m)	Surcharged Depth (m)	Flooded Volume (m³)	Flow / Cap.	Overflow (l/s)	Pipe Flow (l/s)	Status
S1.000	S1	8.862	0.362	0.000	0.07		29.1	SURCHARGED
S1.001	S2	8.864	0.914	0.000	0.89		151.2	FLOOD RISK
S1.002	S3	8.863	0.986	0.000	1.34		150.0	SURCHARGED
S1.003	S4	7.717	-3.283	0.000	0.00		150.0	OK

Summary of Results for 60 minute 100 year Summer (Storm)

Margin for Flood Risk Warning (mm) 300.0 DVD Status OFF
Analysis Timestep Fine Inertia Status OFF
DTS Status ON

PN	US/MH Name	Water Level (m)	Surcharged Depth (m)	Flooded Volume (m³)	Flow / Cap.	Overflow (l/s)	Pipe Flow (l/s)	Status
S1.000	S1	8.825	0.325	0.000	0.07		29.5	SURCHARGED
S1.001	S2	8.857	0.907	0.000	0.86		145.4	FLOOD RISK
S1.002	S3	8.905	1.028	0.000	1.34		150.0	SURCHARGED
S1.003	S4	7.718	-3.282	0.000	0.00		150.0	OK

Summary of Results for 120 minute 100 year Summer (Storm)

Margin for Flood Risk Warning (mm) 300.0 DVD Status OFF
Analysis Timestep Fine Inertia Status OFF
DTS Status ON

PN	US/MH Name	Water Level (m)	Surcharged Depth (m)	Flooded Volume (m³)	Flow / Cap.	Overflow (l/s)	Pipe Flow (l/s)	Status
S1.000	S1	8.303	-0.197	0.000	0.04		17.3	OK
S1.001	S2	8.412	0.462	0.000	0.62		105.5	SURCHARGED
S1.002	S3	8.914	1.037	0.000	0.91		102.0	SURCHARGED
S1.003	S4	7.714	-3.286	0.000	0.00		104.5	OK

Summary of Results for 240 minute 100 year Summer (Storm)

Margin for Flood Risk Warning (mm) 300.0 DVD Status OFF
Analysis Timestep Fine Inertia Status OFF
DTS Status ON

PN	US/MH Name	Water Level (m)	Surcharged Depth (m)	Flooded Volume (m³)	Flow / Cap.	Overflow (l/s)	Pipe Flow (l/s)	Status
S1.000	S1	8.283	-0.217	0.000	0.03		12.9	OK
S1.001	S2	8.361	0.411	0.000	0.42		71.5	SURCHARGED
S1.002	S3	8.759	0.882	0.000	0.62		69.1	SURCHARGED
S1.003	S4	7.713	-3.287	0.000	0.00		70.5	OK

Summary of Results for 480 minute 100 year Summer (Storm)

Margin for Flood Risk Warning (mm) 300.0 DVD Status OFF
Analysis Timestep Fine Inertia Status OFF
DTS Status ON

WARNING: The analysis maybe unstable. Please see the method of analysis help for more details.

PN	US/MH Name	Water Level (m)	Surcharged Depth (m)	Flooded Volume (m^3)	Flow / Cap.	Overflow (l/s)	Pipe Flow (l/s)	Status
S1.000	S1	8.658	0.158	0.000	0.02		7.6	SURCHARGED
S1.001	S2	8.774	0.824	0.907	0.26		43.5	FLOOD
S1.002	S3	8.926	1.049	0.000	0.42		46.6	SURCHARGED
S1.003	S4	7.707	-3.293	0.000	0.00		50.7	OK

Appendix M

Existing A493 Stone Parapet Wall Structural Assessment

File Note

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Capital Waterside
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Project title	A487 New Dyfi Bridge	Job number	244562
cc	Darren Jones Steve Henry	File reference	
Prepared by	Matthew Wright	Date	19 July 2017
Subject	A493 Wall - Resistance to water surcharging		

The Welsh Government proposes to provide a new section of the A487 trunk road which also incorporates the provision of a new crossing of the River Dyfi, upstream of the existing road bridge, Dyfi Bridge (Pont-ar-Dyfi).

Flood levels, as a result of the proposed A487 New Dyfi Bridge scheme, would increase slightly around the existing bridge Dyfi Bridge. The existing A493 and Pen-y-Bont cottages in the vicinity of the bridge currently suffer from flooding in the existing condition, therefore to mitigate the effects of the scheme, and offer an element of improvement, the flood/ drainage proposal is to provide flood protection to the existing A493 and Pen-Y-Bont cottages by sealing the existing stone parapet retaining wall between the river and A493 to form a flood barrier. This will protect the A493 and Pen-y-Bont cottages from fluvial flood water, and pumps will be installed to deal with rain water.

The existing wall is shown in the Google Streetview screenshot below:

File Note

244562 19 July 2017

The flood analysis shows the retained water depth on the river side of the wall to be a maximum of 578mm as the low point of the A493 carriageway is 9.100m AOD. Refer to table below.

Return Period	Proposed Scheme Flood level	Retained water depth
2yr	9.052m	-
5yr	9.106m	6mm
10yr	9.138m	38mm
30yr	9.182m	82mm
50yr	9.204m	104mm
75yr	9.223m	123mm
100yr	9.237m	137mm
100yr + 30%cc	9.41m	310mm
1000yr	9.678m	578mm

Preliminary stability calculations based on the parapet wall acting as a mass wall above carriageway level show the wall to be sufficient to sustain the loading, based on the following assumptions:

1. If the existing wall is repaired/ re-pointed such that the wall is impermeable and acts as a homogenous mass;
2. There are no flood related impact loads.
3. The wall height is approximately 700mm (based on relative height of adjacent traffic cone in Google Streetview capture above, and initial topo survey information);
4. The wall is approximately 400mm thick, based on topographical survey;
5. The wall density 20kN/m3, assuming 24kN/m3 stone and an allowance for voids between stones.
6. The coefficient of friction between the parapet wall and support at carriageway level is 0.4.

Width (m)	Height (m)	Overturning Moment (kNm)	Restoring Moment (kNm)	Sliding Force (kN)	Friction Force (kN)
0.4	1	0.34	1.06	1.75	2.12

The table below shows utilisations of the wall in overturning and sliding at intermediate values of height and width.
Values in bold and highlighted orange relate to the assumed wall dimensions (700mm height x 400mm width).

Sliding

Height (m) \ Width (m)	0.331	0.375	0.400
0.7	1.00	0.88	**0.82**
0.675	1.03	0.91	0.85
0.65	1.07	0.95	0.89
0.625	1.12	0.98	0.92
0.6	1.16	1.03	0.96
0.577	1.21	1.07	1.00

Overturning

Width (m)		
0.331	0.375	0.400
0.46	0.36	**0.32**
0.48	0.37	0.33
0.50	0.39	0.34
0.52	0.40	0.36
0.54	0.42	0.37
0.56	0.44	0.39

File Note

244562 19 July 2017

It is found that the sliding resistance is the dictating factor in the calculation. The friction force is linearly related to the width of the wall and height of the wall. Therefore a reduction of either one of these variables to approx. 82% of their original value would be acceptable.

Minimum values if a **single** variable changed	
Width (m)	Height (m)
0.331	0.578

As part of the proposed A493 works it also proposed to introduce traffic calming by means of build-outs into the carriageway. These will provide a raised kerb and pavement along the edge of A493 behind the parapet wall, effectively reducing the retained depth of water and increasing the resistance to sliding.

Conclusion

Preliminary calcs show that the existing masonry parapet 400mm wide wall would be sufficient to retain the modelled 1000yr return period fluvial flood event after re-pointing and repair works are carried out.

Calculations have been based on the worst case location (at low point of A493 carriageway). At other locations along the wall the carriageway level is higher so retained depth of water would be less.

Further detailed condition survey of the wall will be carried out during detailed design to confirm assumptions and proposed works.

Note that this File Note **does not** make an assessment of scour.

DOCUMENT CHECKING (not mandatory for File Note)

	Prepared by	Checked by	Approved by
Name	Matthew Wright	Darren Jones	Steve Henry
Signature			

Appendix N

Correspondence with No.7 Dyfi Bridge

MORRIS MARSHALL & POOLE

Chartered Surveyors
Auctioneers
Estate Agents
Established 1862
www.morrismarshall.co.uk

Minafon, 7 Dyfi Bridge
Machynlleth, SY20 9JP

• Period Cottage, believed to be a former Huntsman Lodge on the Londonderry Estate • On Banks of River Dyfi • 2 Bedrooms; In need of improvements • Garden & Range of Outbuildings • Separate Garden areas • EER = G1 • •

THE GUILD OF PROFESSIONAL ESTATE AGENTS

Asking price £80,000

Machynlleth Office 01654 702 472 machynlleth@morrismarshall.co.uk

General Remarks & Situation Located about a mile from the town centre, a 2 bedroom period cottage with stunning views over the River Dyfi towards the town & hills beyond. In need of some improvement works, the property was believed to be a former Huntsmans Lodge to the Londonderry Estate in the 18th & 19th Century.

Accommodation

Ground floor

Hall Stairs off

Lounge 18'2" x 9'5" (5.54m x 2.87m) Open fireplace. Back boiler heating domestic hot water. 2 Windows.

Kitchen 9'8" x 9'2" (2.95m x 2.79m) Fully tiled walls. Range of wall & base units to 3 walls. Double drainer stainless steel sink unit. Good River views. Plumbing for automatic washing machine

First floor

Landing

Bedroom (1) 15'10" x 9'8" (4.83m x 2.95m) Exposed roof truss. Exposed purlins. Range of wardrobes and dressing tables.

Bedroom (2) 21'6" x 9'8" (6.55m x 2.95m) Airing cupboard. Exposed purlins.

Bathroom Panelled bath with electric shower over. Pedestal wash basin & low level WC.

Outside Double entrance gates lead off the road to a parking area with space for 2 vehicles. Small lawn and grounds leading down to the River. 2 Store sheds and large outbuilding (formerly garage). Lean to store to the front of the property. Further garden areas, overgrown, within walking distance of the property.

Tenure Freehold with Vacant Possession upon Completion of the Purchase.

Services Mains water, electricity and drainage. None of the services, appliances, central heating system, chimneys flues and fireplaces have been checked and no warranty is given by the Agents.

Outgoings Council tax band 'B'

Energy Performance Certificate A full copy of the EPC is available on request or by following the link below:
Public EPC URL:
https://www.epcregister.com/direct/report/0441-2825-7829-9306-5865

Viewing By arrangement with the selling agents Machynlleth office on - 01654 702472

Negotiations All interested parties are respectfully requested to negotiate direct with the Selling Agents.

Directions Leave the town along Penrallt Street, leave the town passing under the railway bridge and pass over the Dyfi Bridge. Minafon is the first property on the right.

Website To view a complete listing of properties available For Sale or To Let please view our website www.morrismarshall.co.uk Our site enables you to print full sales/rental particulars, book viewings, register your requirements on our mailing list and arrange a valuation of your property.

Ref.: Machynlleth Office: Tel: 01654 702472
Ref: NPE/JF/007537/M Date: 01/16

MMP Survey Department If you dont find the home of your dreams through Morris Marshall & Poole then why not let our qualified surveyors inspect and report on the home you have found before you complete the purchase. We are able to undertake RICS HomeBuyer Reports and RICS Condition Reports that will provide you with a comment on any significant defects or repair items. For further information contact any of our offices.

From: Jeremy Paige [redacted]
Sent: 17 August 2017 10:19
To: Julian Davies
Subject: Re: FW: A487 New Dyfi Bridge - Minafon (No 7 Pont ar Ddyfi)

Acknowledged as accurate record of meeting.
Kind regards,
Jeremy Paige

On 17 Aug 2017 10:15, "Julian Davies" [redacted] wrote:

From: Julian Davies
Sent: 09 August 2017 15:49
To: [redacted]
Cc: Mandy Evans; Richard Bruten; David Rowlands; Steve Henry
Subject: A487 New Dyfi Bridge - Minafon (No 7 Pont ar Ddyfi)

Jeremy
Thanks for your time this morning allowing me to talk through with yourself details of the proposed New Dyfi Bridge Scheme.
In particular I was concerned that you were made aware of the proposed improvement scheme and the impact to the flood water levels around your property. The flood modelling indicates an increase of approx. 60mm at your property and around Pont ar Ddyfi in a 1:100 (plus climatechange) flood event. This increase in level will not impact on the residential part of the property as the threshold is well above flood level but will continue to flood the basement (currently not habitable space).I confirm that you considered that this slight increase in flood water level will have no adverse effect on the property.

I also confirm that we also briefly discussed the following matters:

- Scheme alignment and development – the scheme comprises some 725 metres of viaduct/bridge across the flood plain and river with a new T junction with the A493 north of the river at Y Yfridd
- De-trunking of the A487 south of the bridge – reverts to Powys County Council and provides of access for landowners/farmers, parking areas for tourists/walkers and anglers
- De- trunking of A487 north of river becoming the A493 with a changed priority to traffic (no junction) north of Pont ar Ddyfi where there is proposed traffic calming (agreed with Gwynedd Council)
- Traffic calming north of the bridge comprising build outs in front of the cottages and in front of the retaining wall to reduce the width of road and to slow vehicles down (with associated speed restriction and signage)
- Pont ar Ddyfi will be closed to vehicles with bollards north and south of the structure – allows access for pedestrians/cyclists and farm vehicles only at times of flooding
- Flood mitigation A493 and Dyfi Cottages – there will be additional flood mitigation measures carried out around the cottages including a small pumping station

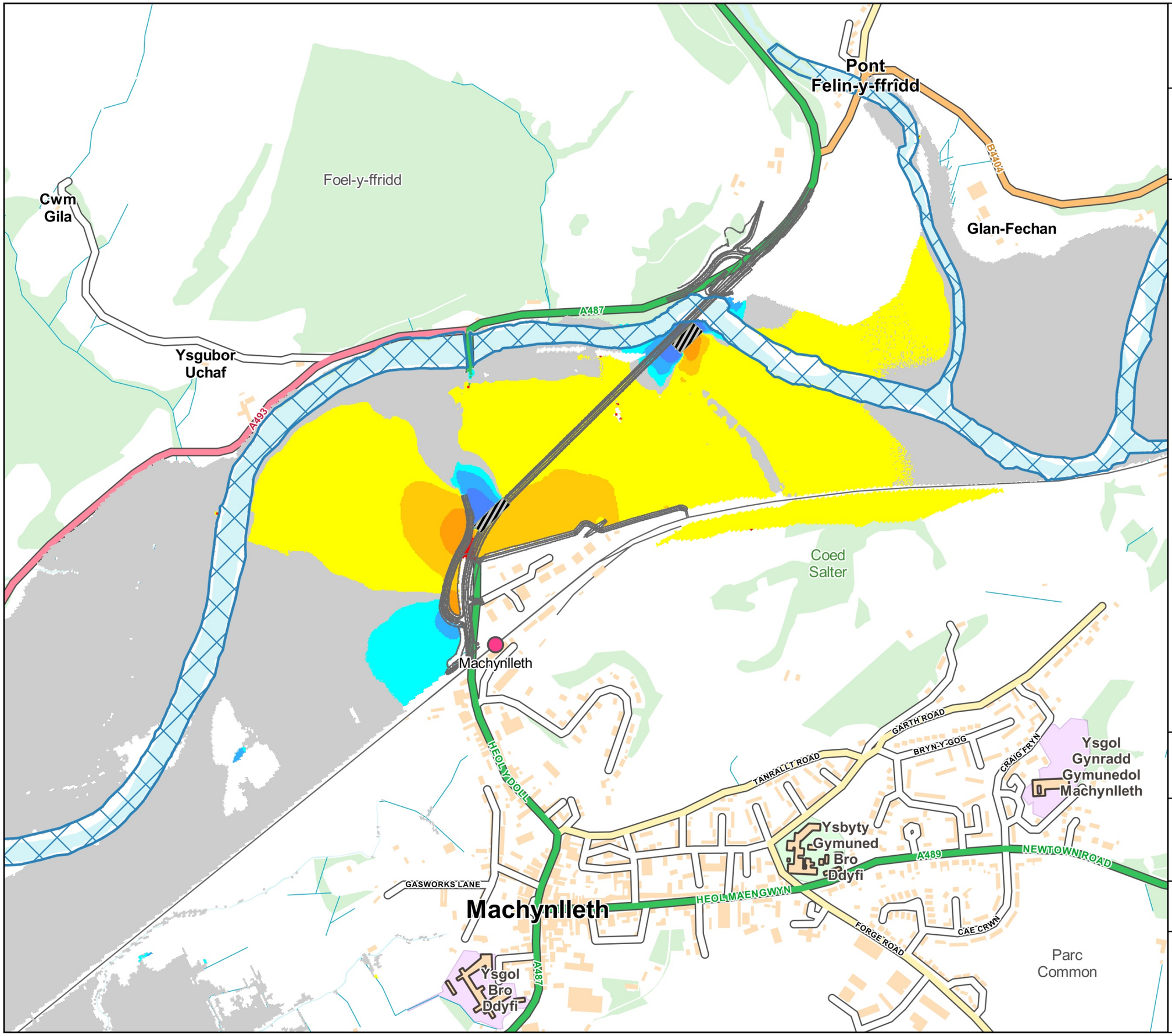
If you require any further information please give me a call.
In the interim I would be pleased if you could acknowledge this e mail as a record of our meeting this morning.
Thanks again.
Regards

Julian

Alun Griffiths (Contractors) Ltd
Tel 01873 857211
Mob 07977 280470

Appendix O

Temporary Works Model Outputs



Project :

A487 New Dyfi Bridge

Client :

GRIFFITHS civil engineering and construction

ARUP

Legend :

- River Dyfi and Tributries
- Propose Scheme
- Temporary Works

Change in Flood Depth (m)

- < -0.10
- -0.10 to -0.05
- -0.05 to -0.02
- -0.02 to -0.005
- -0.005 to 0.005
- 0.005 to 0.02
- 0.02 to 0.05
- 0.05 to 0.10
- > 0.10

Scale :

0 200 400 m

Title :

Impact of Proposed Development
With Temporary Works
1 in 2 year flood event

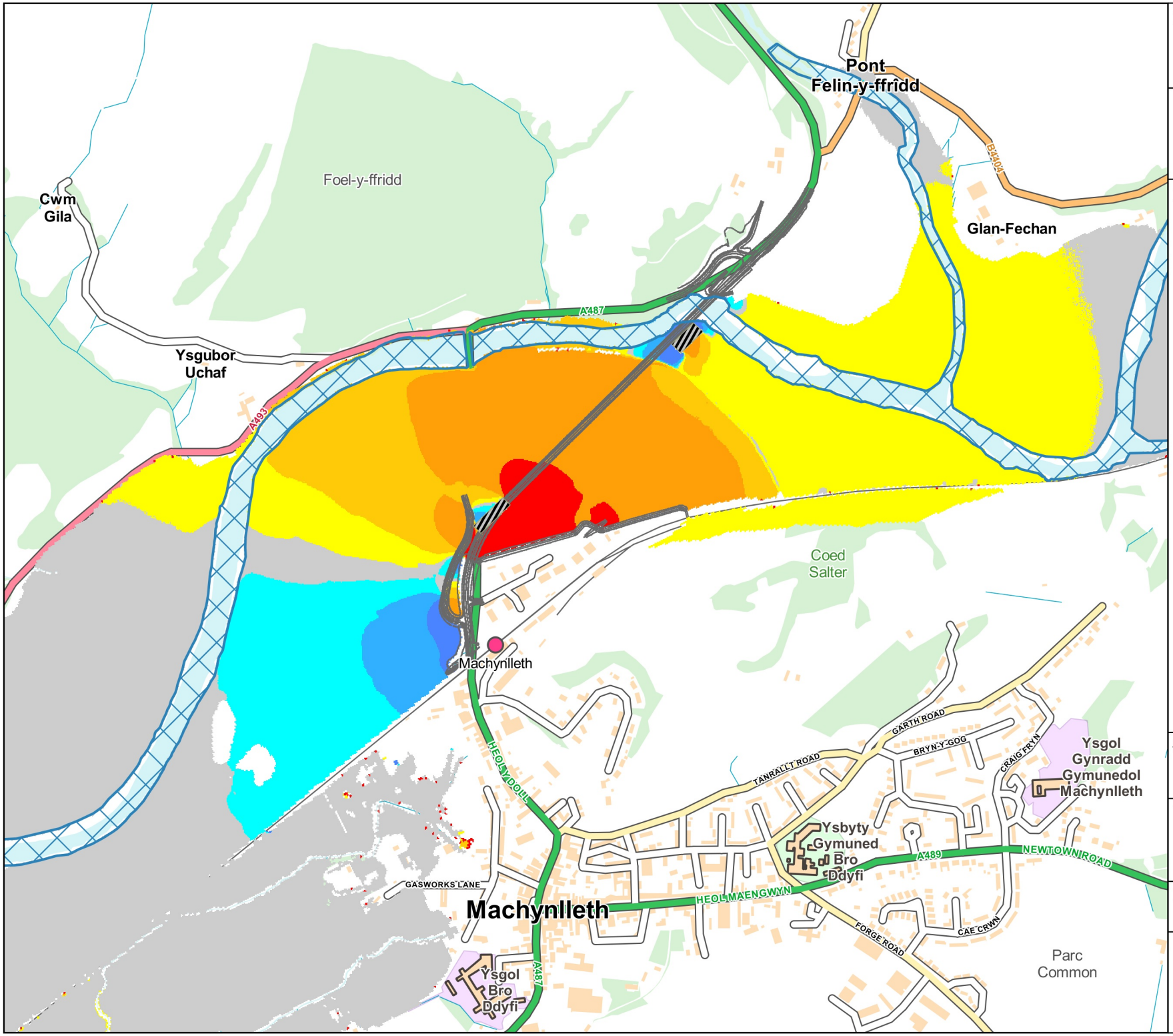
Drawing :

WHS1345-F10-0015

Rev :

4

WHS



Project :

A487 New Dyfi Bridge

Client :

GRIFFITHS civil engineering and construction

ARUP

Legend :

- River Dyfi and Tributries
- Propose Scheme
- Temporary Works

Change in Flood Depth (m)

- < -0.10
- -0.10 to -0.05
- -0.05 to -0.02
- -0.02 to -0.005
- -0.005 to 0.005
- 0.005 to 0.02
- 0.02 to 0.05
- 0.05 to 0.10
- > 0.10

Scale :

0 200 400 m

Title :

Impact of Proposed Development
With Temporary Works
1 in 100 year flood event

Drawing :

WHS1345-F10-0016

Rev :

4

WHS