



Wylfa Newydd Project

6.6.16 ES Volume F - Park and Ride App F8-1 - Dalar Hir - Flood Consequence Assessment

PINS Reference Number: EN010007

Application Reference Number: 6.6.16

June 2018

Revision 1.0

Regulation Number: 5(2)(a) and (e)

Planning Act 2008

Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009

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1 Introduction

1.1 Overview

- 1.1.1 This Flood Consequence Assessment (FCA) describes the assessment of flood risk from all local sources resulting from the operation and decommissioning of the Park and Ride at Dalar Hir. The FCA assesses the flood risk posed to the proposed Park and Ride areas as well as any changes to flood risk arising from the Park and Ride.
- 1.1.2 The hydrological baseline is outlined in chapter F8 (surface water and groundwater) (Application Reference Number: 6.6.8), information from which is used in this FCA. This FCA should be read in conjunction with chapter F8 (Application Reference Number: 6.6.8).
- 1.1.3 Consultation with relevant statutory bodies has taken place during preparation of this FCA. A record of consultation can be found in section 8.3 of chapter B8 (surface water and groundwater) (Application Reference Number: 6.2.8).

1.2 Site location and study area

- 1.2.1 The proposed Park and Ride site is located at Dalar Hir as illustrated in figure F8-1-1. There are a number of watercourses within 500m of the proposed Park and Ride site that have the potential to affect or be affected by the Park and Ride. These are described in section 3 of this FCA.
- 1.2.2 In general, the surface water study area is 500m in all directions around the proposed Park and Ride site (figure F8-1-1). However, when assessing the study area, it was noted that a Site of Special Scientific Interest (SSSI) was located downstream, albeit outside of the study area. Therefore, for the purpose of this FCA, the study area includes Llyn Traffwl SSSI which is 900m downstream of the proposed Park and Ride.
- 1.2.3 The proposed Park and Ride site consists of a series of agricultural fields bounded to the south by Holyhead Road (A5). The A55 runs parallel to and immediately south of the Holyhead Road. The proposed Park and Ride site is located within the base of a shallow valley that is orientated broadly north to south. A topographical survey of the site is provided in appendix F8-1-1. The proposed Park and Ride site is generally flat. At the eastern boundary, adjacent to the Cartio Môn go-karting centre, the land is approximately 17.8m AOD and about 17m AOD to the western extent, adjacent to the road.

1.3 Technical Advice Note (TAN) 15 Development Advice Map

- 1.3.1 There are two initial reference maps for assessing the level of fluvial and tidal flood risk associated with land: the TAN 15 Development Advice Map [RD1] and the Natural Resources Wales (NRW) flood map of fluvial flood risk [RD2]. These are broadly similar, although the NRW flood map provides additional

detail in relation to flood probability. The TAN 15 Development Advice Map, which shows the fluvial and coastal flood zones as issued by the Welsh Government, is primarily used in this assessment as the TAN 15 Development Advice Maps form the basis of assessment of flood risk in accordance with planning policy.

1.3.2 The TAN 15 flood zones are defined as follows:

- Zone A: Considered to be at little or no risk of fluvial or coastal/tidal flooding;
- Zone B: An area known to have been flooded in the past as evidenced by sedimentary deposits;
- Zone C1: An area with an annual probability of flooding from river, tidal or coastal sources equal to or greater than 0.1%, but which are developed and served by significant infrastructure including flood defences; and
- Zone C2: An area with an annual probability of flooding from river, tidal or coastal sources equal to or greater than 0.1% and without significant flood defence infrastructure.

1.4 Planning guidance for a FCA

1.4.1 In Wales, Planning Policy Wales (PPW) [RD3] and TAN 15: Development and Flood Risk [RD4] provide the national policy framework for the assessment and management of flood risk for new developments. Taken together, they establish a presumption against development in areas at the highest risk of flooding, setting a framework for the sequential assessment of the suitability of sites for development. They also set out an assessment methodology (the FCA methodology) for the systematic evaluation of flood risk and the need to integrate mitigation and flood resilience in the design of new development. This FCA has been written to address the planning policy requirements for the Park and Ride, in association with TAN 15 guidance.

1.5 Report objectives

1.5.1 The objectives of this FCA are to:

- identify possible mechanisms by which the proposed Park and Ride site could flood;
- identify any aspects of the design that could exacerbate flooding elsewhere;
- undertake a formal assessment of the risks posed to the Park and Ride from all identified flood risk sources and mechanisms;
- confirm that the Park and Ride would not exacerbate flooding elsewhere;
- consider the level and acceptability of any residual flood risk; and
- produce an FCA compliant with TAN 15 and PPW.

2 Policy and planning

2.1 Planning context

- 2.1.1 The context for planning policy in Wales is set out within PPW [RD3]. This provides the national policy framework for the assessment and management of flood risk for new developments and references a range of European and national legislation that relates to the flood risk. This is supplemented by TAN 15 [RD4] and local planning policy. Although there is other legislation and guidance relevant to flood risk (including National Policy Statement for Energy (EN-1) (NPS EN-1) and Policy Statement for Nuclear Power Generation (EN-6) (NPS EN-6), this is discussed in section 8.2 of chapter B8 (Application Reference Number: 6.2.8) and is not repeated in this FCA.

2.2 PPW

- 2.2.1 The objective of PPW is to avoid the construction of new development within areas defined as being at flood risk, with planning authorities adopting a precautionary approach when formulating development plan policies, including the principle that climate change will likely increase the risk of coastal and river flooding. A strategic approach to flood risk that considers the catchment as a whole is encouraged.
- 2.2.2 PPW states that new development should not be at risk of flooding itself and should not increase the risk of flooding elsewhere. Additionally, hard-engineered flood defences should be considered likely to be unsustainable in the long term, and new development should avoid development in flood hazard zones.
- 2.2.3 Only essential transport and utilities infrastructure is considered acceptable within unobstructed floodplains, and then only when such infrastructure is designed to remain operational during times of flooding and with no net loss of floodplain storage or increase flood risk elsewhere.

2.3 TAN 15

- 2.3.1 TAN 15 provides technical guidance that supplements the policy set out in PPW in relation to development and flooding. It advises on development and flood risk relating to sustainability principles and provides a framework within which risks arising from both river and coastal flooding, and from additional runoff from development in any location, can be assessed. This incorporates climate change scenarios.
- 2.3.2 TAN 15 provides guidance on flood consequences that may not be acceptable for particular types of development. The location of the development needs to be justified in line with TAN 15 and flood risk areas, and the consequence needs to be acceptable given the vulnerability and use of the receptor.
- 2.3.3 Development should be directed towards Flood Zones A and B and will only be acceptable in Flood Zones C1 and C2 if it is necessary as part of a local

regeneration scheme or to sustain an existing settlement or if key to support employment objectives.

- 2.3.4 The guidance defines a threshold for the frequency of flooding below which development should not be allowed. This threshold for General Infrastructure is equivalent to the 1% Annual Exceedance Probability (AEP) event, or an event with a 1 in 100 chance of occurring in any given year, for fluvial flooding and it is equivalent to the 0.5% AEP event, or an event with a 1 in 200 chance of occurring in any given year, for tidal flooding. Additionally, the depth of flooding, regardless of development type, should not be greater than 1m for any return period. These thresholds automatically apply to all developments in Flood Zones A and B and to those in Flood Zone C once the justification test has been passed. A justification test is a set of criteria only applicable to developments located in Flood Zone C, which must be considered for the development to take place.
- 2.3.5 It is also a requirement of TAN 15 that future users and occupiers of all types of development are adequately aware of the flood risk and consequences, that effective flood warning is provided, that emergency flood plans are available and that safe access and egress are available. There is also a requirement that the site is designed to facilitate movement of goods/possessions away from flooding, to minimise structural damage and to facilitate recovery.
- 2.3.6 TAN 15 also states that new development should not increase flooding elsewhere; however, it acknowledges that there may be practical difficulties in achieving this aim.
- 2.3.7 TAN 15 states that consideration must be given to the impacts climate change may have on the risk of flooding over the lifetime of a development, to ensure that development does not take place where flooding would be unacceptable either now or in the future. The Welsh Government has provided guidance (CL-03-16) [RD5] on how the UK climate changes projections (UKCP09) [RD6] for increases in river flows should be used to determine the future flood consequences for developments in Wales; they must be incorporated in all FCAs produced after December 2016.

2.4 Local planning policy

- 2.4.1 The Anglesey and Gwynedd Joint Local Development Plan forms the basis for land use planning in the Anglesey and Gwynedd areas. The Written Statement was published in 2017 [RD7] and is the main source of local planning policy. Within the Plan, the strategic objectives in relation to flood risk are the following.

Strategic Objective 6 (SO6): *“Minimise, adapt and mitigate the impacts of climate change. This will be achieved by: ensuring that highly vulnerable development is directed away from areas of flood risk wherever possible;.....”*.

Strategic Objective 8 (SO8): *“Ensure that settlements are sustainable.....”*. This will be achieved by, amongst others, ensuring that: *“new developments that are vulnerable to harm will not be located in areas at risk from flooding”*.

- 2.4.1 In order to adapt to the effects of climate change Policy PS 6 (Alleviating and adapting to the effects of climate change) requires proposals to take account and respond to a number of concerns, including: *“Locating (developments) away from flood risk areas, and aim to reduce the overall risk of flooding within the Plan area and areas outside it, taking account of a 100 years and 75 years of flood risk in terms of the lifetime of residential and non-residential development, respectively, unless it can be clearly demonstrated that there is no risk or that the risk can be managed”* and to: *“Aim for the highest possible standard in terms of water efficiency and implement other measures to withstand drought, maintain the flow of water and maintain or improve the quality of water, including using sustainable drainage systems”*.
- 2.4.2 The Anglesey and Gwynedd Joint Local Development Plan Stage 1 Strategic Flood Consequence Assessment [RD8] forms a key part of the evidence base for planning with respect to review of FCAs. The document helps to determine appropriate development policies and land allocations that avoid or minimise flood risk from all sources, and helps to assess any future development proposals in line with the precautionary framework in PPW and TAN 15. This document and the IACC’s *Preliminary Flood Risk Assessment* [RD9] include information on surface water, groundwater, ordinary watercourses and small reservoir flooding. Information on the IACC flood strategy and the Council’s objectives in managing flood risk is provided in the *Anglesey Local Flood Risk Management Strategy* [RD10].

2.5 River Basin Management Plan

- 2.5.1 The proposed Park and Ride site is wholly located within the Western Wales River Basin. The Western Wales River Basin Management Plan for 2015 – 2021 [RD11] provides an overview of NRW’s approach to managing flood risk within the Western Wales River Basin. It details measures designed to reduce the potential for flooding, such as use of sustainable drainage systems and improvements and maintenance of flood defence schemes. In addition, the plan proposes improving the understanding of flood risk through the application of mapping and modelling.

3 Baseline site context

3.1 Climate

- 3.1.1 Twenty years of rainfall data are available from the NRW-operated Llyn Alaw rain gauge, which lies 9km to the north-east of the proposed Park and Ride. The RAF Valley rain gauge (approximately 3km to the south-south-west of the Park and Ride) comprises more than 50 years of digitised hourly data (1960–2017). Prior to this, data are only available in analogue form.
- 3.1.2 The Met Office average annual rainfall data available online (UK Met Office, 2015), for the period 1981 to 2010, shows an average annual rainfall at RAF Valley of 841mm/yr. This is below the UK average of 1154mm/yr. The long-term data indicate that rainfall is typically higher in the late autumn/early winter and lowest in late spring/early summer.
- 3.1.3 These two sources of data provide meteorological context of the area. Details of the meteorological data used further in this assessment are contained in appendix F8-1-3.

3.2 Landscape

- 3.2.1 The land proposed for the Park and Ride is in an open landscape. A plan of the land and surrounding area is provided in figure F8-1-1. The vegetation pattern in the vicinity of the proposed Park and Ride site includes hedgerows with dense linear belts of planting. There are also a number of rocky outcrops present within the site and in the surrounding area.

3.3 Topography

- 3.3.1 The proposed Park and Ride would be located at approximately 15–20m AOD. The proposed Park and Ride site is relatively flat with a slight slope down to the Nant Dalar Hir, which runs from north to south at the eastern site boundary. The eastern bank of the watercourse is at a level of approximately 15.5m AOD on approach to the culvert under the A5. The topographic survey is provided in appendix F8-1-1.
- 3.3.2 The proposed Park and Ride site has a low spot on the southern extent where the elevation drops to 14.6m AOD. This extends along the southern boundary and into the centre of the site in a shallow bowl shape. It is assumed that this is a former natural route of the Nant Dalar Hir which has since been diverted to the east along field boundaries.
- 3.3.3 Approaching the western side of the proposed Park and Ride site, there is a raised area (21m AOD) before the land drops towards the road to Bodedern (London Road) at 16.47m AOD.

3.4 Off-site receptors

- 3.4.1 The proposed Park and Ride site is located immediately to the north of the A55 and A5 roads. These roads provide the main access routes across Anglesey, from the mainland to Holyhead. The topography of the area is such that water drains across the proposed Park and Ride site towards the roads. The roads are, however, slightly raised above the natural ground level.
- 3.4.2 Downstream of the proposed Park and Ride site on the Nant Dalar Hir is the Llyn Traffwll Site of Special Scientific Interest. The site is of biological interest with rare species of flora. It is also important for overwintering wildfowl. Lake water levels are critical to maintaining the habitats and are controlled by a sluice on the outfall stream.
- 3.4.3 Adjacent to the east of the proposed Park and Ride is the Cartio Môn go-karting centre. There are a number of farmsteads and private homes in the study area (see section 8.2 of chapter F8 (Application Reference Number: 6.6.8) for details of the study area). Bryn Farm (to the south-west), Heulfre (to the west), Dalar-bach (to the north), The Vicarage (to the north-east), Bryngoleu (to the east) and Alltwen-ddu (to the south-east). South of the proposed Park and Ride site, on the other side of the A55, there is a transmitting station and Caer Elen Farm which is downstream on the Nant Dalar Hir. These are all shown on figure F8-1-1.
- 3.4.4 All off-site developments are classed as highly sensitive to flooding by TAN 15 [RD4]. Undeveloped land is classed as having a medium sensitivity.

3.5 Surface water features

- 3.5.1 Figure F8-1-1 shows the surface water features of the proposed Park and Ride site. A small stream flows from the north to the south along the base of the valley. Ordnance Survey mapping does not provide a name for this watercourse, which will be referred to throughout this FCA as the Nant Dalar Hir. Nant Dalar Hir is fed by runoff from surrounding agricultural fields.
- 3.5.2 At the point where the Nant Dalar Hir reaches the site boundary it is estimated (using the Flood Estimation Handbook CD ROM v3 [RD12]) that the watercourse drains an upstream catchment of approximately 1.3km². The catchment is described as essentially rural by the Flood Estimation Handbook definition. The catchment is low-lying with a maximum elevation of around 40m AOD. The standard percentage runoff is 40%. There are no lakes or reservoirs in the upstream catchment that provide attenuation of flows in the Nant Dalar Hir.
- 3.5.3 Nant Dalar Hir reaches the site boundary close to its north-eastern corner and then flows in a south-westerly direction across the site. It is then culverted beneath both Holyhead Road (A5) and the A55.
- 3.5.4 Nant Dalar Hir is fed on site by a small field drain that rises in the west of the site near the Dalar Hir farmhouse. The stream flows first eastward to the south of the site boundary, and then flows southward beneath Holyhead Road. The

drain then flows eastward between Holyhead Road and the A55 and then joins Nant Dalar Hir just prior to the culvert beneath the A55.

- 3.5.5 The proposed Park and Ride site is also crossed by a series of ditches and wetted field boundaries, assumed to be for land drainage purposes. These drains discharge in a generally southerly direction and, during wetter periods, form marshy ground and small ponds within the site along Holyhead Road, which is located on a small embankment approximately 1m high and is therefore elevated above the adjacent land.
- 3.5.6 A number of additional and larger ponds are situated to the south of Holyhead Road with further ponds to the south of the A55. These are believed to be associated with the road drainage systems.

3.6 Geology and hydrogeology

- 3.6.1 The slowly permeable soils that characterise the proposed Park and Ride site have limited infiltration potential and areas underlain by these soils are typically prone to surface water ponding and high rates of runoff [RD13].
- 3.6.2 With the exception of a small area in the south of the site (which has no superficial deposits) the superficial geology beneath the proposed Park and Ride site includes glacial till, which is defined as a Secondary (undifferentiated) aquifer by NRW. The bedrock at the site is the New Harbour Group (mica schist and psammite) which is classified by NRW as a Secondary (B) aquifer. These aquifers have limited potential for water storage or flow. The eastern portion of the site is underlain by interbedded sandstone and conglomerate.

3.7 Water services

- 3.7.1 There is an existing mains water supply that runs along the A5 just south of the proposed Park and Ride site. It is proposed to take a potable water supply for the site from this supply. There are no existing foul sewers in the immediate area.

3.8 Reservoirs

- 3.8.1 There are no reservoirs in the immediate vicinity of the proposed Park and Ride site and therefore there is no risk of flooding from reservoirs.

4 Park and Ride

4.1 Timescales

- 4.1.1 The construction of the Park and Ride is expected to last for approximately 18 months and the facility is expected to be operational only whilst the Power Station is being constructed. Following the completion of the Power Station, the Park and Ride would no longer be required and the site would be restored to its current agricultural state, albeit that some structures such as the bridge over the Nant Dalar Hir would remain.

4.2 Site layout

- 4.2.1 A parameter based approach has been adopted for the design of the Park and Ride. Parameters have been set for the ten parameter zones (Zones 6-1 to 6-10) comprising car spaces, bus spaces, bus facilities, a staff car park, a cycle store and a new roundabout. The location and extent of these zones is shown on figure F1-6 (Application Reference Number: 6.6.38), and the relevant maximum parameters are detailed in table F1-1 of chapter F1 (proposed development) (Application Reference Number: 6.6.1).
- 4.2.2 The parameters listed in chapter F1 (Application Reference Number: 6.6.1) only allow the size of the hardstanding and buildings to be changed. However, a reduction in the size of a parking area in one part of the Park and Ride site is likely to be offset by an increase in the size of a parking area in another part of the site (in order to meet the total number of spaces required). The total area of impermeable ground (hardstanding and buildings) would not significantly change between possible site layouts and there would be no substantial change to the rainfall / runoff relationship. The FCA has therefore been completed on the basis that areas of hardstanding and building sizes within individual Parameter Zones 6-1 to 6-10 could change, but the total area of hardstanding would not change.
- 4.2.3 Although parameters have been identified, an indicative scheme has been prepared and is shown in figure F8-1-1 with more detail provided in figure F1-3 (Application Reference Number: 6.6.38). It is this indicative scheme that has been used for the purpose of this FCA. The implications of variations within the parameters identified above have been assessed and it has been concluded that within these parameters, and based on the assumptions included in this FCA, the outline design provides a worst case assessment.
- 4.2.4 The draft design shows that the main entrance to the proposed Park and Ride site is off the roundabout at the A55/A5 junction. An access road runs from west to east across the proposed Park and Ride site, crosses the Nant Dalar Hir and then turns right to join the A5. There are three car park areas to the north of the access road, one to the south of the access road adjacent to the bus pick-up and drop-off zone and a further car park area to the east of the Nant Dalar Hir. A central bus station and associated building containing a waiting area and facilities is shown on figure F1-3 (Application Reference

Number: 6.6.38). Between and around the car park areas are proposed landscaped areas of grasslands or shrubs.

- 4.2.5 The layout has been designed to keep the number of watercourse crossings on access roads to a minimum. In addition, a 15m buffer zone has been left along the watercourse which would be vegetated. Upstream of the crossing of the Nant Dalar Hir to the north-east extent there are larger areas of grassland.

4.3 Proposed drainage

- 4.3.1 All piped surface and foul water systems would be designed in accordance with Sewers for Adoption [RD14], which contains guidance on the design and construction of sewers. The design would be as if it were to be adopted by sewerage undertakers in accordance with Section 104 of the *Water Industry Act 1991*.
- 4.3.2 A new surface water drainage network is proposed to serve the site's drainage requirements, which would include drainage of the bus transport facility building roof, parking areas, permeable and impermeable hardstanding areas.
- 4.3.3 The drainage design would include the following:
- Pipes would be designed for flow for a 1 in 5 year (20% AEP) storm event plus a 20% allowance for climate change with no surcharging above soffit.
 - There would be no above ground flooding from manholes (allowing for a 300mm freeboard below ground level) for a 1 in 30 year (3.33% AEP) storm plus a 20% allowance for climate change. In this case, climate change values used are those that represent a middle estimate of rainfall intensity increase to the 2080s [RD6].
 - The drainage system would be designed so that the peak runoff rates for a 1 in 100 year (1% AEP) storm event, incorporating climate change, would be constrained to greenfield runoff rates for the mean annual maximum flow rate.
 - Attenuation would be sized to contain 1 in 100 year storm flows, incorporating climate change, with a restriction at greenfield runoff rate.
 - All proposed drainage facilities would be designed to ensure self-cleansing velocities are achieved as far as possible, in order to limit the level of maintenance throughout the assets life.
- 4.3.4 Surface water runoff would be captured by permeable paving or traditional gully, channel and kerb drain systems. The permeable paving would be laid on a granular sub-base which would form a below-ground storm water attenuation/storage system. Surface water runoff in impermeable areas would be captured by traditional gully, channel and kerb drain systems and temporarily stored within a below-ground attenuation system. Calculations within the drainage design have incorporated a 20% uplift to account for potential increases in rainfall due to climate change [RD15].

- 4.3.5 The design of surface water open channels would comply with the Design Manual for Roads and Bridges, Volume 4 [RD16] and the Sustainable Urban Drainage Systems Manual [RD17].

4.4 Water services

- 4.4.1 Initial discussions have been held with Dŵr Cymru Welsh Water to identify foul sewer services which have connection feasibility. As there are no existing foul sewers in the area foul flows would be discharged to an on-site package treatment plant. Flows would be treated and discharged into the surface water network to meet conditions of an Environmental Permit.
- 4.4.2 Discussions have been held with Dŵr Cymru Welsh Water to identify potable water services which have connection feasibility. There is a potable distribution main that runs along the existing A5, south of the proposed Park and Ride site, from which it is proposed to take a potable water supply for the facilities on site.

5 Flood modelling

5.1 Sources of modelling data

5.1.1 The sources of flood modelling data and flood mapping described below have been considered within the preparation of this FCA.

- **NRW river and tidal flood mapping [RD2]:** This mapping, delivered as part of a national programme, delineates indicative areas of elevated flood risk into four flood zones and includes major fluvial (catchment area >3km²), surface water, tidal and surface water sources.
- **TAN 15 Development Advice Map [RD1]:** This mapping, which is primarily based on the NRW flood map, defines indicative areas where the annual probability of inundation from fluvial and tidal sources is greater than 0.1% (Zone C). It also identifies areas where there are geological indicators of elevated flood risk (Zone B) with low risk areas classified as Flood Zone A.
- **Pluvial Flood Risk Hydraulic Modelling (appendix F8-1-3):** Hydraulic modelling (see appendix F08-1-3 for full details) was undertaken to better understand the baseline pluvial flood risk for a range of events and to inform the development of measures to mitigate and manage the pluvial risk, as well as to inform an understanding of the need for adaptation for more extreme events.

5.2 NRW and TAN 15 flood maps

5.2.1 While the NRW flood map [RD2] provides additional detail in relation to flood probabilities over and above the TAN 15 Development Advice Map, the two are broadly comparable. The TAN 15 Development Advice Map, which shows the fluvial and coastal flood zones, as issued by the Welsh Government, is the main focus here, as the classifications from this better relate to planning policy.

5.2.2 The TAN 15 Development Advice Map categorises locations from A to C based on their perceived flood risk as detailed in section 1.3. The maps are based on the best currently available data. They use the Environment Agency's extreme flood outlines to inform Zone C and the British Geological Survey's drift data to inform Zone B.

5.2.3 The TAN 15 map [RD1] (figure F8-1-2) indicates that land within the proposed Park and Ride site is at low risk of fluvial and tidal flooding (Zone A). However, there are watercourses that cross the site; Nant Dalar Hir towards the eastern boundary and other drainage ditches, which have associated floodplains. Due to the small size of the hydrological catchments (less than 3km²) these watercourses have not been included in the broad-scale modelling used to produce the maps.

- 5.2.4 The NRW surface water flood maps (figure F8-1-3) indicate four different areas within the proposed Park and Ride site at risk of surface water flooding. These consist of areas adjacent to the Nant Dalar Hir to the east of the proposed Park and Ride, an area to the south where the Nant Dalar Hir passes under the A55, an area to the north-west and a flow route from north to south across the centre of the proposed Park and Ride site. These surface water risk zones would affect car park areas, access roads and potentially the bus transport facility building.

5.3 Fluvial and pluvial flood modelling

- 5.3.1 Fluvial and pluvial modelling has been undertaken by Horizon for the proposed Park and Ride. Fluvial and pluvial flooding were modelled separately using Flood Modeller Pro [RD18] and the TUFLOW model [RD19]. The fluvial flood models were run for 5% AEP, 1% AEP and 0.1% AEP storm return periods. The pluvial flood model was run for the 3.3%AEP, 1% AEP and 0.1% AEP return periods for the 360-minute summer storm.
- 5.3.2 The modelling uses more detailed topography and modelling methods and provides a more accurate representation of flood risk than the TAN 15 Development Advice Map. The 1% AEP event was run for the periods incorporating a climate change allowance of 30% (reasonably foreseeable) for the 2080s [RD15].
- 5.3.3 A number of points and lines have been used to retrieve model results as shown on the model outputs in appendix F8-1-3 from which flood depths and flows have been obtained.

Comparison to the NRW and TAN 15 flood maps

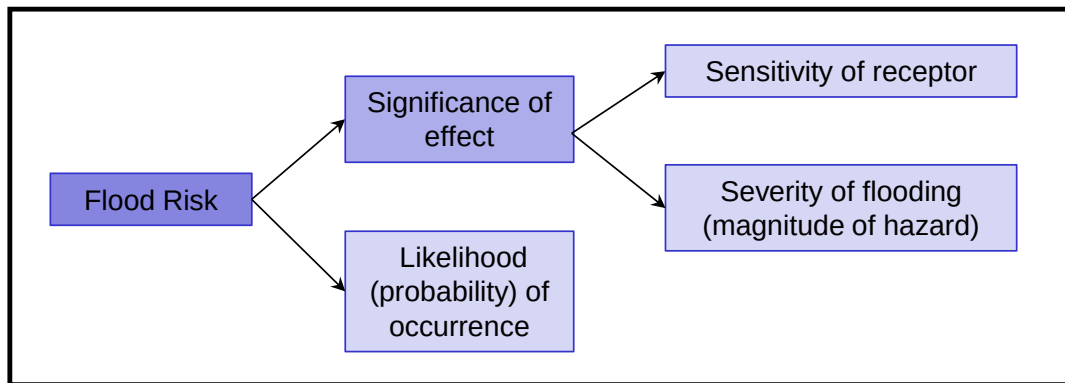
- 5.3.4 The TAN 15 flood map suggests that the proposed Park and Ride site is in Zone A and there is little or no risk of fluvial flooding. However, the small river catchment of the Nant Dalar Hir would not have been included in the large-scale modelling exercise. The more detailed fluvial modelling undertaken to inform this FCA shows that there is a risk of flooding from the watercourse and that it would impact the Park and Ride.
- 5.3.5 Comparing the pluvial modelling results to those on the NRW surface water flood maps suggests flooding in the same locations but that the extents of flooding are greater. Both the fluvial and pluvial modelling results show more extensive flooding to the centre of the site than do the NRW surface water flooding maps, with the fluvial extent being the greater of the two in this area. The fluvial flood map, however, does not show any flooding to the west of the proposed Park and Ride.

6 Flood risk assessment

6.1 FCA methodology

6.1.1 The risk assessment methodology used within this FCA is set out in appendix F8-1-4 and is based on PPW [RD3] and associated guidance [RD4]. The guidance recommends that flood risk be assessed through consideration of both the significance of potential effects and the likelihood of occurrence. The significance of effect is then dependent on two factors: the sensitivity of potential receptors and the severity of the flooding. Thus, the three criteria on which flood risk is assessed are:

- sensitivity of the receptor;
- severity of flooding (i.e. the magnitude of the hazard); and
- likelihood (i.e. probability) of occurrence.



Sensitivity of receptors

6.1.2 The sensitivity of receptors is defined according to the method outlined in appendix F8-1-4 with a range of sensitivities from very high through high, medium and low, to very low. TAN15 guidance outlines the vulnerability of different types of on-site development and also classes all off-site receptors as highly sensitive to flooding. The sensitivity of the receptors at and around the proposed Park and Ride are defined in section 6.3.

Severity of flooding

6.1.3 Appendix 1 of TAN 15 identifies acceptable thresholds of flooding for different types of development and also presents indicative consequences of flooding that may be acceptable subject to adequate warnings and preparation. This guidance has been used to define consequences of flooding that fall within the categories negligible, low, medium, high and very high hazard. Further information on the typical criteria against which the category is defined is presented in appendix F8-1-4.

Likelihood of occurrence

- 6.1.4 The likelihood of occurrence is used to give an understanding of how regularly a given event or outcome will occur. This is fully defined within appendix F8-1-4, and the classification of these criteria is discussed for the different flood sources in the sections below.

Consideration of seasonality

- 6.1.5 Flooding can occur at any time of year, although it can exhibit quite different seasonal characteristics. Summer flooding is generally associated with localised, high intensity, convective rainfall events, resulting in rapid runoff response in which the peak flow is the main driver of flood risk. This can be a particular issue in urban catchments where significant areas of impermeable surfaces result in rapid runoff. Winter events are generally associated with slower moving frontal systems, they are often prolonged and less intensive and they occur on typically wetter catchments, resulting in longer hydrographs with lower peaks but substantially more volume.
- 6.1.6 The catchments of concern in this study are essentially rural, they are generally small in size and have shallow low permeability soils meaning that they are likely to be more susceptible to high intensity summer storms than to winter frontal events; a conclusion that is supported by predicted flood flows and levels from modelling of both winter and summer rainfall profiles. Presentation of the results for a summer event only is therefore, based on the source of key flood risks to the Park and Ride. Furthermore, the mitigation measures proposed (see section 7 of this FCA and chapter F8 (Application Reference Number: 6.6.8)) are effective and appropriate for the hazards identified, and these are equally appropriate and no-less valid whether the hazard is derived from intense periods of runoff during summer events or longer volume-based events in the winter months.

6.2 FCA screening

- 6.2.1 Industry guidance [RD20] recommends that an FCA should consider all possible sources of flooding for a given site. This is also reflected in the TAN 15 guidance on flood risk. Table F8-1-1 summarises a range of potential risks and whether these are relevant to the proposed Park and Ride.

Table F8-1-1 Screening of potential flood sources and receptors

Flood type	Source	Pathway	Receptor	Consider further?
Tidal	Irish Sea flooding	The Park and Ride would be situated away from the Irish Sea and is not within the flood zone so there is no pathway	Park and Ride	No
Fluvial and pluvial	Baseline fluvial flooding of the Application Site	Risk of flooding from Nant Dalar Hir and other drainage ditches that run across the site	Park and Ride	Yes
	Baseline pluvial flooding of the Application Site	Surface water flooding due to intense rainfall	Park and Ride	Yes
	Pluvial runoff as a result of site development	Increases to impermeable areas would increase runoff from the site to the surrounding area	Off-site receptors	Yes
Groundwater	Groundwater	Groundwater movement and emergence at the surface	Park and Ride	Yes
Services	Water mains	Overland flows due to failure of Water Main running adjacent to the A55	Park and Ride	Yes
	Site drainage system	Overland flows due to surcharge or failure of drainage systems associated with the development	Off-site receptors	Yes
Reservoir flooding	Failure of reservoir walls	There are no reservoirs that would cause a flood risk to the site	Park and Ride	No

6.3 Sensitivity of receptors

6.3.1 Following TAN 15 guidance the proposed Park and Ride can be classified as a general industrial site and place of employment, therefore classifying it as a 'less vulnerable development'. Following appendix F8-1-4, this is assessed as having medium sensitivity within this assessment. As noted above, off-site developments are classified as having a high vulnerability. Based on the methodology in appendix F8-1-4, the A5 and A55 are defined as being of very high sensitivity as they are key access routes, with all other off-site receptors having a high sensitivity.

6.4 Fluvial and pluvial flooding

Fluvial flood risk

6.4.2 Appendix F8-1-3 includes a series of figures that show the results of the detailed modelling exercise for the baseline case. It can be seen that fluvial flooding is expected at the Park and Ride at all modelled events from the 5%

AEP event upwards. The flood extents shown indicate that the land adjacent to the Nant Dalar Hir would be affected but that water would also flow westwards along the site boundary along the A5 and pond in the centre of the Park and Ride.

- 6.4.3 At the 5% event the maximum depth reached would be between 1 and 1.5m. The maximum depth increases with return period to reach depths greater than 2m at the 0.1% AEP event in the south central area of the Park and Ride. The area at risk of the deepest flood inundation corresponds to the bus drop-off/pick-up point, the building for the bus transport facility and the car park area south of the access road. Also within this area would be the package treatment plant to treat the sewage from the Park and Ride. The maximum water velocity that would be reached during the 1% plus 40% climate change event would be 0.50m/s as indicated by the modelling results provided in Appendix F8-1-3.
- 6.4.4 The depths of flood water that have been suggested in the modelling exercise classify the magnitude of the hazard (in some locations within the Park and Ride) as high, and the significance of effect is considered to be moderate. Therefore the overall flood risk is determined to be high.

Pluvial flood risk

- 6.4.5 Pluvial flood waters enter the proposed Park and Ride site via two pathways: overland from the western catchment along its northern boundary, largely via a small ditch before ponding in the lower lying central areas, and also from the Nant Dalar Hir.
- 6.4.6 Appendix F8-1-3 shows the baseline results of the 1 in 30 year event. The extents of the event are more extensive than those shown on the NRW surface water flooding map displayed in figure F8-1-3. There is a greater floodplain area adjacent to the Nant Dalar Hir and more ponding in the centre of the site due to the restriction on flow caused by the culvert under the A5. The flow route southwards from the Nant Dalar Hir, shown on the NRW flood map, however, is not as extensive in the more detailed modelling results detailed in appendix F8-1-3.
- 6.4.7 At the 1 in 100 year pluvial event (appendix F8-1-4) the extents are greater still with a small section of the flooding reaching a depth of over 2m. During the 1 in 1000 year event (appendix F8-1-3) depths greater than 2m would be expected adjacent to the Nant Dalar Hir, in the south central area adjacent to the A5 and also to the western edge of the Park and Ride. The maximum water velocity that would be reached during the 1% plus 40% climate change event would be 0.29m/s as indicated by the modelling results provided in Appendix F8-1-3.
- 6.4.8 The different areas at risk from surface water flooding have been assessed separately. Adjacent to the Nant Dalar Hir and the areas to the west of the Park and Ride there is a high likelihood of flooding. The magnitude of the hazard is assessed as medium, due to the potential depth of flooding, the

significance of effect is therefore considered to be moderate. The likelihood of flooding in these areas is high, therefore, the overall risk from this source is considered high.

- 6.4.9 Where deeper flood waters are expected, in the south central area of the Park and Ride, the magnitude of the hazard is assessed as high, due to the potential depth of flooding, and the significance of effect is therefore considered to be moderate. The likelihood of flooding in these areas is high, therefore, the overall risk from this source is considered high.

Risk of increased flooding off-site

- 6.4.10 The introduction of impermeable surfaces would increase the risk of flooding due to increases in the runoff of rainwater from the proposed Park and Ride. The receptors identified in section 3.3, if they are located in flow paths downhill from the proposed Park and Ride site, would potentially be at risk of flooding due to the additional runoff. These include the A55 and A5, the transmitting station and the properties Bryn Farm and Alltwen-ddu. In addition, the detailed modelling exercise has shown an existing pluvial and fluvial flood risk to the A55 and A5, i.e. the A55 and A5 are currently at risk of flooding irrespective of the proposed Park and Ride.
- 6.4.11 However, the car park areas, constituting a large proportion of the paved area, would be covered in a permeable surface, to reduce the volume of runoff. This, plus the incorporation of underground attenuation storage into the drainage design, would reduce runoff from the site to the existing greenfield runoff rates. These mitigation measures are embedded in the design.
- 6.4.12 The incorporation of the attenuation within the drainage design reduces the risk of flooding to off-site receptors to the south of the A55 to that currently experienced and therefore the magnitude of the hazard is considered low, as is the significance. Therefore the overall risk associated with the Park and Ride is considered low. The drainage system would be regularly inspected to ensure that it functions correctly for the operational period of the Park and Ride such that there is no increase in flood risk.
- 6.4.13 The Park and Ride would not exacerbate the flood risk to the A55 or A5, although the risk would remain high post development with no additional mitigation (see section 7). The magnitude of the hazard concerned with the A5 and A55 is considered to be high, as is the significance. The overall flood risk is therefore high.

6.5 Groundwater

Groundwater emergence at surface

- 6.5.2 The slowly permeable soils at the proposed Park and Ride site limit the infiltration potential and result in high rates of surface water runoff and can cause surface water ponding. The movement of surface water through the soil into the underling geology is therefore limited at the proposed Park and

Ride. In addition to this, the majority of the site is underlain by glacial till, which although classed as a Secondary (undifferentiated) aquifer will have a low permeability where it has a dominantly clay matrix.

- 6.5.3 The combination of the low permeability soils and glacial till at the site would limit groundwater recharge into the underlying bedrock. The bedrock itself (mica schist and psammite of the New Harbour Group), is classified by NRW as a Secondary (B) Aquifer, with lower permeability layers of rock which may store and yield limited amounts of groundwater.
- 6.5.4 The site walkover carried out by Horizon in January 2016 found the watercourse which feeds into the Nant Dalar Hir to be dry and therefore unlikely to be sustained by baseflow, which suggests that groundwater levels are not close to ground surface. Groundwater from the bedrock is therefore unlikely to support streams and drains on site.
- 6.5.5 Whilst the consequences and severity of groundwater emerging at ground level could be significant for any sensitive receptors vulnerable to water ingress, the likelihood of encountering groundwater at surface level is considered to be low for the reasons outlined above. During heavy rainstorms the majority of rainfall would form surface runoff rather than recharging the groundwater body and causing groundwater flooding. The magnitude of the hazard is assessed as low, and the significance of effect is considered to be low. The overall risk of groundwater flooding at the proposed Park and Ride is therefore low.

6.6 Services

Water main

- 6.6.2 There is an existing water main that runs between the proposed Park and Ride site and the A55. However, since the area slopes generally from north to south, any flooding from this source would flow away from the proposed Park and Ride. The magnitude of hazard is considered to be low, and the significance is considered to be low. Overall flood risk from this source is therefore assessed as low.

6.7 Decommissioning

- 6.7.1 Decommissioning would involve returning the site to its current state, albeit with the bridge over the Nant Dalar Hir remaining. There would therefore be changes in runoff associated with the decrease in the impermeable areas due to the removal of hardstanding, which could restore a rainfall/runoff response similar to the baseline, increase recharge to groundwater and result in a flood risk similar to the current flood risk. It is possible that the flood risk post decommissioning could be lower than current flood risk, but this would depend upon the nature of the mitigation measures implemented as part of development of the Park and Ride, as outlined in section 7. Where structures remain within the watercourses, these would be checked following the

decommissioning of the site to ensure that they are still in good condition and functioning correctly.

6.8 Flood risks

- 6.8.1 The flood risk from the sources outlined above, to the receptors identified in section 3, are detailed in table F8-1-2. This is based on the methodology detailed in appendix F8-1-4.

Table F8-1-2 Flood risk

Flood type	Source	Pathway	Receptor	Sensitivity	Magnitude of potential hazard	Significance of potential effect	Likelihood of occurrence	Current Flood risk	Post development flood risk
Fluvial and Pluvial	Fluvial	Risk of flooding from Nant Dalar Hir	Park Ride and	Medium	High	Moderate	High	-	High
	Fluvial	Risk of flooding from Nant Dalar Hir	A55 and A5	Very high	High	High	Medium	High	High
	Pluvial	Surface water runoff ponding in the south of the site	Park Ride and	Medium	High	Moderate	High	-	High
	Pluvial	Surface water runoff adjacent to the Nant Dalar Hir	Park Ride and	Medium	Medium	Moderate	High	-	High
	Pluvial	Surface water ponding to the west of the Park and Ride	Park Ride and	Medium	Medium	Moderate	High	-	High
	Pluvial	Surface water flow route from the north of the site	Park Ride and	Medium	Medium	Moderate	High	-	High
	Pluvial	Surface water flow	A55 and A5	Very high	High	High	High	High	High
	Site development	Increased runoff from site	Off-site receptors	High	Low	Moderate	Low	Low	Low

Flood type	Source	Pathway	Receptor	Sensitivity	Magnitude of potential hazard	Significance of potential effect	Likelihood of occurrence	Current Flood risk	Post development flood risk
Ground water	Groundwater	Risk of flooding due to groundwater emergence at the surface	Park Ride and	Medium	Low	Low	Low	-	Low
Services- water mains		Flooding from the adjacent water main	Park Ride and	Medium	Low	Low	Low	-	Low

Note: for the A55 and A5 the high risk of flooding currently exists and development of the Park and Ride would not exacerbate this. This is also true for the Off-site receptors, albeit that the risk of flooding to these is currently low.

7 Additional Mitigation

- 7.1.1 It is considered that there is a high risk of fluvial flooding from the Nant Dalar Hir to the Park and Ride and so additional mitigation is required in order to alleviate this. Further detailed manipulation of the topography of the Park and Ride would be progressed and redirection of flow paths would be used to manage the flood waters from both fluvial and pluvial sources within the Park and Ride without increasing flood risk elsewhere.

8 Conclusions

- 8.1.1 The flood consequences of the Park and Ride have been assessed. Flooding from all sources has been considered with the risk to both the Park and Ride and off-site receptors determined.
- 8.1.2 Based upon the information referenced within this FCA, parts of the Park and Ride are assessed to be at high risk of flooding from both fluvial and pluvial sources. In addition, the baseline modelling results suggest that the A55 and A5 are currently at risk of flooding from both of these sources. The Park and Ride would not exacerbate this.
- 8.1.3 Additional mitigation measures are being considered which would serve to reduce the risk from flooding.
- 8.1.4 The risk of flooding to other off-site receptors, due to the development, is considered low due to the implementation of a drainage system to reduce runoff to the greenfield runoff rate. Groundwater flooding and flooding from services are both considered a low risk.

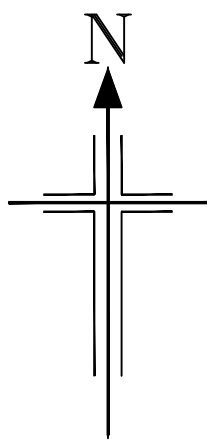
9 References

Table F8-1-3 Schedule of references

ID	Reference
RD1	Welsh Government. 2017. <i>Technical Advice Note TAN 15 Development Advice Map</i> . [Online]. [Accessed: May 2017]. Available from: https://maps.cyfoethnaturiolcymru.gov.uk/Html5Viewer/Index.html?configBase=https://maps.cyfoethnaturiolcymru.gov.uk/Geocortex/Essentials/REST/sites/Flood_Risk/viewers/Flood_Risk/virtualdirectory/Resources/Config/Default .
RD2	Natural Resources Wales. 2016. <i>Flood Risk Map</i> . [Online]. [Accessed: April 2017]. Available from: https://naturalresources.wales/our-evidence-and-reports/maps/flood-risk-map/?lang=en .
RD3	Welsh Government. 2016. <i>Planning Policy Wales (PPW)</i> . Edition 9 [Online]. [Accessed: April 2017]. Available from: http://gov.wales/topics/planning/policy/ppw/?lang=en .
RD4	Welsh Government. 2004. <i>Technical Advice Note (TAN) 15: Development and Flood Risk</i> . [Online]. [Accessed: April 2017]. Available from: http://wales.gov.uk/docs/desh/publications/040701tan15en.pdf .
RD5	Welsh Government. 2016. <i>CL-03-16 Climate Change Allowances for Planning Purposes</i> . [Online]. [Accessed: April 2017]. Available from: http://gov.wales/topics/planning/policy/policyclarificationletters/2016/cl-03-16-climate-change-allowances-for-planning-purposes/?lang=en .
RD6	Defra. 2009. <i>UK Climate Projections</i> . [Online] [Accessed April 2017] Available from http://ukclimateprojections.metoffice.gov.uk/22530
RD7	Isle of Anglesey County Council (IACC) and Gwynedd Council. 2017. <i>Anglesey and Gwynedd Joint Local Development Plan 2011-2026, Written Statement</i> . [Online] [Accessed: September 2017]. Available from: http://www.anglesey.gov.uk/planning-and-waste/planning-policy/joint-local-development-plan-anglesey-and-gwynedd/
RD8	Isle of Anglesey County Council and Gwynedd Council. 2013. <i>Anglesey and Gwynedd Joint Local Development Plan, Topic Paper 8: Strategic Flood Consequence Assessment (Level 1)</i> . [Online]. [Accessed: April 2017]. Available from: http://www.anglesey.gov.uk/download/31094 .
RD9	Isle of Anglesey County Council. <i>Flood Risk Regulations 2009: Preliminary Flood Risk Assessment Report</i> . [Online]. [Accessed: April 2017] Available from: http://webarchive.nationalarchives.gov.uk/20140328084622/http://cdn.environment-agency.gov.uk/flho1111bvfk-e-e.pdf .
RD10	Isle of Anglesey County Council. 2013. <i>Anglesey Local Flood Risk Management Strategy</i> . [Online]. [Accessed: April 2017]. Available from: http://www.anglesey.gov.uk/download/32358 .
RD11	Natural Resources Wales. 2015. <i>Western Wales River Basin Management Plan 2015-2021</i> . [Online] [Accessed: April 2017] Summary available from: https://naturalresources.wales/media/676165/wwrbdssummary.pdf .
RD12	Centre for Ecology and Hydrology. 2009. <i>Flood Estimation Handbook</i> . CD-ROM version 3.
RD13	Cranfield Soil and Water Institute. 2015. <i>Soilscapes</i> . [Online]. [Accessed: 06 June 2017]. Available from: http://www.landis.org.uk/soilscapes/
RD14	WRc plc. 2012. <i>Sewers for Adoption: A Design & Construction Guide for Developer</i> . 7th Edition.
RD15	Welsh Government. 2016. <i>Flood Consequence Assessments: Climate Change Allowances</i> . [Online]. [Accessed: April 2017]. Available from: http://gov.wales/docs/desh/publications/160831guidance-for-flood-consequence-assessments-climate-change-allowances-en.pdf .

ID	Reference
RD16	Highways England. 2016. <i>Design Manual for Roads and Bridges. Volume 4 - Geotechnics and Drainage</i> , Williams Lea Tag.
RD17	CIRIA. 2007. <i>Sustainable Urban Drainage Systems Manual</i> . Report C697. CIRIA, London.
RD18	CH2M. 2015. <i>Flood Modeller Pro v4.1</i> modelling software.
RD19	BMT Group Limited. 2015. <i>TUFLOW.2016 -03-AA-iSP-w64</i> modelling software.
RD20	Lancaster, J. W., Preene, M. and Marshall. C. T.. 2004. <i>Development and flood risk: guidance for the construction industry</i> . Report C624. CIRIA, London.

Appendix F8-1-1 Topographical survey



ANNOTATIONS:			
AV	Air Valve	RE	Rodding Eye
BH	Borehole	RNP	Road Name Plate
BL	Bed Level	RP	Reflector Post
Bol	Bollard	RS	Road sign
OSBM	Bench Mark	SAP	Sagitt
BS	Bus Stop	SF	Soft Level
BT	Telecom IC	SH	Shalt Box
Cox	Control Box	ST	Stop Tap
Culv	Culvert	SV	Sluice Valve
CL	Cover Level	Tap	Water Tap
CTV	Cable TV	TCB	Telephone Call Box
DP	Down Pipe	TS	Traffic Signal
Dr	Drain cover	TL	Traffic Light
EBx	Electric Box	TH	Threshold Level
EC	Electric Cover	TM	Traffic Master
EP	Electric Pole	TP	Telegraph Pole
PY	Electric Pylon	CCTV	CCTV Camera
ER	Earthing Rod	Gvp	Vent Pipe
FH	Fire Hydrant	WE	Water Cover
FL	Flood Light	WL	Water Level
FS	Flag Staff	WM	Water Meter
Gas	Gas Manhole	WO	Wash Out
Scam	Speed Camera		
G	Gate Post		
GV	Gas Valve		
IC	Inspection Cover		
IL	Invert Level		
Jbx	Junction Box		
KO	Kerb Outlet		
KI	Kerb Inlet		
LB	Litter Bin		
LC	Light Column		
LP	Lamp Post		
MH	Manhole		
Mkr	Marker Post		
MP	Mile Post		
MS	Mile Stone		
NB	Notice Board		
PI	Pipe		
PM	Parking Meter		
P	Post		
PU	Pump		
PZ	Piezometer		
SYMBOLS:			
Building	Kerb	Tree (spread varies)	
Open Building	Overhead Line	Bush (spread varies)	
Gate	Road Edge (no kerb)	1 (value)	
Bottom of Bank	Rock Outcrop	(Spot Level)	
Ditch	Top of Bank	name	
Fence	Track Edge	value	
Pollage Line	Verge	(Survey Station)	
Hedge (width varies)	Wall		

Notes:

Survey Control Coordination Method:

A Leica AX1230 SmartRover GPS Receiver was used to coordinate all survey control points to Ordnance Survey National Grid (OSGB36) following TSA guidelines.

Three minute observations were taken on each control point, twice; over a 20 minute time period in order to record data using different satellite configurations. The mean of the 2 observations were used as final coordinates.

Transformation:

In order to be able to use National Grid for topographical surveying purposes, the scale factor inherent within these coordinates has to be removed and transformed onto a local grid. This is done via the following calculation.

$$(NG - LGO) / LSF + LGO = LG$$

Where:

NG are the National Grid coordinates obtained via GPS observations.

LGO is the local grid origin.

LSF is the local scale factor for the centre of the site. Obtained from the OS Excel Spreadsheet (<http://gps.ordnancesurvey.co.uk/convert.asp>)

LG are the coordinates in local grid (Scale Factor = 1)

Local Grid Origin = 232899.563, 378427.391

Scale Factor = 0.999944031

Transformation between survey grids - All survey data was recorded and processed using local grid coordinates and scale factor 1. In order to produce drawings in National Grid the survey has to be translated and scaled by two known points, this was carried out within LSS using the points below. These points were also used to calculate the local scale factor at the mid point between them.

P200

NG - E: 232470.918, N: 378706.805

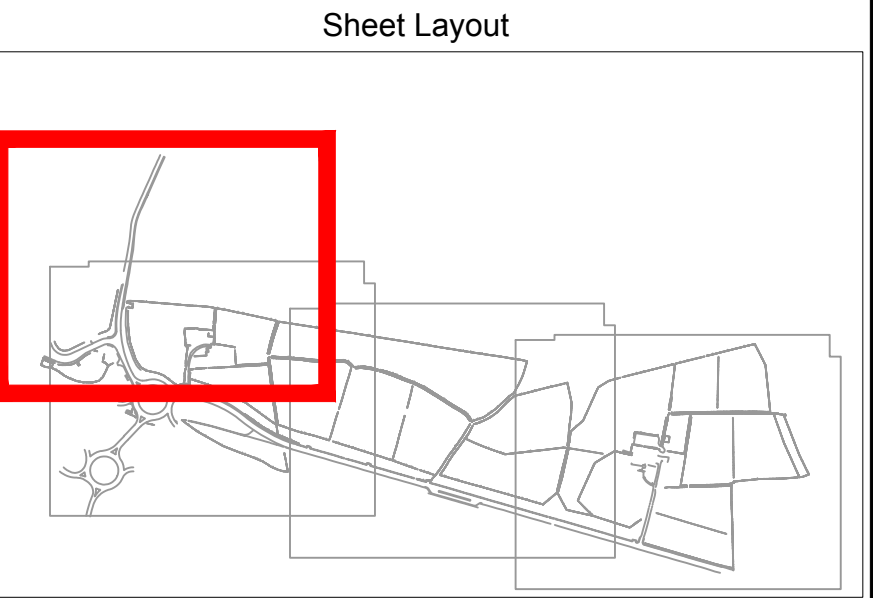
LG - E: 232470.894, N: 378706.821

P208

NG - E: 233328.208, N: 378147.978

LG - E: 233328.232, N: 378147.962

Survey Stations			
Name	Easting (m)	Northing (m)	Level (m)
P200	232470.894	378706.821	19.476
P201	232433.680	378526.748	18.660
P202	232463.548	378411.079	21.939
P203	232553.200	378408.544	21.723
P204	232666.799	378338.688	18.765
P205	232866.638	378280.360	15.704
P206	233015.239	378227.475	16.711
P207	233188.397	378167.125	18.420
P208	233328.232	378147.962	18.929



Rev	Rev. Date	Purpose of revision	Drawn	Checked	Rev'd	Apprv'd
3.0	28.07.16	Updated to include south roundabout	SP	NJH	NJH	LM
2.0	21.05.16	Updated to include Cartageway Survey	SP	NJH	NWB	LM
1.0	15.04.16	Final Revision	SP	NJH	NWB	LM

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HORIZON
NUCLEAR POWER

Client
Associated Development Sites
Dalar Hir

Project
2d Topographical Survey
Sheet 1 of 4

Drawing title

Drawing status
FINAL

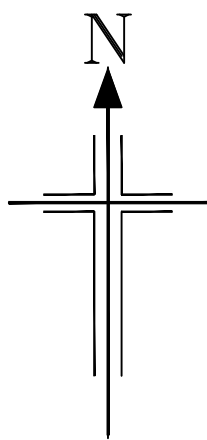
Scale
1:500 @ A0
DO NOT SCALE

Client no.
60PO8049

Drawing number
60PO8049/JAC/TOPO/DRG/00003

Rev
2.0

This drawing is not to be used in whole or part other than for the intended purpose and project as defined on this drawing. Refer to the contract for full terms and conditions.



ANNOTATIONS:

AV	Air Valve	RE	Rodding Eye
BH	Borehole	RNP	Road Name Plate
BL	Bed Level	RP	Reflector Post
Bol	Bollard	RS	Road sign
OSBM	Bench Mark	SAP	Sagging
BS	Bus Stop	SF	Soft Level
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Br	Slay Wire	SV	Sluice Valve
CL	Culvert	Tap	Water Tap
CLV	Cable TV	TCB	Telephone Call Box
CTV	Cable TV	TS	Traffic Signal
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Scam	Speed Camera		
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KI	Kerb Inlet		
LB	Litter Bin		
LC	Light Column		
LP	Lamp Post		
MH	Manhole		
Mkr	Marker Post		
MP	Mile Post		
MS	Mile Stone		
NB	Notice Board		
PI	Pipe		
PM	Parking Meter		
P	Post		
PU	Pump		
PZ	Piezometer		

FENCE TYPES:

CBF	Close Boarded Fence
IRF	Iron Railings Fence
PWF	Post & Wire Fence
PRC	Post & Rail Fence
BWF	Barbed Wire Fence
PCLF	Post & Chain Link Fence

WALL TYPES:

AB	Abutment Wall
BW	Brick Wall
SW	Stone wall
DSW	Dry Stone Wall
RTW	Retaining Wall
CW	Concrete Wall

SYMBOLS:

Building	Kerb	Tree (spread varies)
Open Building	Overhead Line	Bush (spread varies)
Gate	Road Edge (no kerb)	1 (value)
Bottom of Bank	Rock Outcrop	(Spot Level)
Ditch	Top of Bank	name
Fence	Track Edge	value
Pollage Line	Verge	(Survey Station)
Hedge (width varies)	Wall	

Notes:

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LG are the coordinates in local grid (Scale Factor = 1)

Local Grid Origin = 232899.563, 378427.391

Scale Factor = 0.99944031

Transformation between survey grids - All survey data was recorded and processed using local grid coordinates and scale factor 1. In order to produce drawings in National Grid the survey has to be translated and scaled by two known points, this was carried out within LSS using the points below. These points were also used to calculate the local scale factor at the mid point between them.

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NG - E: 232470.918, N: 378706.805

LG - E: 232470.894, N: 378706.821

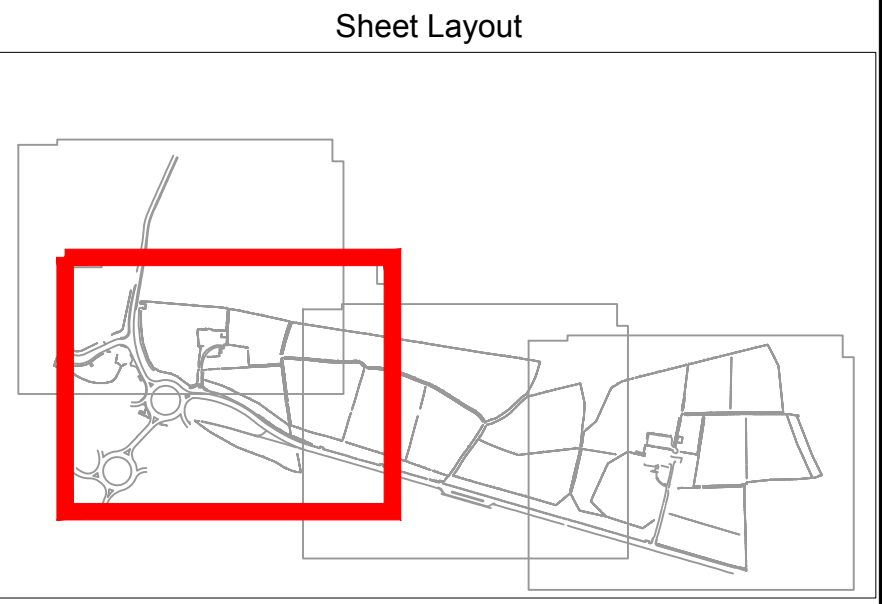
P208

NG - E: 233328.208, N: 378147.978

LG - E: 233328.232, N: 378147.962

Survey Stations

Name	Eastings (m)	Northings (m)	Level (m)
P200	232470.894	378706.821	19.476
P201	232433.680	378526.748	18.660
P202	232463.548	378411.079	21.939
P203	232553.200	378408.544	21.723
P204	232665.759	378338.698	18.755
P205	232866.638	378280.360	15.704
P206	233015.239	378227.475	16.711
P207	233188.397	378187.125	18.420
P208	233328.232	378147.962	18.929



3.0	28.07.16	Updated to include south roundabout	SP	NH	NH	LM
2.0	21.05.16	Updated to include Carriageway Survey	SP	NH	NH	LM
1.0	15.04.16	Final Revision	SP	NH	NH	LM
Rev	Rev. Date	Purpose of revision	Drawn	Checked	Rev'd	Approved

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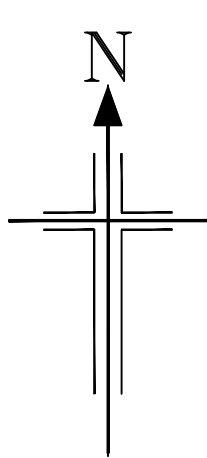
Project: Associated Development Sites
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Drawing title: **2d Topographical Survey**
Sheet 2 of 4

Drawing status: **FINAL**

Scale	1:500 @ A0	DO NOT SCALE
Jacobs No.	60PO8049	
Client no.	WN016-JAC-OS-DRG-00020	
Drawing number	60PO8049/JAC/TOPO/DRG/00003	Rev
		2.0

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ANNOTATIONS:			
AV	Air Valve	RE	Rodding Eye
BH	Borehole	RNP	Road Name Plate
BL	Bed Level	RP	Reflector Post
Bol	Bollard	RS	Road sign
OSBM	Bench Mark	SAP	Sapping
BS	Bus Stop	SF	Soft Level
BT	Telcom IC	SH	Shalt Box
Br	Stay Wire	ST	Stop Tap
Cbx	Control Box	SV	Sluice Valve
Culv	Culvert	Tap	Water Tap
CL	Cover Level	TCB	Telephone Call Box
CTV	Cable TV	TS	Traffic Signal
DP	Down Pipe	TL	Traffic Light
Dr	Drain cover	TH	Threshold Level
Ebx	Electric Box	TM	Traffic Master
EC	Electric Cover	TP	Telegraph Pole
EP	Electric Pole	CCTV	CCTV Camera
PY	Electric Pylon	Gvp	Vent Pipe
ER	Earthing Rod	WE	Water Cover
FH	Fire Hydrant	WL	Water Level
FL	Flood Light	WM	Water Meter
FS	Flag Staff	WO	Wash Out
GS	Gas Manhole		
GT	Gate Post		
G	Gully		
GV	Gas Valve	CBF	Close Boarded Fence
IC	Inspection Cover	IRF	Iron Railings Fence
IL	Invert Level	PWF	Post & Wire Fence
Jbx	Junction Box	PRC	Post & Rail Fence
KO	Kerb Outlet	BWF	Barbed Wire Fence
KL	Kerb inlet	PCLF	Post & Chain Link Fence
LB	Litter Bin		
LC	Light Column		
LP	Lamp Post		
MH	Manhole	AB	Abutment Wall
Mkr	Marker Post	BW	Brick Wall
MP	Mile Post	SW	Stone wall
MS	Mile Stone	DSW	Dry Stone Wall
NB	Notice Board	RTW	Retaining Wall
Pl	Pipe	CW	Concrete Wall
PM	Parking Meter		
P	Post		
PU	Pump		
PZ	Piezometer		

SYMBOLS:	
Building	Kerb
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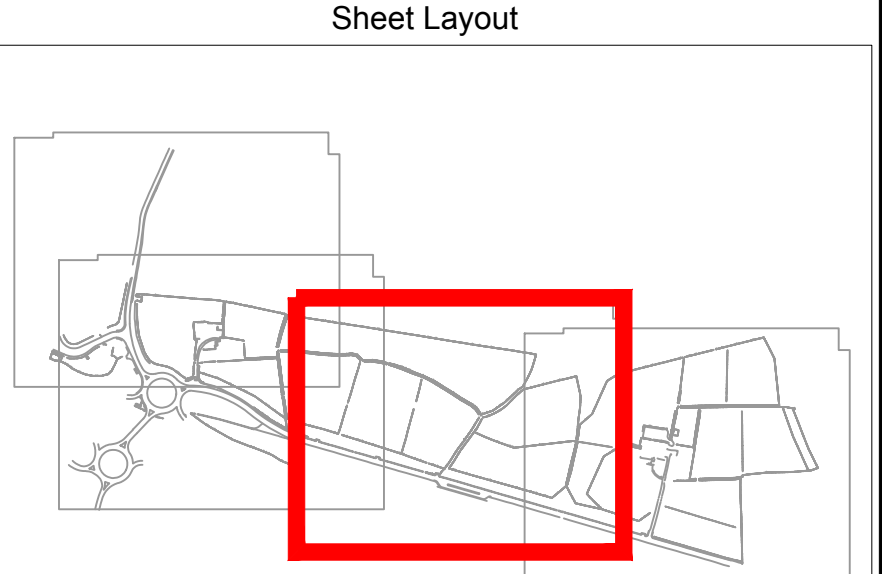
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Rev	Rev. Date	Purpose of revision	Drawn	Checked	Rev'd	Apprv'd
3.0	28.07.16	Updated to include south roundabout	SP	NJH	NJH	LM
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Client no.

WN016-JAC-OS-DRG-00020

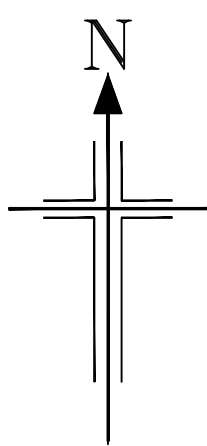
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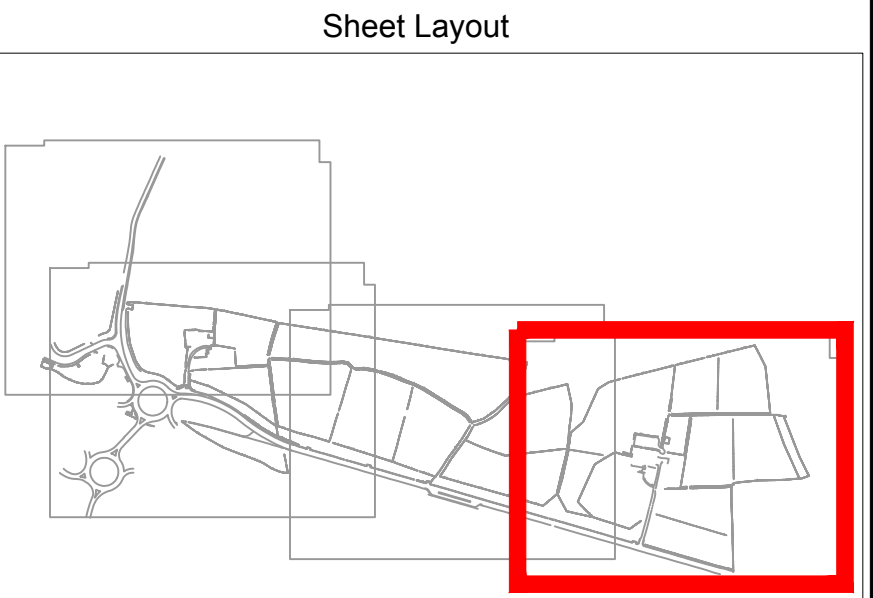
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Sheet 4 of 4

Drawing status
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Scale
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Jacobs No.
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WN016-JAC-OS-DRG-00020

Drawing number
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Appendix F8-1-2 Figures

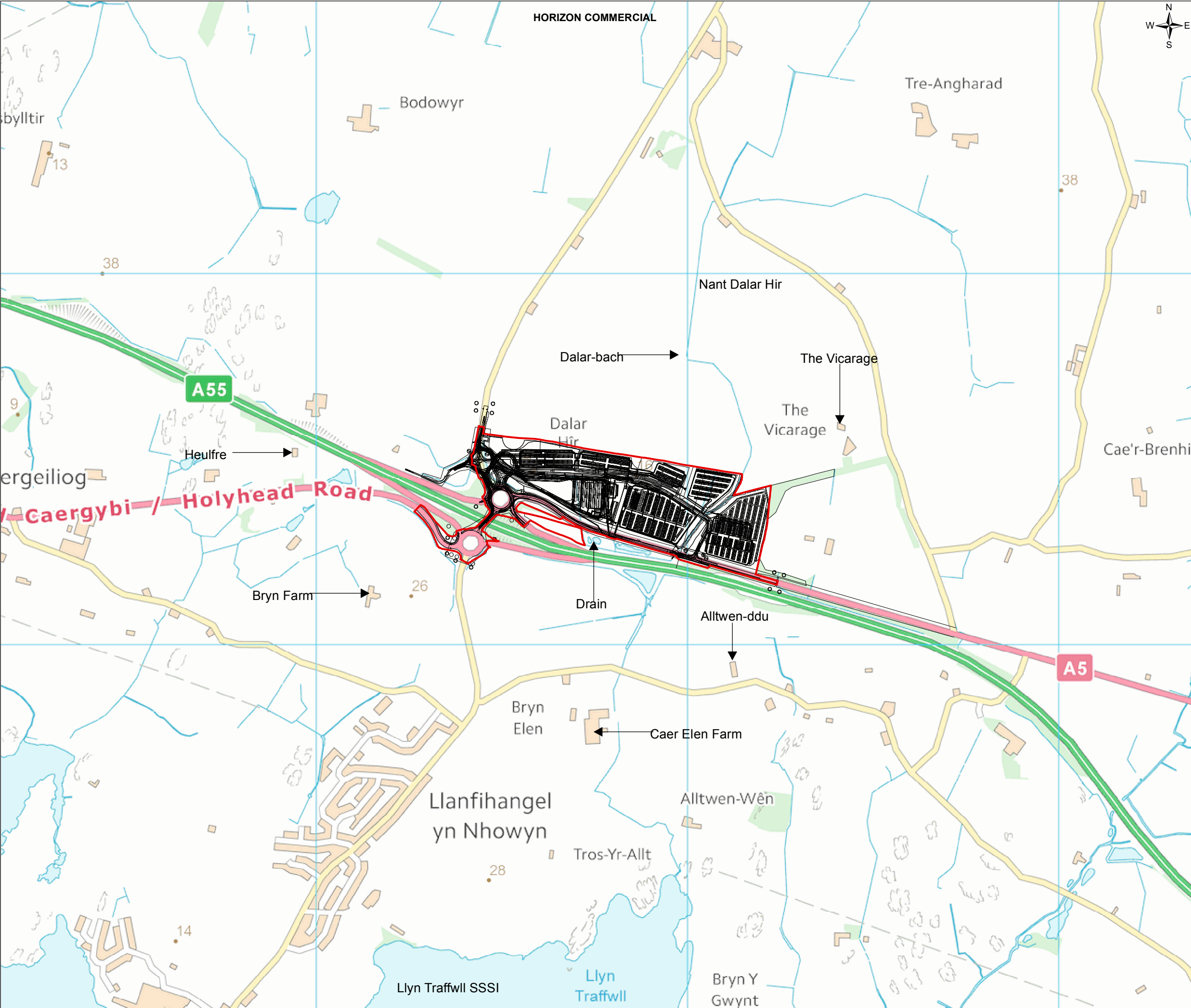


FIGURE F8-1-1

Legend

- Park and Ride
- Park and Ride masterplan

0	AUG 17	Initial Issue	RM	AJ	SH	RB
Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	App'd

Client

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NUCLEAR POWER

Project

WYLFA NEWYDD PROJECT
FLOOD CONSEQUENCE ASSESSMENT

Drawing Title

FLOOD RISK STUDY AREA
AND SURFACE WATER FEATURES

Scale @ A3

1:10,000

DO NOT SCALE

Jacobs No.

60PO8077

Client No.

Drawing No.

60PO8077_DCO_VOL_F_08_01_01_01

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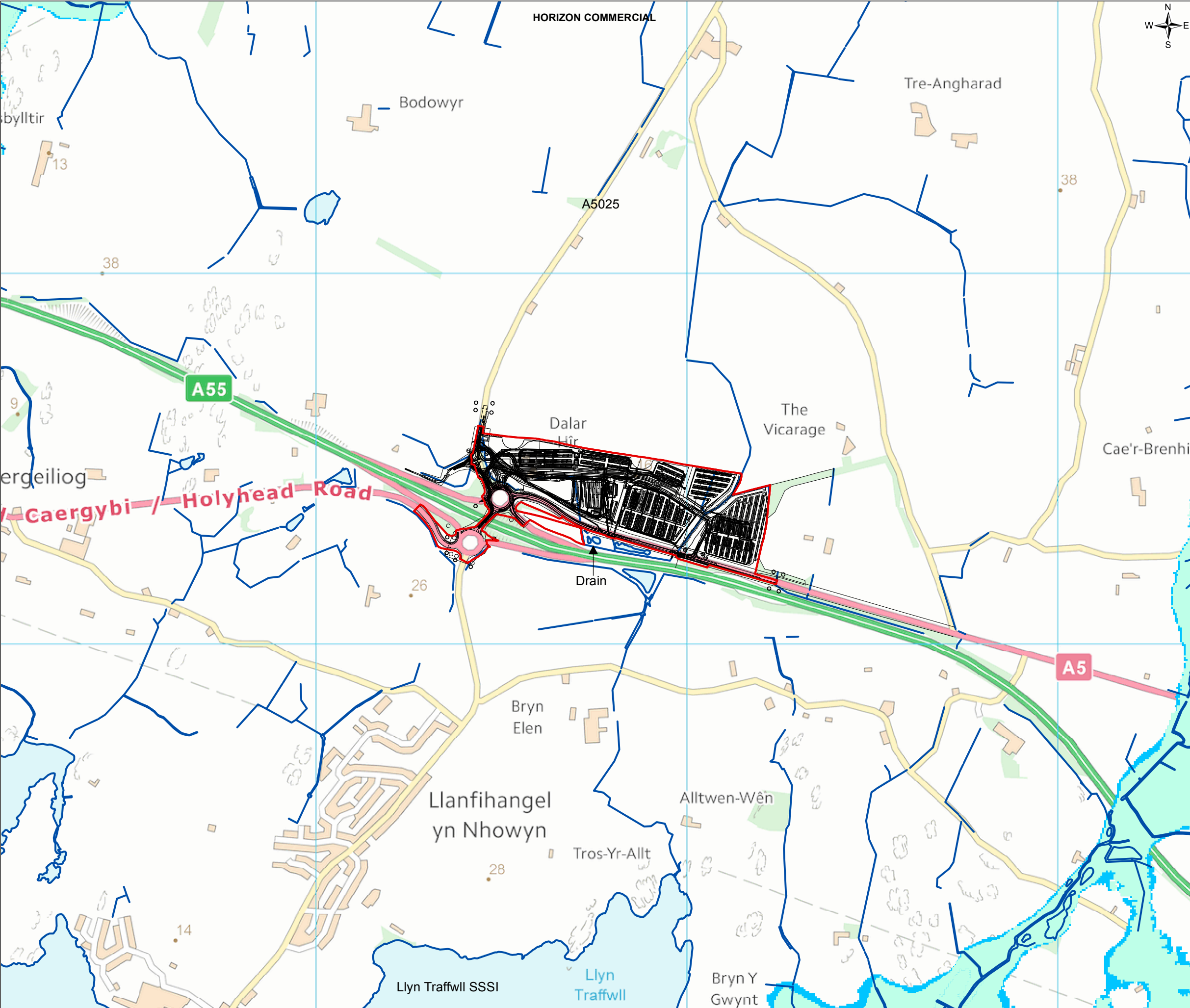


FIGURE F8-1-2

Legend

- Park and Ride
- Park and Ride masterplan
- Surface water features
- Flood Zone 3
- Flood Zone C2

0	AUG 17	Initial Issue	BW	AJ	SH	RB
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Client

HORIZON
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Project

WYLFA NEWYDD PROJECT
FLOOD CONSEQUENCE ASSESSMENT

Drawing Title

RISK OF FLOODING
FROM RIVERS AND SEA

Scale @ A3	1:10,000	DO NOT SCALE
Jacobs No.	60PO8077	
Client No.		
Drawing No.	60PO8077_DCO_VOL_F_08_01_01_02	

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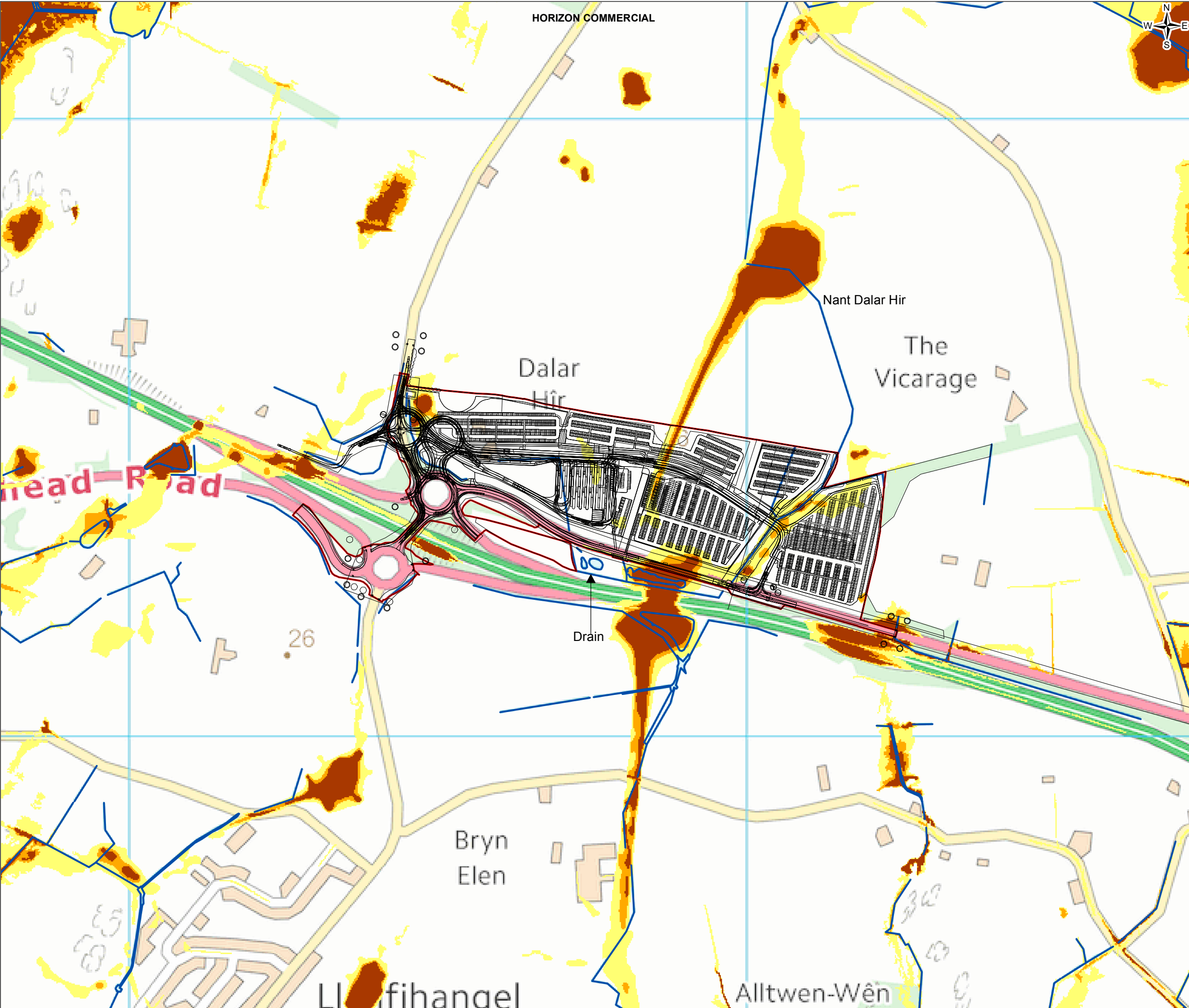


FIGURE F8-1-3

- Legend
- Park and Ride
 - Park and Ride masterplan
 - Surface water features
 - High surface water flood risk - extent
 - Medium surface water flood risk - extent
 - Low surface water flood risk - extent

0	JUL 17	Initial Issue	HT	AJ	SH	RB	
Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd	
Client							
HORIZON NUCLEAR POWER							
Project							
WYLFA NEWYDD PROJECT FLOOD CONSEQUENCE ASSESSMENT							
Drawing Title							
RISK OF FLOODING FROM SURFACE WATER							
Scale @ A3	1:6,000				DO NOT SCALE		
Jacobs No.	60PO8077						
Client No.							
Drawing No.	60PO8077_DCO_VOL_F_08_01_01_03						
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Appendix F8-1-3 Modelling results



Horizon Nuclear Power

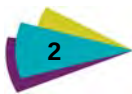
Wylfa Newydd DCO Project - Associated Development – Park & Ride, Dalar Hir, Anglesey, NW Wales

Hydraulic and Hydrology Modelling Factual Report



January 2018

Amec Foster Wheeler



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Report for

Horizon Nuclear Power
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1420 Charlton Court
Gloucester Business Park
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GL3 4AE

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Appendix A	Supporting Mapping
Appendix B	Channel roughness representation
Appendix C	Structure representation

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1. Introduction

1.1 Purpose of this report

This factual report has been produced for the purpose of describing the hydrology assessment and the pluvial and fluvial hydraulic modelling undertaken to support the Wylfa Newydd DCO Project and associated consents, specifically for the proposed Park and Ride (P&R) facility situated to the north of the A5 and A55, east of the existing Dalar Hir Interchange. This factual report does not present an assessment of the results. This factual report provides a detailed statement of the hydrological and hydraulic modelling methods applied, assumptions made and the limitations within the approaches. For details of the scheme proposed and the site context the reader is directed to the parent FCA (Flood Consequence Assessment) or ES (Environmental Statement) chapter.

1.2 Purpose of modelling

1D-2D Modelling has been undertaken to support the FCA of the proposed car park and ride scheme at the Dalar Hir site, Anglesey, NW Wales. To achieve this the scenarios detailed in Table 1.1 have been modelled. The modelling documented in this report has re-defined the baseline (present day) fluvial and pluvial flood risk to the Park and Ride (P&R) facility location at Dalar Hir. The modelling also quantifies the impacts of future risk including an allowance for climate change impacts. A range of flood events have been represented in the model to establish the extent of the baseline flood risk position which the project has used to inform the Site design of the park and ride scheme. The modelling has been undertaken to quantify any changes in the level of pluvial and fluvial flood risk due to the proposed scheme including the representation of embedded flood risk mitigation measures. A summary of the model scenarios required for hydrology assessment and hydraulic modelling is shown in Table 1.1.

Please note the two sources of flooding (fluvial and pluvial) have been assessed independently from each other using the same model. There was no requirement to model an in-combination event within the scope of the assessment. Fluvial events are catchment wide events and often have a different critical duration to a localised pluvial flooding event. It is common practice to model the two sources of flooding separately.

Table 1.1 Summary of model scenarios

Source	Hydrology method	Event	Season	Storm duration	Epoch	Climate change
Pluvial	ReFH2.2 with FEH13 rainfall data	1:30, 1:100, 1:1000 year AEP	Summer	6 hour*	2017	N/a
		1:100 year AEP	Summer	6 hour*	2080s	20% increase in rainfall depth 40% increase in rainfall depth
Fluvial	ReFH2.2 with FEH13 rainfall data	1:20, 1:100, 1:1000 year AEP	Summer	Critical	2017	N/a
		1:100 year AEP	Summer	Critical	2080s	30% increase in flows

AEP = Annual exceedance probability

* Critical duration taken for all pluvial events

Details on the climate change uplift factors can be found in Section 3.3 and 3.4

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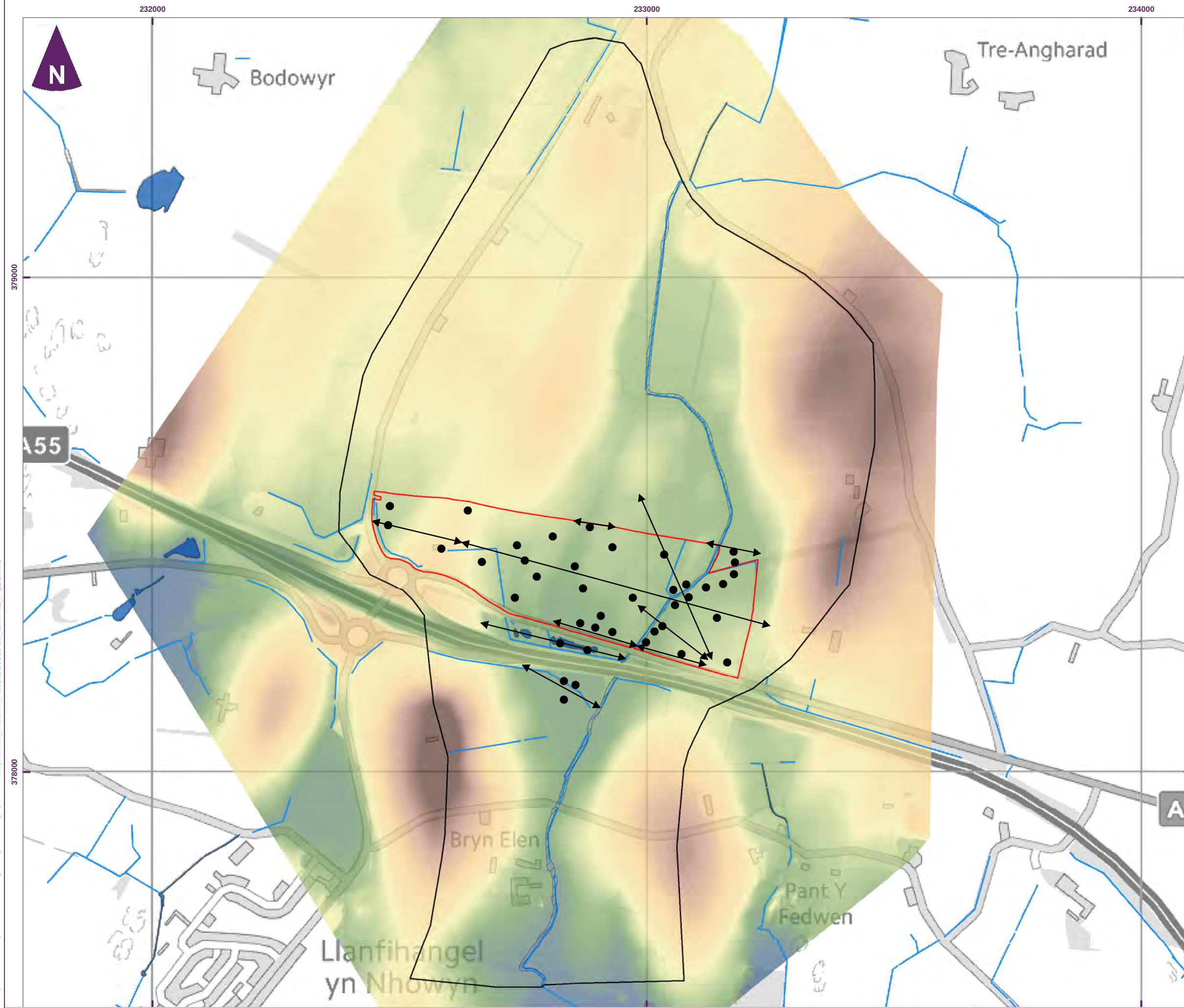
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1.3 Site overview

The P&R Site (hereafter referred to as the Site), is located to the north of the A5 and A55, east of the existing Dalar Hir Interchange and to the north of the town of Llanfihangel-yn-Nhowyn (Figure 1.1). The Site at present is agricultural land used for pasture, with a small unnamed watercourse (referred to in this report as the Dalar Hir Stream) which flows southwards from south of Bodedern towards the Llyn Traffwll shallow lake, located south of the A5 and A55. There are no other significant surface water features near the Site.

A catchment has been delineated for the Dalar Hir Stream. This encompasses the topographic highs to the east of the Dalar Hir Stream between Castell to Bryngoleu, and to the west between Dalar Hir and Ty'npwll.

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Key

LiDAR Data (25cm resolution)
34 mAOD
11 mAOD

Model boundary

1D Model Domain

Site Boundary

Results Point

Results Line

OS Mapping

Inland Water (OS Mastermap)

Watercourses (OS Vector Map)

0100200300400 m

Scale at A3

Wylfa Newydd
Associated
Developments
Hydraulic Modelling

Figure 1.1
Dalar Hir Setting

May 2017

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1.4 Overview of modelling approach

To fulfil the requirements of the Flood Consequence Assessment (FCA) it was necessary to construct a detailed 1D-2D model of the Dalar Hir area to determine the fluvial and pluvial flood hazard in the vicinity of the Site (Figure 1.1). The requirements were to develop a robust baseline flood risk position against which the impacts of the proposed car park and ride scheme could be robustly compared. There were no existing models that could be used. The 1D-2D approach was adopted as it was known that development would likely occur within a zone of flood risk and that this might have an impact on flood levels. The 1D-2D platform is deemed superior when it comes to defining those impacts in specific land parcels and for understanding overland flooding pathways. The model has been used to model both fluvial flood hazard and pluvial flood hazard. These sources of flooding have been assessed independently from each other using the same model. Fluvial events are catchment wide events and often have a different critical duration to a localised pluvial flooding event. In reality both sources may occur at the same time but separate fluvial and pluvial results when combined provide representative results.

The software used was Flood Modeller-TUFLOW. These are industry standard software packages, widely used for flood modelling.

The 2D model domain encompasses the Dalar Hir catchment from the road running between Ty'ny'graig and Bryngoleu in the north (upstream), to 350m downstream of the Alltwen Goch road bridge (downstream). The 2D domain has been further extended to west to include London Road to ascertain the impact of pluvial modelling in the western third of the Site as shown in Figure 1.1. The catchment was delineated using the OS Terrain 5 digital terrain model (DTM). This catchment was used to inform the pluvial hydrology assessment (Section 3) and to inform the spatial extent of the 2D model domain, described in Section 4.

1.5 Key assumptions

A detailed channel survey was conducted in September 2016 of the channels and associated structures. Detailed (0.25m) LiDAR data was captured in March 2017, and was used to represent the floodplain topography. The following key assumptions have been made:

- ▶ 1D and 2D Model extents have been determined to prevent any model boundary influence on the focus area around the Site;
- ▶ 'Soft bed' channel survey readings have been utilised in the 1D model build;
- ▶ The baseline results presented assume the culvert under the A5 is free of debris and bed materials, and has no blockage. There is a risk of blockage for this culvert and that 30% blockage would increase flood depths at the site by a maximum of 0.080m and that this should be considered in the FCA;
- ▶ LiDAR data (captured for the DCO Project in March 2017) has been assumed to be representative of the catchment, and critical elements within the catchment, such as roads, watercourses and land depressions;
- ▶ LiDAR data (captured for the DCO Project in March 2017) has been assumed to be the best available elevation data providing complete coverage of the required model domain;
- ▶ It has been assumed that representation of the minor field drains within the floodplain (as defined by LiDAR) which feed into the Dalar Hir Stream, in the 2D domain, provides a sufficiently accurate representation of the channel capacity to not influence the flood hazard on Site; and
- ▶ It has been assumed that the summer storm profile is the critical seasonal profile over which to apply total pluvial rainfall volumes. This has been selected based on pluvial modelling being

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undertaken for Wylfa Newydd DCO Project at the Main Site. The transfer of the conclusion of seasonal dominance from the main site is a limitation of the modelling, but was done to reduce the scope to meet the original programme. This assumption will be verified through follow up sensitivity testing not reported here.

The model is considered the best representation of the Dalar Hir Stream in the vicinity of the Site. The available data was appropriate for this study as the main purpose is to provide an estimate of flood extent across the Site and determine the potential impact of the P&R development. The model has been built for the purpose of flood risk mapping; therefore, it has been optimised for high flows.

1.6 Document structure

The remainder of this report is structured as follows:

- ▶ Section 2 - Available data: Identifies data collated or commissioned to aid model build and catchment representation;
- ▶ Section 3 - Hydrology: Details the fluvial and pluvial hydrology assessment;
- ▶ Section 4 - Model Overview: Details the representation of the 1D-2D model including any assumptions made;
- ▶ Section 5 - Model Runs: Lists the model scenarios run;
- ▶ Section 6 - Model Results: Provides a summary of model results, including flood extents and depths; and
- ▶ Section 7 - Sensitivity Testing: Lists sensitivity runs carried out on the 1D-2D model and discusses outputs.

As part of quality assurance (QA) of the modelling and reported results, internal peer reviews and audits were undertaken at various phases and they are separately documented as model logs and sign-off reviews. These are not presented here, however will be handed over to the HNP as part of the model handover.

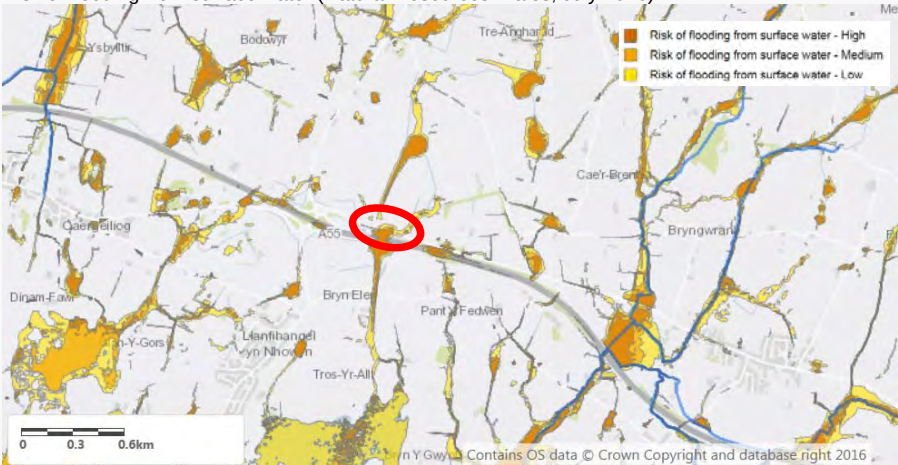
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2. Data summary

The 1D-2D model was built following collation of data to represent the Site and the surrounding catchment area. Table 2.1 lists the data sets used and provides a description of the contents of each data set.

Table 2.1 Data summary

Item	Comments
Cross section survey	For 1D flood model cross section survey data undertaken by Storm Geomatics; April 2016, conforming to NRW specification. Surveyed channels: Dalar Hir - Ty'nppwll, downstream of road (NGR: 233044, 378343) to Tros-Yr-Allt ~350m upstream of Llyn Traffwll (NGR: 232746, 377601) Overall location plan: channel and structure locations Channel cross sections: bed level (hard/soft); bank levels; water levels; location photos Channel survey also included adjacent floodplain, banks and bed to represent the channel geometry appropriately. Structure surveys: culverts/bridges/obstructions/walls with road/deck levels;
Topography data	LiDAR flown by BlueSky, March 2017. 0.25m resolution Digital Terrain Model (DTM) The LiDAR data has a stated vertical accuracy as $\pm 0.05\text{m}$ or better and the horizontal accuracy as $\pm 0.15\text{m}$ The extent of the LiDAR is represented in Figure 1.1
Gauging stations	None
Calibration/verification events	No calibration events identified due to no gauged data available
Flood history	Natural Resources Wales (NRW) and Isle of Anglesey County Council (IACC) currently have no available information on historic flooding.
Surface water flood risk	Risk of flooding from surface water (Natural Resources Wales, July 2016):  Red oval indicates indicative site location.
FEH 2013 DDF rainfall data	Pluvial inflow for hydraulic modelling, and to derive hydrographs FEH Web Service https://fehweb.ceh.ac.uk

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Item	Comments
	Sourced from FEH catchment centred at SH 33320 78744. Key Information: Area: 2.02km ² BFIHOST: 0.384 SPRHOST: 40.18 SAAR4170: 40.18
Catchment descriptors	Used to derive the fluvial hydrographs FEH Web Service https://fehweb.ceh.ac.uk
OS Terrain 5 topography	To delineate the hydrological catchment: Ordnance Survey https://www.ordnancesurvey.co.uk/business-and-government/products/os-terrain-5.html
Climate change allowance factors	To determine the climate change allowance factors applied to the 1:100 year AEP event the latest guidance was used. Flood Consequence Assessments: climate change allowances (Llywodraeth Cymru/Welsh Government, 2016)
OS mapping	Used in catchment delineation and verification of catchment descriptors OS 1:50,000 and Vector Maps. Available from: https://www.ordnancesurvey.co.uk/business-and-government/products/vectormap-products.html https://www.ordnancesurvey.co.uk/business-and-government/products/opendata-products.html

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3. Hydrology assessment

This section describes the process to derive the hydrology inputs for the hydraulic modelling. The pluvial hydrology inputs were in the form of hyetograph (rain/time) data for a range of storm durations and annual exceedance probability (AEP) events. Fluvial hydrology inputs to the hydraulic model were hydrographs (flow/time) for a range of storm durations and AEP events. The hydrology inputs have been calculated for the current baseline at the site.

3.1 Method of hyetograph calculation

Hyetographs were required to model the following events: 1:30, 1:100, 1:100 plus climate change and 1:1,000 year AEPs. The critical storm duration was modelled in each case, and was ascertained as described below.

Deriving hyetographs

Rainfall depths were obtained from FEH13 DDF tables for the Site. The FEH13 data provides total and net rainfall depths for storm durations from 5 mins to 240 hours, and for annual exceedance probabilities for the 1:1.3 year AEP to 1:100,000 year AEP). The ReFH2.2 method and associated software was used to derive the hyetographs for events required, as listed in Table 1.1.

Season profile

At the Wylfa Newydd DCO Project Main Site, the seasonal profile was assessed in detail and it was concluded that the summer storm profile applied as this represented a conservative approach. The critical profile is not expected to differ across the Isle of Anglesey or for relatively small differences in topography. It is therefore considered reasonable to adopt the summer profile as the critical season for the Dalar Hir site – this assumption will be verified by further sensitivity testing yet to be undertaken.

Rainfall parameters

Rainfall hyetographs were calculated using total rainfall depths, applying the default seasonal correction factor (SCF) calculated by ReFH2.2 from catchment descriptors, and overwriting the areal reduction factor (ARF) to 1. Using an ARF of 1 represents rain falling on all areas of the 2D domain, which is appropriate for the small area represented near the Site. The net rainfall hyetographs generated by ReFH2.2 were used as a direct input for the pluvial scenarios in the TUFLOW 2D model. As the losses were already considered in ReFH2.2 output, the net rainfall depths were directly applied and no losses were considered in the 2D domain explicitly.

Critical storm duration

The 1:100 year AEP event was used to determine the critical storm duration for the Site, by running five storm durations (0.5, 1, 3, 6 and 24 hour storms). The critical storm was determined based on which storm duration resulted in the largest peak depth achieved on the Site. The selection of the critical storm is discussed in further detail in Section 5.1. The critical storm duration was identified as the 6 hour storm (360 minutes).

Table 3.1 presents the pluvial scenarios that were represented in the Flood Modeller - TUFLOW model.

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Table 3.1 Pluvial scenarios represented in the model

Parameter	1:30 year AEP	1:100 year AEP	1:100 year AEP + 20% CC	1:100 year AEP + 40%CC	1:1000 year AEP
Storm duration (hour)	Critical duration	0.5, 1, 3, 6, 24 hours (to determine critical duration)	Critical duration	Critical duration	Critical duration

Note: AEP: Annual Exceedance Probability

Climate change allowance

Climate change was applied to the 1:100 year AEP event only. Climate change to the 2080s was accounted for in two scenarios, by applying a central change 20% uplift factor and an upper end estimate 40% uplift factor to rainfall depth. This increase is informed by guidance from Llywodraeth Cymru/Welsh Government (2011), (for pluvial rainfall intensity, for the 2080's epoch). The central change factor would normally be applied to the 1:100 year AEP event for design.

Net rainfall

The net rainfall depths calculated for the required events by ReFH2.2 is shown in Table 3.2.

Table 3.2 Net rainfall depths

Storm duration (hour)	Net rainfall depth (mm)		
	1:30 year AEP event	1:100 year AEP event	1:1000 year AEP event
0.5	-	17.44	-
1	-	24.00	-
3	-	32.14	-
6	26.18	37.94	65.35
24	-	51.10	-

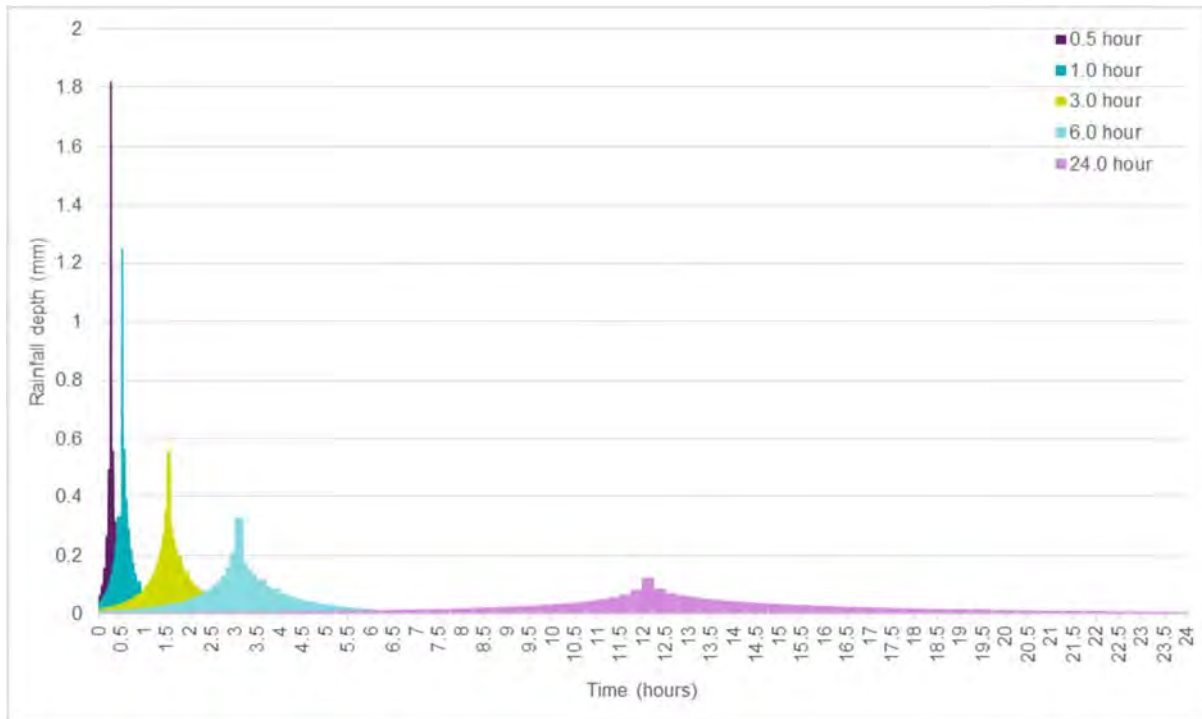
3.2 Hyetographs for pluvial scenarios

This section presents the rainfall hyetographs which are used in the hydraulic model. Figure 3.1 displays the storm profiles of the five different storm durations for the 1:100 year AEP event. The 0.5 hour storm duration has the highest peak rainfall at approximately 1.8 mm, with the 24 hour storm duration peaking at approximately 0.1 mm. Based on peak flows at the site, the 6 hour storm duration, which resulted in the highest peak flows is taken as the critical storm duration.

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Figure 3.1 Pluvial 1:100 year AEP event hyetographs for all storm durations

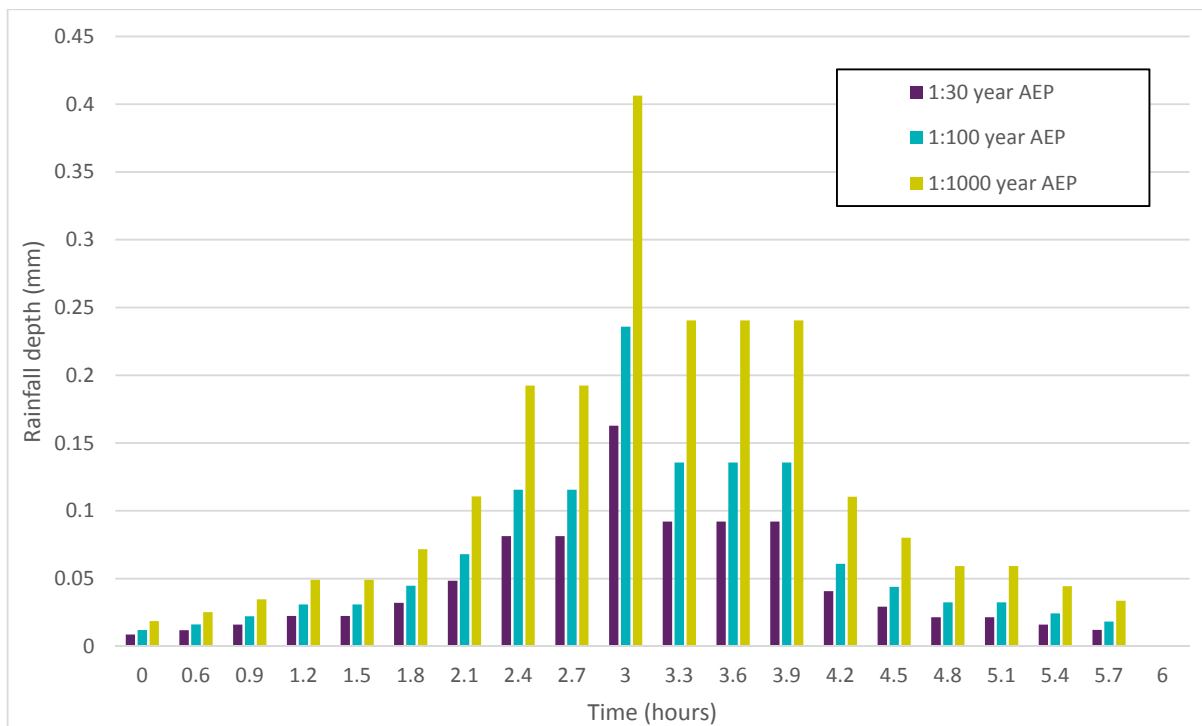


The critical 6 hour design hyetographs for the different events are displayed in Figure 3.2. Rainfall for the 1:1000 year AEP event peaks at a depth of 0.4 mm (at 180 minutes).

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Figure 3.2 Pluvial 6 hour critical storm hyetographs



3.3 Method of hydrograph calculation

A hydrological assessment was undertaken for the Dalar Hir Stream to determine the fluvial inflow to the model. The assessment was undertaken for the catchment to the downstream limit of the model (NGR SH 32750 77650), but applied at the upper extent of the 1D model domain (NGR SH 33030 79009).

Hydrographs were required to model the following events: 1:20, 1:100, 1:100 plus climate change and 1:1000 year AEP events. The critical storm duration was represented for each event as determined by the assessment and described in the storm duration sub-section.

Catchment boundary and catchment descriptors

The Dalar Hir Stream catchment identified on the FEH CD-ROM 3 was compared to that derived using OS Terrain 5 topographic data. This showed a change in catchment location, but only a very minor difference in overall catchment extent, increasing the catchment area from 2.02 km² to 2.06 km². The change in area was considered too minimal to have any impact on the catchment descriptors, so they were unchanged, with the exception of the small increase to area. The topographic and FEH derived catchments are shown in Figure 3.3, with the key hydrological parameters for each location presented in Table 3.3.

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Figure 3.3 Dalar Hir Stream catchments

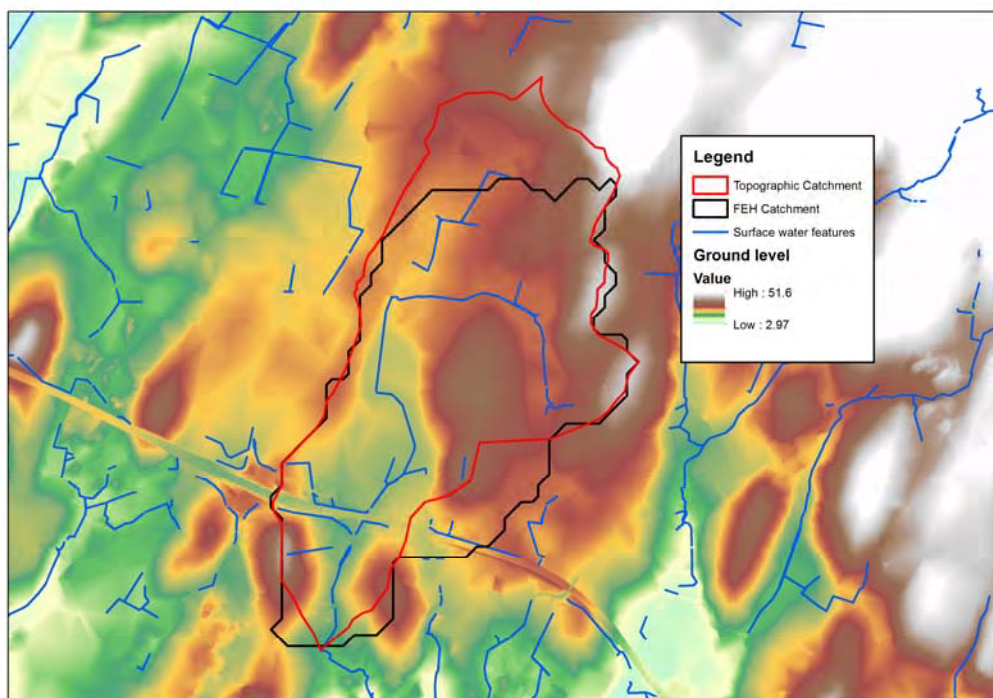


Table 3.3 Key hydrological parameters

Watercourse	Location description	National Grid Reference (NGR)	Area (km ²) [1]	SAAR (mm/yr)	FARL	BFIHOST	URBEXT 2000
Dalar Hir	Downstream model extent	SH 32750 77650	2.06	927	1	0.384	0

Source: FEH Web Service (<https://fehweb.ceh.ac.uk>)

[1] Area adjusted based on the updated delineation from topography.

Deriving hydrographs

Current guidance from Natural Resources Wales (NRW), in the form of Technical Guidance: Flood Estimation (NRW, 2016), identifies two recommended methods to estimate flow for events up to and including a 1:1000 year AEP event:

- ▶ Flood Estimation Handbook (FEH) statistical method; and
- ▶ Revitalised Flood Hydrograph (ReFH, Version 2.2) method.

NRW's preferred approach for estimating peak flows up to and including a 1:100 year AEP event is the FEH statistical method based on Technical Guidance: Flood Estimation (NRW, 2016). The FEH statistical method uses pooled annual maxima flow data from a group of hydrologically similar gauged catchments. Although NRW's preferred method was to use FEH statistical method so as to make the best use of locally observed data, rainfall-runoff method as implemented in ReFH2 method has been used for this site considering the size of the catchment. As most gauges are located in large catchments, it can be problematic to derive

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hydrologically similar pooling groups for small catchments such as Dalar Hir. The ReFH2.2 method can be reliably used with small catchments and produces full hydrographs, as required by the hydraulic model.

In deriving the hydrographs using ReFH2.2, the SCF and ARF were left at their default values.

Storm duration

The indicative storm duration is calculated by the ReFH2.2 software using catchment descriptors, but this is not necessarily the storm duration that produces the highest peak flow for every event. Storm durations longer and shorter than the indicative duration were checked in order to identify the storm duration that produced the highest peak for each event. Where more than one duration produced the same peak, the duration that produced the larger total volume was selected as the critical duration for design hydrology. A spectrum of ReFH2.2 results for the peak flows and the total volumes have been presented in Table 3.4 for each return period event considered.

Table 3.4 Peak flows (m³/s) and total volumes (ML) for various storm durations

Storm Duration	1:2 year AEP		1:20 year AEP		1:100 year AEP		1:1000 year AEP		Remarks
(hours)	flow	volume	flow	volume	flow	volume	flow	volume	
3.5	-	-	-	-	4.52	132.72	7.97	229.11	
4.5	1.34	39.8	2.74	83.85	4.59	141.89	7.97	247.87	Critical for all peak flows
5.5	1.39	43.61	2.78	89.44	4.59	149.3	7.88	257.83	Critical for 1:100 years AEP
6.5	1.42	46.85	2.79	94.09	4.55	155.32			Critical for 1:20 years AEP
7.5	1.44	49.58	2.78	98.04	-	-			
8.5	1.45	52.08	-	-	-	-			
9.5	1.45	54.45	-	-	-	-			Critical for 1:2 years AEP
10.5	1.44	56.43	-	-	-	-			

Considering both peak flow and total volume fluvial events, the critical storm durations that were taken forward for the analysis are summarised in Table 3.5. These values were also presented during a consultation meeting with NRW on 12, April, 2017 (Ref 'NRW Consultation Meeting Presentation 120417 v2.pdf')

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Table 3.5 Storm durations for fluvial scenarios

Event	Critical storm duration based on ReFH2.2 peak flow (hours)	Critical storm duration based on ReFH2.2 peak flow and volume (hours)	Selected Final Critical storm duration (hours)
1:2 year AEP	4.5	9.5	9.5
1:20 year AEP	4.5	6.5	6.5
1:100 year AEP	4.5	5.5	5.5
1:1000 year AEP	4.5	4.5	4.5

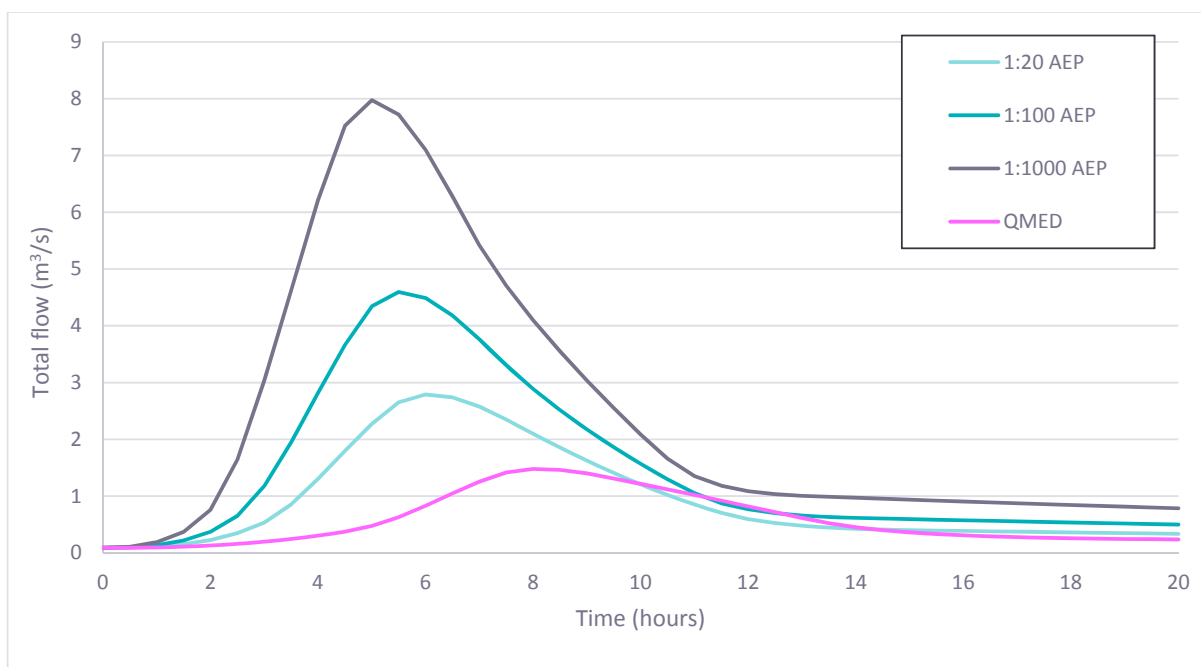
Climate change allowance

Climate change is applied by using a 30% uplift on the 1:100 year AEP event as per current guidance (Llywodraeth Cymru/Welsh Government, 2016). This is the central estimate for climate change allowance for the 2080s. Although this has been applied to the peak flow for this report, when representing in the model the entire hydrograph was scaled to this adjusted peak.

3.4 Hydrographs for fluvial scenarios

This section presents the hydrographs which are used in the Flood Modeller - TUFLOW hydraulic modelling, based on the approach presented in Section 3.3. The derived hydrographs are shown on Figure 3.4, with the peaks listed in Table 3.4. The inflow hydrographs will be applied as point inflows to the upstream extent of the hydraulic model representation of the Dalar Hir Stream.

Figure 3.4 Final hydrographs to be modelled



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Table 3.6 Final hydrograph peak flows to be modelled

Event	Method	Peak flow (m ³ /s)
1:2 year AEP (QMED)	ReFH2	1.48
1:20 year AEP	ReFH2	2.79
1:100 year AEP	ReFH2	4.59
1:100 year AEP + climate change	ReFH2 + 30%	5.97
1:1000 year AEP	ReFH2	7.97

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4. Baseline Hydraulic Model Build

This section provides an overview of the 1D and 2D models used to determine the impact of the proposed P&R development. The software chosen (Table 4.1) and model extents (Table 4.2) are detailed below. Figure 4.1a and Figure 4.1b display the spatial extent of the model roughness, and the results lines where model output is available.

Table 4.1 Model approach and software

Item	Comments
Model approach	Fluvial and Pluvial modelling undertaken using 1D-2D hydraulic modelling approach.
Model software	1D Model: Flood Modeller v4.2 2D Model: TUFLOW.2016-03-AA-iSP-w64 (fluvial runs); TUFLOW.2016-03-AE-IDP-w64 (pluvial runs)

Table 4.2 Model extent

Watercourse	Channel representation	Floodplain representation	Upstream limit	Downstream limit	Area of 2D model
Dalar Hir	Flood Modeller	TUFLOW	233068 379198	232791 377569	Fluvial and Pluvial Model 1.28 km ²

4.1 1D model

This section provides an overview of the 1D model built to represent the Dalar Hir Stream near the P&R development. The Dalar Hir 1D model was built in Flood Modeller Pro. The overview of the 1D baseline model set up is detailed in Table 4.3.

Table 4.3 1D baseline model overview

Item	Comments
Inflow boundaries	One inflow boundary where Dalar Hir Stream flows under the unnamed road at north of catchment (DALA01_1907). Inflow was set to baseflow for pluvial baseline scenario. See hydrology section for fluvial inflows. The pluvial modelling was undertaken to predict overland flow routes and ponding areas. The fluvial modelling was undertaken to define the extent of the pluvial floodplain to be avoided. The purpose of which was to allow impacts of the development to be assessed on a standalone basis. There was no intention or requirement to model a combined event.
Lateral catchment weighting	No lateral catchment boundary.
Downstream boundary	Downstream normal depth boundary set at southernmost extent of model catchment. The boundary has been sited far enough downstream to ensure the downstream boundary condition does not affected the water levels predicted on site. (This has been confirmed as part of the sensitivity testing see Section 8.2).
Lateral outflow boundary	Boundary to the north of the Dalar Hir Interchange to allow water to drain from the model to the west of the topographic divide.

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Item	Comments																						
Backwater length	This is a calculation to work out how far upstream you would expect the model downstream boundary to influence the model results upstream. The calculation ensures that the downstream boundary is far enough from the site of interest to not influence the fluvial results. Recommended backwater length (Samuels, 1989): ~ 1km Backwater equation: $0.7 \times (\text{Depth/Slope})$ Average depth of channel (bank to bed): ~ 1.17m Surveyed slope in downstream section of Dalar Hir Stream (between section DALA01_0269 and DALA01_0000): $(13.22 - 11.56) / 268.78 = 0.006$ Backwater length = $0.7 \times (1.17\text{m} / 0.006) = 136.5\text{m}$																						
1D Model length (km)	1.9 km																						
Total Number of nodes and structures	<table> <tr> <td>River Section (surveyed)</td><td>24</td></tr> <tr> <td>River Section (copied)</td><td>2</td></tr> <tr> <td>Interpolate units</td><td>23</td></tr> <tr> <td>Junctions</td><td>8</td></tr> <tr> <td>Orifices</td><td>1</td></tr> <tr> <td>Conduits (culverts upstream and downstream)</td><td>3</td></tr> <tr> <td>Culvert Inlet (General Loss)</td><td>2</td></tr> <tr> <td>Culvert Outlet</td><td>2</td></tr> <tr> <td>Spills over structures</td><td>5</td></tr> <tr> <td>QTBDY</td><td>1</td></tr> <tr> <td>NCDBDY</td><td>1</td></tr> </table>	River Section (surveyed)	24	River Section (copied)	2	Interpolate units	23	Junctions	8	Orifices	1	Conduits (culverts upstream and downstream)	3	Culvert Inlet (General Loss)	2	Culvert Outlet	2	Spills over structures	5	QTBDY	1	NCDBDY	1
River Section (surveyed)	24																						
River Section (copied)	2																						
Interpolate units	23																						
Junctions	8																						
Orifices	1																						
Conduits (culverts upstream and downstream)	3																						
Culvert Inlet (General Loss)	2																						
Culvert Outlet	2																						
Spills over structures	5																						
QTBDY	1																						
NCDBDY	1																						
Labelling/ Numbering system	DALA01_#### (for sections along the Dalar Hir Stream) Where #### represents chainage from drains downstream boundary Node names may be suffixed by the following: _u upstream copy of surveyed node _d downstream copy of surveyed node _c1 culvert inlet _c2 culvert outlet _S spill unit - O orifice Where labelling exceeds the permitted number of characters the four digit chainage suffix "_####" has been reduced to three digits "_###".																						
Hydraulic roughness values	Channel roughness values have been represented in the models by Manning's 'n'. Descriptions in Chow (1959) were examined against photos and conditions seen on the site visit/survey. Detail values used why used, provide a breakdown of values and evidence can be seen in Appendix B.																						
Structures	Structure representation detailed in Appendix C.																						

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4.2 2D model

This section provides an overview of the 2D model built to represent the Dalar Hir site. The Dalar Hir 2D model was built using TUFLOW. The model was built with the same geometry for both the fluvial and pluvial baseline models as detailed in Table 4.4. For the most part the fluvial and pluvial baseline models are the same, aside from two additional components which are included in the pluvial 2D model; the pluvial model included an additional rainfall boundary polygon (same area as model domain) which is not included in the fluvial model and there is an additional stage-discharge boundary to the north of the Dalar Hir Interchange which allows water to drain from the model to the west of the topographic divide (which generally follows along the road). This boundary was added as it was noted in a pluvial event there was an area of glass walling along this section of the 2D boundary. From an assessment of the topography it was evident that the water would in fact continue to flow away from the site in this area. Therefore this boundary condition was added based on the slope of the surrounding land to allow water to flow 'out' of the model domain rather than 'glass wall'.

Table 4.4 2D model overview

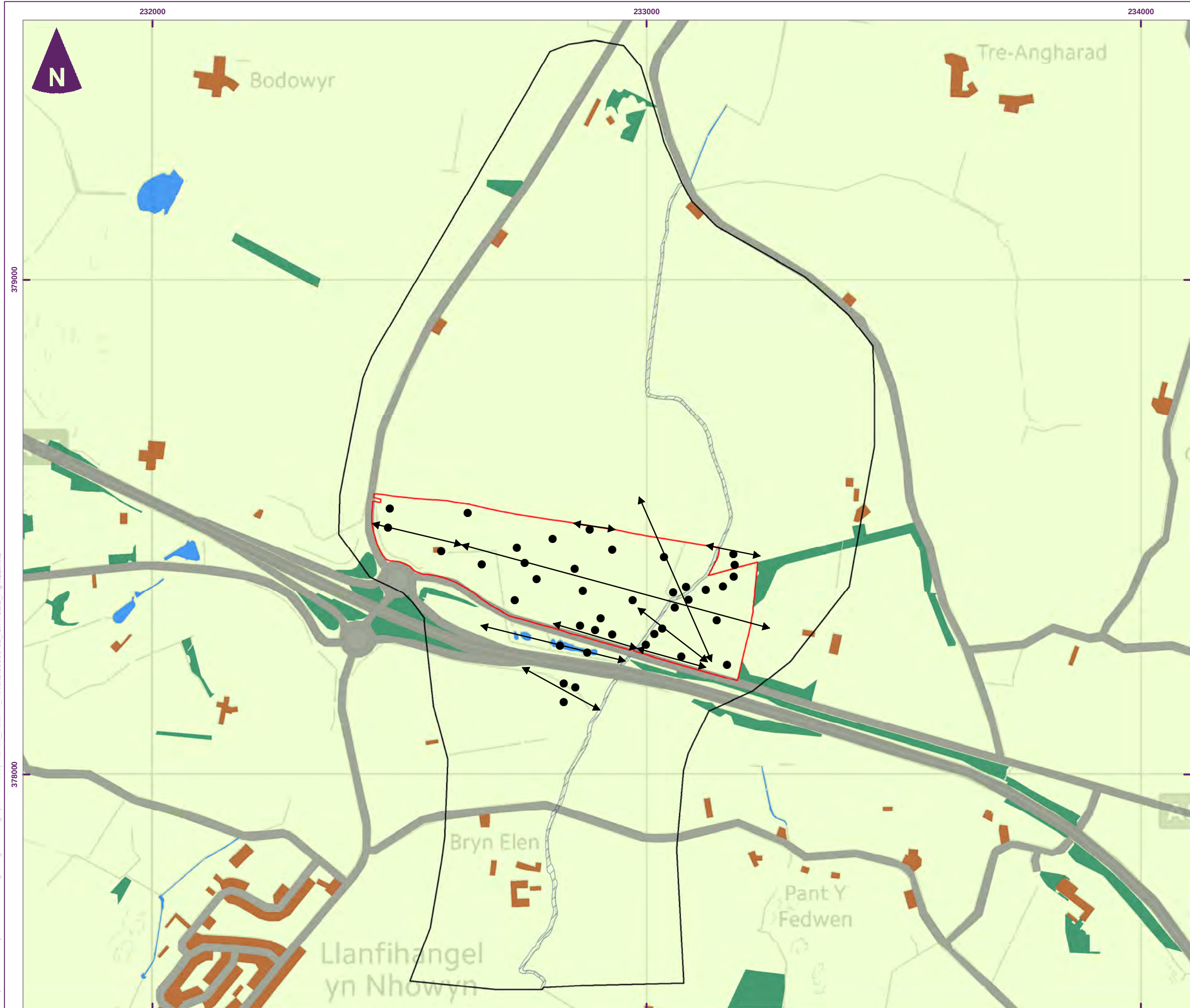
Item	Comments												
Resolution of grid	2m												
Orientation of grid	North - South												
Topographic modifications	Topographic patch added to A5 to east of slip road, where LiDAR data appears to have had the road crossing filtered out and therefore the data here did not follow reality. Update undertaken in 2d_zsh_Road_005, where a patch was interpolated from the LiDAR levels of the road either side of the crossing.												
Representation of buildings	Buildings are represented at ground level with an increased roughness of $n=0.3$.												
Representation of river banks	0.25m LiDAR was used as bank top levels. The LiDAR is read into the TUFLOW Grid and those grid cells which form the 1D-2D link (along the bank tops) are therefore informed by the underlying LADR level.												
1D-2D Link	The 1D-2D link has been digitised along the top of bank. The 'Flood Modeller' cross sections are a width consistent with the 1D-2D link and deactivated area in the 2D TUFLOW model. Slight alterations of locations of banks were occasionally made in the 1D-2D link to ensure the 1D banks matched the 2D LiDAR bank locations.												
2D boundary conditions	Point source inflows are represented in 1D model. 1D-2D links between cross-section nodes and the river banks in the 2D mode in layer '1d_nwk_Base_008' 2D HQ (Head Flow) downstream boundary represented adjacent to the most downstream cross section in the model. HQ boundary gradient of 0.015 for area adjacent to channel and across the southern extent of the catchment. Gradient informed by LiDAR. To the north of the A55 the boundary has been set to the west of the road that runs from the Dalar Hir Interchange up to Bodedern. The western limit and eastern limit to the south of the A5 is the topographic highs which form the catchment extent. The north eastern limits of the 2D domain extends beyond the topographic high. Thus, the model extent covers the pluvial watershed associated with the development site.												
Delineation of roughness areas	OS Vector Maps and digitising roads from aerial photography used for roughness boundaries.												
Hydraulic roughness values	<table> <tr> <th>2D surface</th><th>Roughness value</th></tr> <tr> <td>Grass/General Surface</td><td>0.04</td></tr> <tr> <td>Building/Glasshouses/Structures</td><td>0.3</td></tr> <tr> <td>Rough grassland/Scrub/Trees</td><td>0.08</td></tr> <tr> <td>Inland/Tidal Water</td><td>0.035</td></tr> <tr> <td>Path/Roadside</td><td>0.025</td></tr> </table>	2D surface	Roughness value	Grass/General Surface	0.04	Building/Glasshouses/Structures	0.3	Rough grassland/Scrub/Trees	0.08	Inland/Tidal Water	0.035	Path/Roadside	0.025
2D surface	Roughness value												
Grass/General Surface	0.04												
Building/Glasshouses/Structures	0.3												
Rough grassland/Scrub/Trees	0.08												
Inland/Tidal Water	0.035												
Path/Roadside	0.025												

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Item	Comments
	Stability patch - An area of higher roughness (0.1) has been used to improve stability along bank tops for approximately 200m north of A55 culvert (2d_mat_stability_002).
Additional amendments for pluvial model	Rainfall polygon which matches extent of Dalar Hir model domain and adds rainfall equally across the model (2d_rf_Base_004). Please refer to the hydrology section in Section 3 for details of the hydrology calculations. The rainfall applied to the model is effective rainfall, with infiltration losses accounted for in the FEH methodology There is a western outflow 2D HQ boundary that allows water to flow out past topographic high (2d_bc_Base_019).

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Key

- Roughness Zones
(Mannings n coefficient)**
- 0.015 - Road
 - 0.025 - Path, Roadside
 - 0.035 - Inland Water
 - 0.08 - Rough Grassland, Scrub, Trees
 - 0.3 - Buildings, Glasshouse
 - 0.04 - Grass, General surface
- Model boundary
- 1D Model Domain
- Site Boundary
- Results Point
- Results Line
- OS Mapping

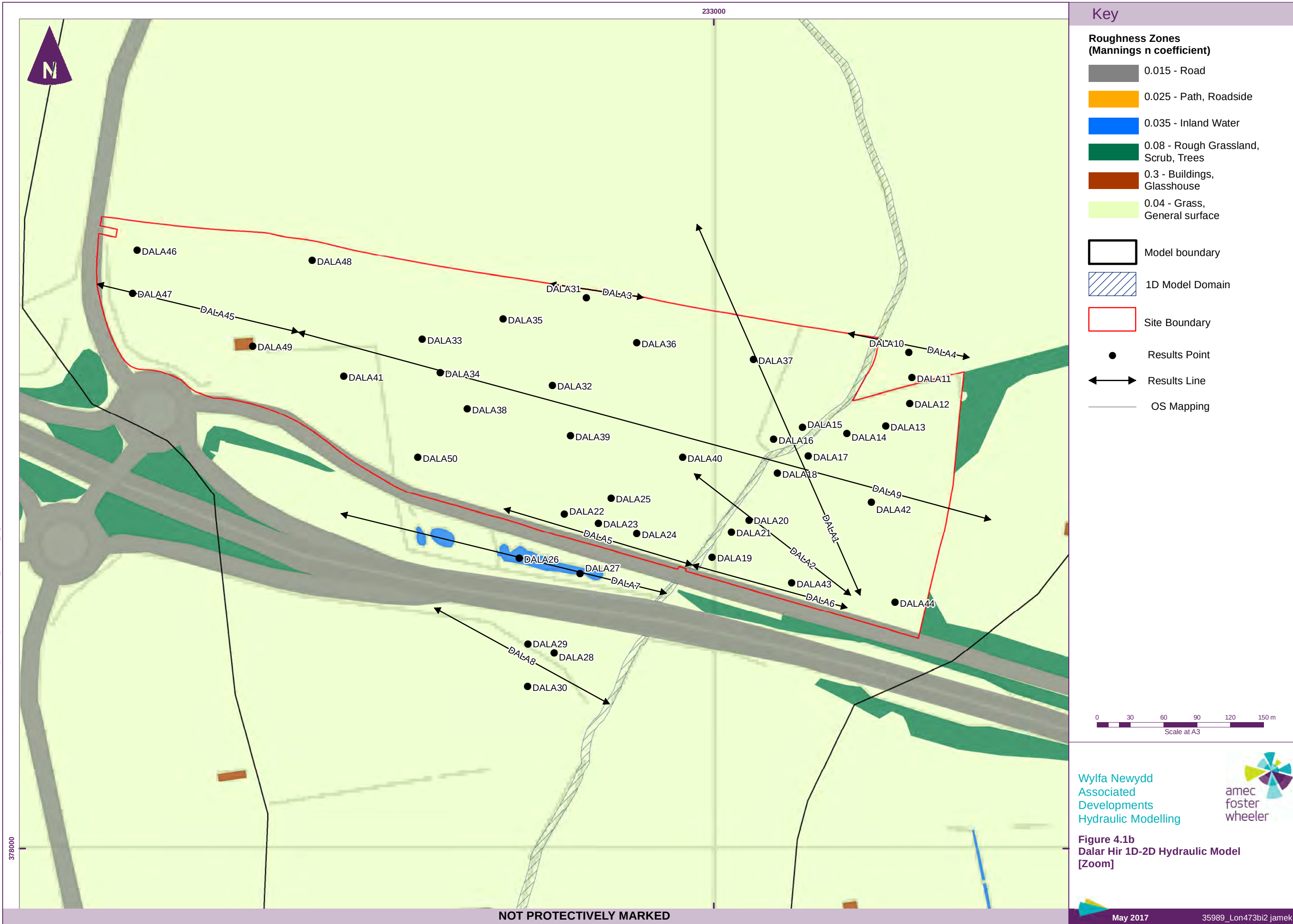


Wylfa Newydd
Associated
Developments
Hydraulic Modelling



Figure 4.1a
Dalar Hir 1D-2D Hydraulic Model

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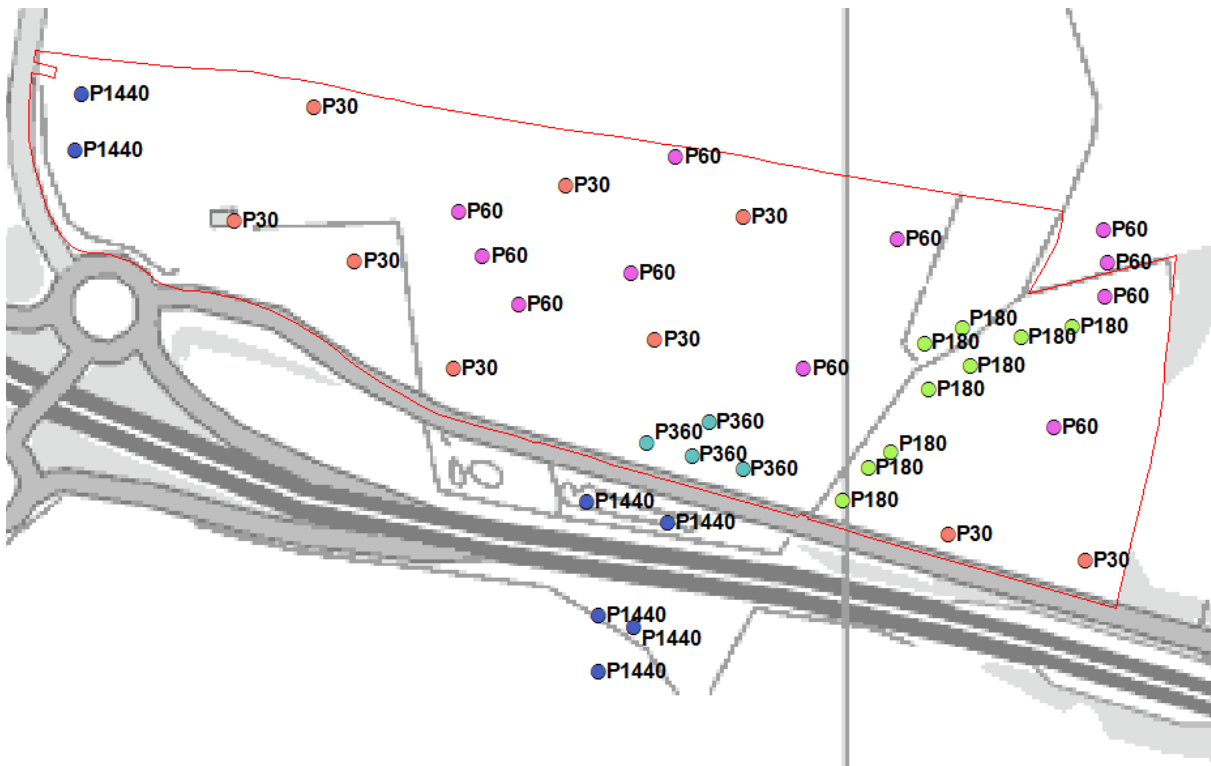
5. Model runs

The 1D-2D Dalar Hir model described in Section 4 was run for a range of separate pluvial and fluvial events. This section details all runs which have been completed and the process undertaken to identify the pluvial 'critical' storm duration.

5.1 Selection of the pluvial critical storm duration

It is usual practice to test a realistic range of storm durations to find the critical duration storm at the site of interest. The critical duration storm is the one that produces the largest flow, highest water level or greatest storage (volume) at the subject site (EA, 2016). The Dalar Hir model was run using the 1:100 year AEP event for the 0.5 hour, 1 hour, 3 hour, 6 hour and 24 hour storm durations for the baseline scenario. The peak flood depths across results points (Figure 4.2) in the 2D zone are displayed in Table 5.1 and Figure 5.1. There was no single duration that was resulting in the highest peak levels across the site (see Figure 5.1), therefore the duration that resulted in the peak flood depths for the known problem area was selected. As the 6 hour storm duration generated the highest peak flow, it was selected as the critical storm duration to the Site, and has been used for the baseline and development pluvial modelling runs for the remaining AEP scenarios.

Figure 5.1 Location of durations resulting in peak depth



P30 = 0.5 hour event; P60 = 1 hour event; P180 = 3 hour event; P360 = 6 hour event; P1440 = 24 hour event

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Table 5.1 1:100 year AEP event summary results – peak flood depth (m) at a point

Results point (P)	0.5 hour depth (m)	1 hour depth (m)	3 hour depth (m)	6 hour depth (m)	24 hour depth (m)
DALA10	0.18	0.19	0.18	0.17	0.14
DALA11	0.10	0.11	0.10	0.09	0.07
DALA12	0.10	0.11	0.10	0.09	0.07
DALA13	0.10	0.13	0.15	0.13	0.06
DALA14	0.27	0.33	0.35	0.34	0.23
DALA15	0.21	0.27	0.29	0.27	0.16
DALA16	0.26	0.32	0.34	0.32	0.21
DALA17	0.15	0.21	0.23	0.21	0.11
DALA18	0.35	0.41	0.43	0.41	0.30
DALA19	0.66	0.72	0.74	0.73	0.62
DALA20	0.50	0.56	0.58	0.56	0.45
DALA21	0.41	0.47	0.49	0.47	0.36
DALA22	0.61	0.89	1.05	1.05	0.93
DALA23	0.72	1.00	1.15	1.15	1.03
DALA24	0.68	0.96	1.11	1.12	0.99
DALA25	0.44	0.72	0.87	0.88	0.75
DALA26	0.31	0.37	0.45	0.49	0.60
DALA27	0.26	0.32	0.39	0.44	0.54
DALA28	0.62	0.69	0.74	0.77	0.78
DALA29	0.28	0.35	0.41	0.43	0.45
DALA30	0.15	0.22	0.28	0.30	0.32
DALA31	0.14	0.15	0.14	0.13	0.10
DALA32	0.13	0.14	0.14	0.13	0.10
DALA33	0.13	0.14	0.13	0.12	0.10
DALA34	0.15	0.16	0.15	0.14	0.12
DALA35	0	0	0	0	0
DALA36	0.01	0.01	0.01	0.01	0
DALA37	0.01	0.01	0.01	0.01	0
DALA38	0.02	0.02	0.02	0.01	0

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Results point (P)	0.5 hour depth (m)	1 hour depth (m)	3 hour depth (m)	6 hour depth (m)	24 hour depth (m)
DALA39	0.01	0.01	0.01	0.01	0
DALA40	0.01	0.01	0.01	0.01	0
DALA41	0.01	0.01	0.01	0.01	0
DALA42	0.01	0.01	0.01	0.01	0.01
DALA43	0.01	0.01	0.01	0.01	0.01
DALA44	0.01	0.01	0.01	0.01	0
DALA46	0.32	0.35	0.43	0.49	0.59
DALA47	0.09	0.12	0.20	0.25	0.36
DALA48	0	0	0	0	0
DALA49	0.01	0.01	0.01	0.01	0
DALA50	0.01	0.01	0.01	0	0

5.2 Baseline runs

The details of the baseline design runs are in Tables 5.2 and 5.3. Five pluvial design runs with different annual exceedance probabilities and climate change factors were run using the critical 6 hour storm duration (Table 5.2). Four fluvial design runs with different annual exceedance probabilities were run using the fluvial version of the 1D-2D model (Table 5.3). When more than one duration produced the same highest peak, the duration that produced the larger total volume was selected as critical duration for the fluvial events.

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Table 5.2 Baseline pluvial runs

Item	Comments
Pluvial baseline events	For the critical duration pluvial storm (6 hour): ▶ R30: 1:30 year AEP event, present day. ▶ R100: 1:100 year AEP event, present day. ▶ R100CC: 1:100 year AEP event with climate change (20%). ▶ R100CC: 1:100 year AEP event with climate change (40%). ▶ R1000: 1:1000 year AEP event, present day Note all pluvial events were run with a constant baseflow of 0.275m³/s in the channel.
1D model files	DALA01_025.dat Baseflow.IED DALA001_1D-020.zzs ▶ DALA01_1D-025_2D-039_Base_P360_R30.ief ▶ DALA01_1D-025_2D-039_Base_P360_R100.ief ▶ DALA01_1D-025_2D-039_Base_P360_R100cc20.ief ▶ DALA01_1D-025_2D-039_Base_P360_R100cc40.ief ▶ DALA01_1D-025_2D-039_Base_P360_R1000.ief
2D model files	▶ DALA01_Base_039_P360_R30.tcf ▶ DALA01_Base_039_P360_R100.tcf ▶ DALA01_Base_039_P360_R100cc20.tcf ▶ DALA01_Base_039_P360_R100cc40.tcf ▶ DALA01_Base_039_P360_R1000.tcf 35589-24_S1_Base_031.tgc 35589-24_S1_Base_023.tbc bc_dbase_003_R100_P360m.csv
Model run parameters and settings	Default parameters were used for all settings except those listed below: Automatic Preissmann Slot for River Sections

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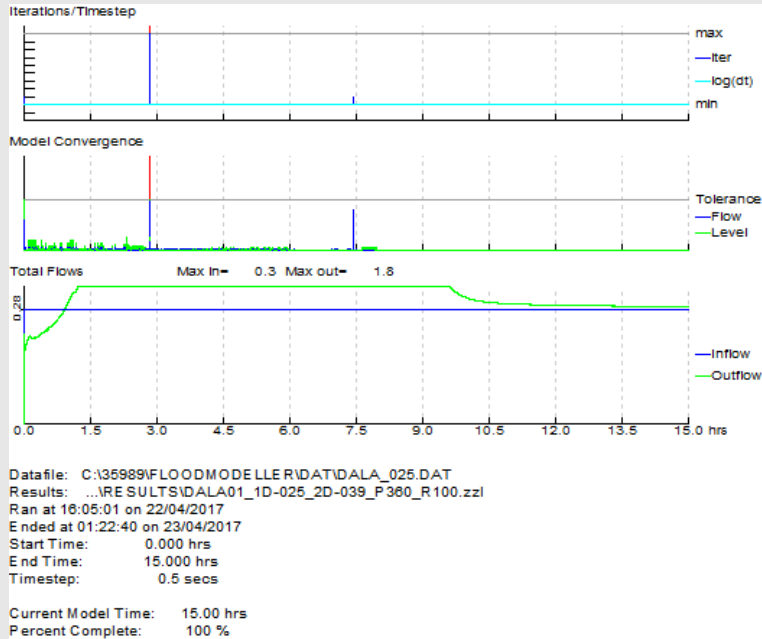
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Item

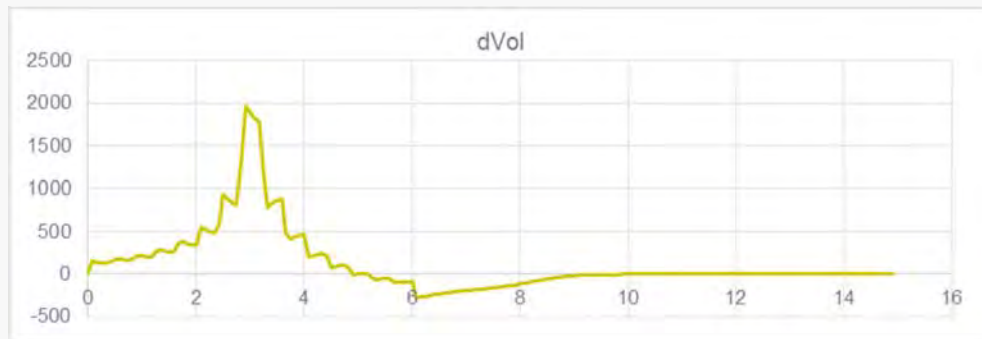
Comments

1D model stability

1D convergence .bmp files (below) for the 1:100 year AEP 6 hour pluvial event indicate one minor instance of non-convergence in the model. In general, the model is stable performing all the calculations within the maximum number of iterations and tolerances allowed. The fluvial inflow is a constant flow hence the straight line in the inflow plot. The inflow for these pluvial scenarios is just a baseflow, and considered appropriate for it to be applied as a constant flow. The outflow increases throughout the duration of the rainfall event.

**2D model stability**

Mass Balance error (Q me%) and change in water volume in the 2D model (dVol) time series plots for the 1:100 year AEP 6 hour pluvial event show no oscillations or instabilities. The stepped nature of the plots is a function of the stepped nature of the inflow rainfall hyetograph being applied to the model. Mass balance error is outside of the acceptable range of $\pm 1\%$ at the start of the rainfall event. This occurs when the model begins to 'wet' but by the peak of the event the mass balance has returned to an acceptable range. So is not deemed to be affecting results.



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Item	Comments
	Cumulative Mass Error (%) (1:100 year AEP pluvial event for 6 hour storm duration) 

Table 5.3 Fluvial baseline runs

Item	Comments
Fluvial baseline events	▶ F20: 1:20 year AEP event, present day. ▶ F100: 1:100 year AEP event, present day. ▶ F100CC: 1:100 year AEP event with climate change (30%). ▶ F1000: 1:1000 year AEP event, present day.
1D model files	DALA01_025.dat ▶ F20_6-5h.ied ▶ F100_5-5h.ied ▶ F100cc_5-5h.ied ▶ F1000_4-5h.ied DALA001_1D-020.zzs ▶ DALA01_1D-025_2D-040_Base_F20.ief ▶ DALA01_1D-025_2D-040_Base_F100.ief ▶ DALA01_1D-025_2D-040_Base_F100cc.ief ▶ DALA01_1D-025_2D-040_Base_F1000.ief.
2D model files	35589-24_S1_Base_032.tgc 35589-24_S1_Base_024.tbc ▶ DALA01_Base_040_F20.tcf ▶ DALA01_Base_040_F100.tcf ▶ DALA01_Base_040_F100cc.tcf ▶ DALA01_Base_040_F1000.tcf no bcdbase – all inflows from 1D model.
Model run parameters and settings	Default parameters were used for all settings except those listed below: Automatic Preissmann Slot for River Sections.

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Item	Comments
1D Model stability	1D convergence .bmp files (below) indicate two minor instances of non-convergence in the model. In general, the model is stable performing all the calculations within the maximum number of iterations and tolerances allowed. The fluvial inflow is consistent with the hydrograph being applied, and the outflow is smooth. This is consistent across all events. Datafile: C:\35989\FLOODMODELLER\DATA\DALA_025.DAT Results: ...RESULTS\DALA01_1D-025_2D-040_F100.zzi Ran at 14:22:55 on 23/04/2017 Ended at 18:47:17 on 23/04/2017 Start Time: 0.000 hrs End Time: 20.000 hrs Timestep: 0.5 secs Current Model Time: 20.00 hrs Percent Complete: 100 %
2D Model stability	Mass Balance error (Q me%) and change in water volume in the 2D model (dVol) time series plots show no oscillations or instabilities. Mass balance error is within the acceptable range of ± 1.

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Item	Comments
	Cumulative Mass Error (%) (1:100 year AEP fluvial event)

5.3 'With development and mitigation' model runs

As part of the proposed P&R Site, a number of mitigation measures are proposed including ground lowering, void storage under the car parking areas and a low flood defence wall. A further area of car park has been raised to delay flooding to this area. Areas of proposed ground level changes, including the proposed levels, and new areas of hard standing are shown in Figure 5.2. The mitigation incorporated in the P&R Site, proposed ground levels and extents, and how it was represented in the hydraulic model was as follows:

- ▶ Areas to the north-east and north-west of the Dalar Hir Stream to be lowered to 15.03mAOD and retained as grass, which differs from original proposed design as defined in shape file '*Line_String.shp*'. The location was identified from drawing number '60PO8081-JAC-DRN-DRG-00001 rev0.1 (file name: *Potential Solution.pdf*) and *Line_String.shp*'. Proposed levels were represented in the model by lowering the elevation of grid squares falling within the extent, this was achieved using a Zshape layer in TUFLOW(*2d_zsh_Mit_002.mif*);
- ▶ Car park to the south-east of the Dalar Hir Stream (adjacent to the A5) has void storage underneath. The model cannot readily represent voids and therefore ground levels were lowered by the void proportion to 15.04mAOD. A void proportion of 30% has been applied considering 1m depth layer and the volume requirements are detailed on the *mark-up of drawing number '60PO8081-JAC-DRN-DRG-00001 rev0.1'*, the proposed drainage plan map. The location was identified from *Ground_Lowering.shp*. Proposed levels were represented in the model by lowering the elevation of grid squares falling within the extent (*2d_zsh_Mit_002.mif*). Change of roughness for new areas of hardstanding was represented in the roughness layer (*2d_mat_Mit_001.mif*);
- ▶ Car park to south-west of the Dalar Hir Stream (adjacent to the A5) has void storage underneath. The model cannot readily represent voids and therefore ground levels in the south were lowered by the void proportion to 15.04mAOD. Ground levels to the north will be built up, but also include void storage represented in the model by a level of 15.99mAOD. The location was identified from *Ground_Lowering.shp* and adjusted slightly westwards in some locations to ensure the wall (see next bullet point) was fully represented. Proposed levels were represented in the model by lowering the elevation of grid squares falling within the extent (*2d_zsh_Mit_002.mif*). Change of roughness for new areas of hardstanding was represented in the roughness layer (*2d_mat_Mit_001.mif*); and

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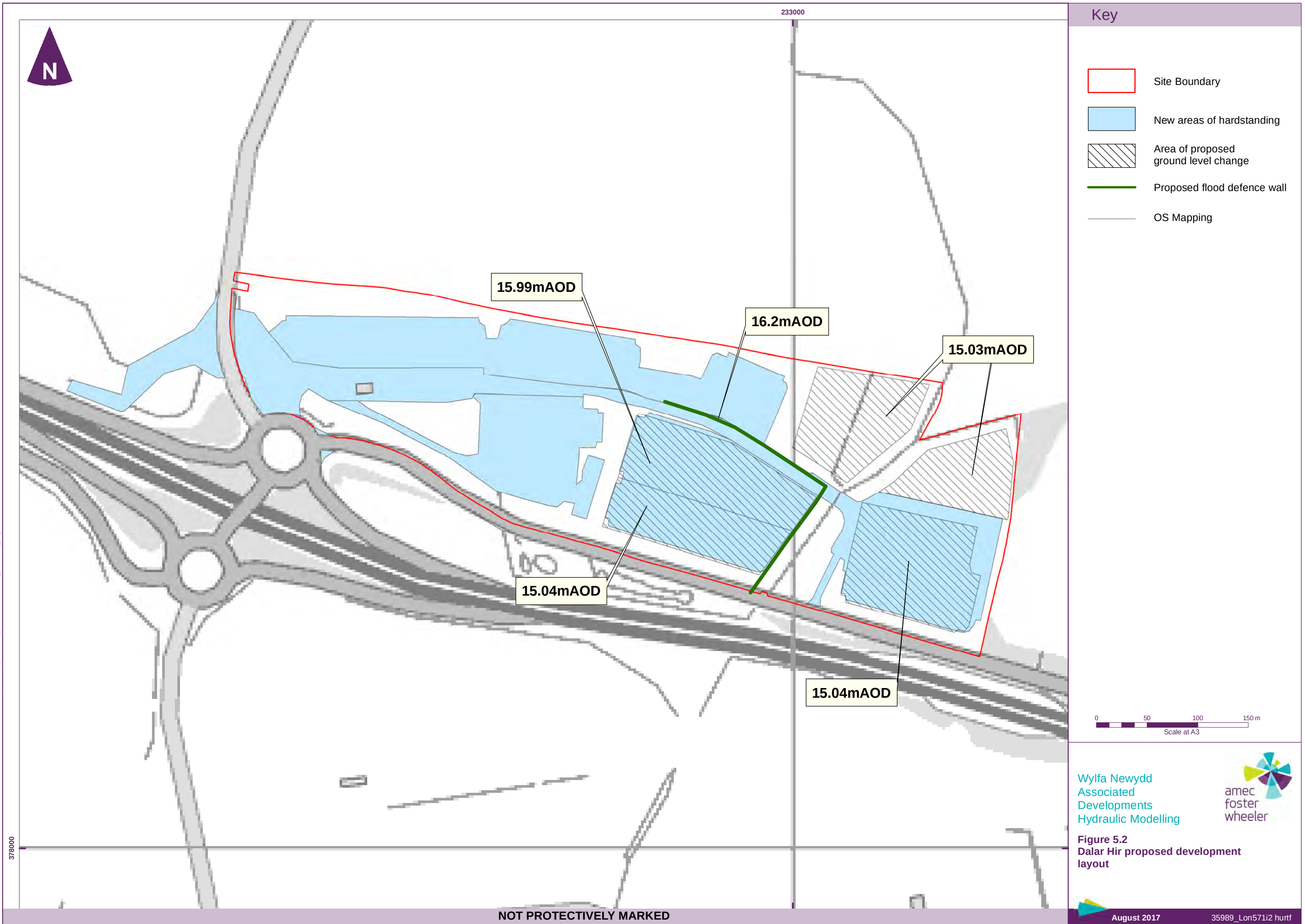
- ▶ A raised 'wall' feature to be constructed along the western edge of the car park to the south-west of the Dalar Hir Stream to 16.2mAOD. The location was identified from *Mark-up of Potential Solution.pdf*. Proposed levels were represented in the model by raising the elevation along the length of the wall to 2m width, the width of a single grid cell, (*2d_zln_Mit_002.mif*).

The 'with development and mitigation' modelling encompassed two additional changes:

- ▶ New reduced roughness in the 1D channel through the car park to represent the change in roughness associated with improved maintenance of the channel through the car park.
- ▶ New roughness layer (*2d_mat_Mit_001.mif*) to represent the change in roughness due to the access as identified on *Line_String.shp*.

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In addition, the tgc file was updated to include reference to the new topography changes and roughness layer (35589-24_S1_Mit_003.tgc for the fluvial and 35589-24_S1_Mit_004.tgc for the pluvial).

The revised roughness represented new areas of car parking as road. The 'grd_check.mif' file was used to check that the levels in the 'with development' model were correct and that the roughness applied as expected.

Model results were required for only two events: the 1:100 year AEP fluvial event with a 30% uplift representing climate change and for the 1:100 year AEP pluvial event with a 40% uplift representing climate change. These events provide an understanding of the flood depth and extent during the 'with development' phase for a 1:100 year AEP event with climate change beyond the lifetime of the development and therefore the design team did not required representation of more frequent events.

The details of the 'with development' design runs are in Table 5.4 and Table 5.5. One pluvial design run with different annual exceedance probabilities and climate change factors were run using the critical 6 hour storm duration (Table 5.4). Four fluvial design runs with different annual exceedance probabilities were run using the fluvial version of the 1D-2D model (Table 5.5).

Table 5.4 'With development' pluvial runs

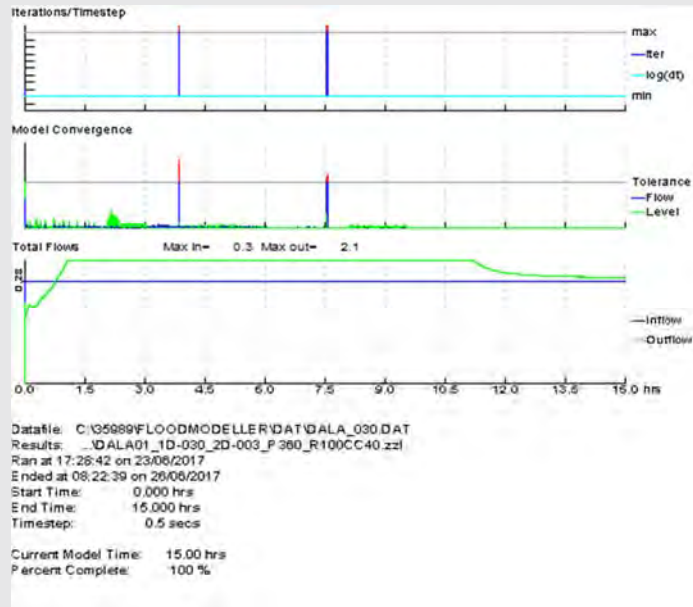
Item	Comments
Pluvial events	For the critical duration pluvial storm (6 hour): ► R100CC: 1:100 year AEP event with climate change (40%).
1D model files	DALA01_030.dat Baseflow.IED DALA001_1D-020.zzs ► DALA01_1D-025_2D-039_Base_P360_R100cc40.ief
2D model files	► DALA01_Mit_003_P360_R100cc40.tcf 35589-24_S1_Mit_004.tgc 35589-24_S1_Base_023.tbc bc_dbase_003_R100_P360m.csv
Model run parameters and settings	Default parameters were used for all settings except those listed below: Automatic Preissmann Slot for River Sections
1D model stability	The 1D model is acceptably stable throughout the run, with two isolated occasions when the model had difficulty converging requiring a larger number of iterations to solve the equations, but continued to run through. There were no corresponding oscillations in the model results at these times. Model iterations and convergence plot is shown below.

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Item

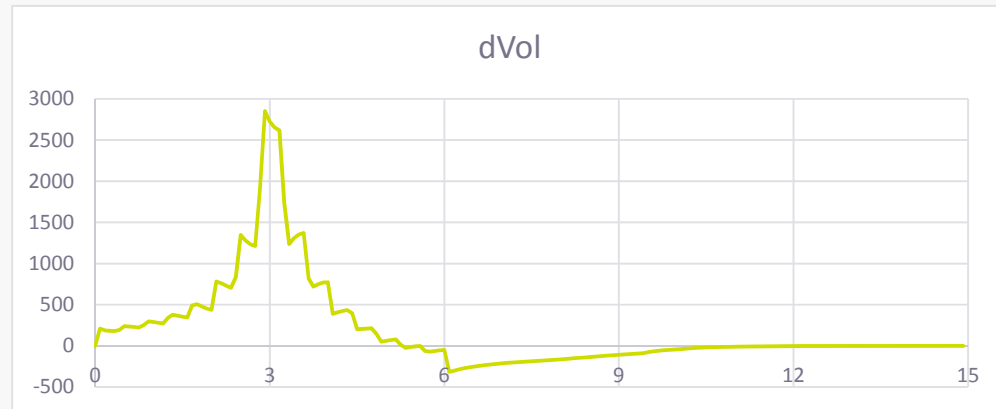
Comments



2D model stability

The change in volume (dVol) is consistent with expectations, peaking at a similar time to inflow with no change by the end of the event. Mass error is within the $\pm 1\%$ recommended range for most of the model run, although it is high initially this is not unusual for 2D models and is well within the recommended range by 1.3hr into the run.

Change in water volume in the 2D model (dVol) 1:100 year AEP pluvial event +40% for 6 hour storm event



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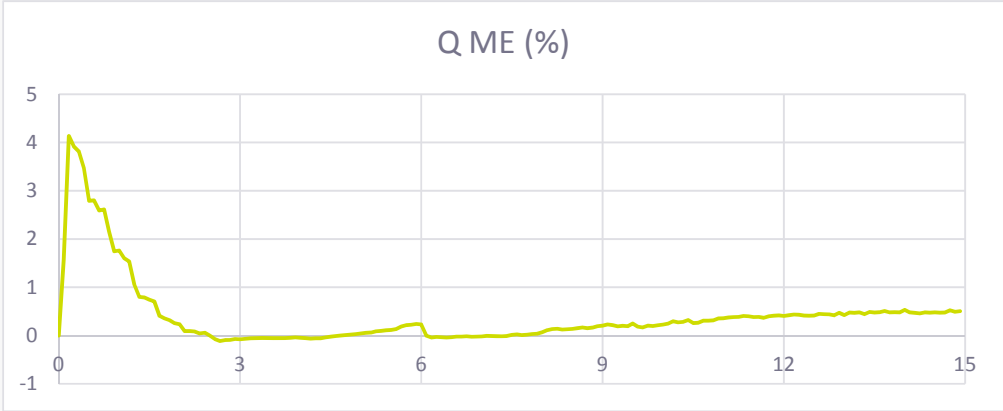
Item	Comments
	Cumulative Mass Error (%) 1:100 year AEP pluvial event +40% for 6 hour storm duration 

Table 5.5 'With development' fluvial runs

Item	Comments
Fluvial baseline events	► F100CC: 1:100 year AEP event with climate change (30%).
1D model files	DALA01_030.dat ► F100cc_5-5h.ied DALA001_1D-020.zzs ► DALA01_1D-025_2D-040_Base_F100cc.ief
2D model files	35589-24_S1_Mit_003.tgc 35589-24_S1_Base_024.tbc ► DALA01_Mit_003_F100cc.tcf no bcdbase – all inflows from 1D model
Model run parameters and settings	Default parameters were used for all settings except those listed below: Automatic Preissmann Slot for River Sections
1D Model stability	The 1D model is acceptably stable throughout the run, with one isolated occasion when the model had difficulty converging requiring a larger number of iterations to solve the equations, but continued to run through. There were no corresponding oscillations in the model results at this time. Model iterations and convergence plot is shown below:

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The screenshot displays a 2D model stability report with the following components:

- Iterations/Timestep:** A line graph showing the number of iterations per timestep. The y-axis ranges from 0 to 100. The x-axis represents time in hours from 0.0 to 15.0. A sharp peak is visible at approximately 4.5 hours, reaching a value of about 100. The legend indicates 'max' (blue), 'iter' (red), 'log(dt)' (green), and 'min' (yellow).
- Model Convergence:** A line graph showing convergence metrics. The y-axis ranges from 0 to 100. The x-axis represents time in hours from 0.0 to 15.0. A sharp peak is visible at approximately 4.5 hours, reaching a value of about 100. The legend indicates 'Tolerance' (blue), 'Flow' (red), and 'Level' (green).
- Total Flows:** A line graph showing inflow and outflow rates. The y-axis ranges from 0.0 to 5.0. The x-axis represents time in hours from 0.0 to 15.0. The inflow (blue line) peaks at approximately 4.5 hours with a value of about 4.5. The outflow (green line) peaks at approximately 6.0 hours with a value of about 1.5. The legend indicates 'Inflow' (blue) and 'Outflow' (green).

Metadata information provided in the report:

- Datefile: C:\35999\FLOODMODELLER\DAT\DALA_030.DAT
- Results: _RESULTS\DALA01_ID-030_2D-003_MIT_F100CC.zxl
- Ran at 09:25:12 on 23/08/2017
- Ended at 12:38:56 on 23/08/2017
- Start Time: 0.000 hrs
- End Time: 15.000 hrs
- Timestep: 0.5 secs
- Current Model Time: 15.00 hrs
- Percent Complete: 100 %

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Item	Comments																																		
	Cumulative Mass Error (%) (1:100 year AEP fluvial event +30%) Q ME (%) <table border="1"><caption>Approximate data points for Cumulative Mass Error (%)</caption><thead><tr><th>Time (x)</th><th>Q ME (%) (y)</th></tr></thead><tbody><tr><td>0</td><td>0.00</td></tr><tr><td>1</td><td>0.25</td></tr><tr><td>2</td><td>0.25</td></tr><tr><td>3</td><td>-0.35</td></tr><tr><td>4</td><td>-0.40</td></tr><tr><td>5</td><td>-0.25</td></tr><tr><td>6</td><td>-0.20</td></tr><tr><td>7</td><td>-0.18</td></tr><tr><td>8</td><td>-0.18</td></tr><tr><td>9</td><td>-0.17</td></tr><tr><td>10</td><td>-0.16</td></tr><tr><td>11</td><td>-0.15</td></tr><tr><td>12</td><td>-0.14</td></tr><tr><td>13</td><td>-0.13</td></tr><tr><td>14</td><td>-0.12</td></tr><tr><td>15</td><td>-0.10</td></tr></tbody></table>	Time (x)	Q ME (%) (y)	0	0.00	1	0.25	2	0.25	3	-0.35	4	-0.40	5	-0.25	6	-0.20	7	-0.18	8	-0.18	9	-0.17	10	-0.16	11	-0.15	12	-0.14	13	-0.13	14	-0.12	15	-0.10
Time (x)	Q ME (%) (y)																																		
0	0.00																																		
1	0.25																																		
2	0.25																																		
3	-0.35																																		
4	-0.40																																		
5	-0.25																																		
6	-0.20																																		
7	-0.18																																		
8	-0.18																																		
9	-0.17																																		
10	-0.16																																		
11	-0.15																																		
12	-0.14																																		
13	-0.13																																		
14	-0.12																																		
15	-0.10																																		

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6. Baseline model results

This section summarises the results of the baseline model runs. Model results have been extracted for a series of preselected plot output (PO) points and lines for both the fluvial and pluvial models for each baseline scenario. The results denote the maximum flood levels (mAOD) and velocities (m/s) at each of the points and lines. Water levels can be converted into flood depth levels (m). Appendix A contains the following flood depth and extent and flood velocities maps which describe the baseline flood hazard:

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NOT PROTECTIVELY MARKED*Pluvial flood depths*

- Figure 6.1 Dalar Hir baseline peak pluvial flood extents
Figure 6.2 Dalar Hir baseline peak pluvial flood depth 1:30 year AEP present day (6 hour storm event)
Figure 6.3 Dalar Hir baseline peak pluvial flood depth 1:100 year AEP present day (6 hour storm event)
Figure 6.4 Dalar Hir baseline peak pluvial flood depth 1:1000 year AEP present day (6 hour storm event)
Figure 6.5 Dalar Hir baseline peak pluvial flood depth 1:100 year AEP (6 hour storm event) plus climate change (20%)
Figure 6.6 Dalar Hir baseline peak pluvial flood depth 1:100 year AEP (6 hour storm event) plus climate change (40%)

Fluvial flood depths

- Figure 6.7 Dalar Hir baseline peak fluvial flood depth 1:20 year AEP present day
Figure 6.8 Dalar Hir baseline peak fluvial flood depth 1:100 year AEP present day
Figure 6.9 Dalar Hir baseline peak fluvial flood depth 1:1000 year AEP present day
Figure 6.10 Dalar Hir baseline peak fluvial flood depth 1:100 year AEP plus climate change (30%)
Figure 6.11 Dalar Hir baseline peak fluvial flood extents

Pluvial velocities

- Figure 6.12 Dalar Hir baseline peak pluvial flood velocity 1:30 year AEP present day (6 hour storm event)
Figure 6.13 Dalar Hir baseline peak pluvial flood velocity 1:100 year AEP present day (6 hour storm event)
Figure 6.14 Dalar Hir baseline peak pluvial flood velocity 1:1000 year AEP present day (6 hour storm event)
Figure 6.15 Dalar Hir baseline peak pluvial flood velocity 1:100 year AEP (6 hour storm event) plus climate change (20%)
Figure 6.16 Dalar Hir baseline peak pluvial flood velocity 1:100 year AEP (6 hour storm event) plus climate change (40%)

Fluvial velocities

- Figure 6.17 Dalar Hir baseline peak fluvial flood velocity 1:20 year AEP present day
Figure 6.18 Dalar Hir baseline peak fluvial flood velocity 1:100 year AEP present day
Figure 6.19 Dalar Hir baseline peak fluvial flood velocity 1:1000 year AEP present day
Figure 6.20 Dalar Hir baseline peak fluvial flood velocity 1:100 year AEP plus climate change (30%)

Pluvial flood hazard ratings

- Figure 6.21 Dalar Hir baseline peak pluvial flood hazard 1:30 year AEP present day (6 hour storm event)
Figure 6.22 Dalar Hir baseline peak pluvial flood hazard 1:100 year AEP present day (6 hour storm event)
Figure 6.23 Dalar Hir baseline peak pluvial flood hazard 1:1000 year AEP present day (6 hour storm event)
Figure 6.24 Dalar Hir baseline peak pluvial flood hazard 1:100 year AEP (6 hour storm event) plus climate change (20%)
Figure 6.25 Dalar Hir baseline peak pluvial flood hazard 1:100 year AEP (6 hour storm event) plus climate change (40%)

Fluvial flood hazard ratings

- Figure 6.26 Dalar Hir baseline peak fluvial flood hazard 1:20 year AEP present day
Figure 6.27 Dalar Hir baseline peak fluvial flood hazard 1:100 year AEP present day
Figure 6.28 Dalar Hir baseline peak fluvial flood hazard 1:1000 year AEP present day
Figure 6.29 Dalar Hir baseline peak fluvial flood hazard 1:100 year AEP plus climate change (30%)

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6.1 Model results lines and points

The results data (as csv files) contain the results of water level and velocity time-series for a range of observation lines and points across the 2D model. The labelled location of these lines and points are in Figure 4.1 (Appendix A).

The observation points are in the TUFLOW model as a series of plot output (PO) points. They have been positioned at key points within the Site boundary and surrounding area to provide the time series of water level (mAOD) and velocity (m/s) at each individual location (DALA10 – DALA44 and DALA46 – DALA50) from which water depths have been calculated (m).

In addition, the observation lines are in the model as plot observation (PO) lines. They have been positioned at strategic locations to provide a time series of maximum water levels (mAOD) and the time series of velocity values (m/s) experienced in the TUFLOW grid cells at each individual location (DALA1 – DALA9 and DALA45).

6.2 Pluvial results

The peak pluvial flood depths in Table 6.1 have been extracted from the TUFLOW model at PO lines and points, the locations of which are shown in Figure 4.1 (in Appendix A). For all baseline runs, the highest depth is across line DALA45 which is located to the west of the proposed Site and at point DALA26 (1:100 to 1:1,000 year AEP events) which is located between the A5 and A55 roads. At DALA45 within the Site pluvial flood depths can extend are recorded up to 2.70 m, with the deepest water level observed during the 1:1,000 year AEP event) as would be expected. DALA26 has a peak pluvial flood depth of 1.45 m under the same scenario.

Table 6.1 Baseline pluvial runs summary results – peak flood depth (m) across a line or at point

Results ID	Point (P) or Line (L)	1:30 yr AEP Velocity (m/s)	1:30 yr AEP Depth (m)	1:100 yr AEP Velocity (m/s)	1:100 yr AEP Depth (m)	1:100 yr AEP + 20%CC Velocity (m/s)	1:100 yr AEP + 20%CC Depth (m)	1:100 yr AEP + 40%CC Velocity (m/s)	1:100 yr AEP + 40%CC Depth (m)	1:1000 yr AEP Velocity (m/s)	1:1000 yr AEP Depth (m)
DALA2	L	0.01	1.81	0.01	1.81	0.01	1.81	0.01	1.81	0.01	1.81
DALA3	L	0.29	0.73	0.49	0.75	0.49	0.77	0.49	0.78	0.49	0.79
DALA4	L	0.06	0.66	0.06	0.74	0.06	0.77	0.03	0.80	0.06	0.84
DALA5	L	0.19	0.63	0.18	0.81	0.17	0.94	0.17	1.06	0.18	1.10
DALA7	L	0.04	1.15	0.04	1.23	0.04	1.27	0.04	1.33	0.04	1.72
DALA8	L	0.01	0.79	0.01	0.82	0.02	0.84	0.02	0.86	0.02	0.90
DALA10	P	0.07	0	0.08	0.06	0.09	0.11	0.10	0.14	0.10	0.19
DALA11	P	0.03	0	0.03	0	0.03	0	0.01	0	0.03	0
DALA12	P	0.12	0.01	0.13	0.01	0.14	0.01	0.14	0.02	0.14	0.06
DALA13	P	0.05	0	0.07	0	0.08	0.01	0.09	0.01	0.10	0.01
DALA14	P	0.02	0	0.03	0.01	0.03	0.01	0.03	0.01	0.03	0.01
DALA15	P	0.04	0	0.01	0	0.04	0	0.04	0.01	0.04	0.05

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Results ID	Point (P) or Line (L)	1:30 yr AEP Velocity (m/s)	1:30 yr AEP Depth (m)	1:100 yr AEP Velocity (m/s)	1:100 yr AEP Depth (m)	1:100 yr AEP + 20%CC Velocity (m/s)	1:100 yr AEP + 20%CC Depth (m)	1:100 yr AEP + 40%CC Velocity (m/s)	1:100 yr AEP + 40%CC Depth (m)	1:1000 yr AEP Velocity (m/s)	1:1000 yr AEP Depth (m)
DALA16	P	0.03	0	0.04	0	0.04	0	0.05	0	0.05	0
DALA17	P	0.01	0	0.01	0	0.01	0	0.01	0	0.01	0
DALA18	P	0.08	0.09	0.12	0.21	0.14	0.26	0.14	0.29	0.15	0.32
DALA19	P	0.12	0.56	0.12	0.68	0.13	0.72	0.13	0.75	0.12	0.79
DALA20	P	0.07	0.38	0.08	0.50	0.08	0.54	0.08	0.57	0.10	0.61
DALA21	P	0.14	0.54	0.14	0.66	0.14	0.70	0.14	0.73	0.14	0.77
DALA22	P	0.03	0.30	0.03	0.55	0.03	0.72	0.03	0.84	0.04	0.88
DALA23	P	0.02	0.27	0.02	0.53	0.03	0.70	0.05	0.82	0.07	0.85
DALA24	P	0.03	0	0.03	0.25	0.04	0.42	0.06	0.55	0.07	0.58
DALA25	P	0.03	0.10	0.02	0.36	0.03	0.53	0.02	0.65	0.03	0.68
DALA26	P	0.05	0.49	0.05	0.70	0.06	0.80	0.06	1.13	0.07	1.45
DALA27	P	0.02	0.48	0.01	0.69	0.02	0.79	0.01	1.12	0.05	1.44
DALA28	P	0.03	0	0.03	0	0.03	0	0.03	0	0.03	0
DALA29	P	0.04	0.47	0.04	0.52	0.04	0.55	0.04	0.57	0.04	0.63
DALA30	P	0.07	0.06	0.09	0.11	0.09	0.14	0.08	0.17	0.08	0.22
DALA31	P	0.03	0	0.05	0	0.06	0	0.07	0	0.07	0
DALA32	P	0.03	0	0.03	0	0.04	0.10	0.04	0.23	0.04	0.26
DALA33	P	0.08	0.01	0.10	0.01	0.11	0.01	0.13	0.01	0.16	0.01
DALA34	P	0.04	0.02	0.06	0.03	0.06	0.03	0.07	0.03	0.09	0.04
DALA35	P	0.02	0	0.03	0	0.03	0	0.04	0	0.05	0
DALA36	P	0.04	0	0.06	0.01	0.07	0.01	0.07	0.01	0.07	0.01
DALA37	P	0	0	0	0	0.01	0	0.01	0	0.01	0
DALA38	P	0.01	0	0.01	0	0.01	0	0.01	0	0.01	0
DALA39	P	0.04	0	0.05	0	0.05	0.14	0.06	0.26	0.07	0.30
DALA40	P	0.02	0	0.02	0	0.02	0	0.02	0	0.02	0
DALA41	P	0.13	0.01	0.17	0.01	0.19	0.01	0.21	0.01	0.22	0.01
DALA42	P	0.03	0	0.03	0	0.03	0	0.03	0	0.03	0
DALA43	P	0.02	0	0.02	0	0.02	0	0.03	0	0.03	0

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Results ID	Point (P) or Line (L)	1:30 yr AEP Velocity (m/s)	1:30 yr AEP Depth (m)	1:100 yr AEP Velocity (m/s)	1:100 yr AEP Depth (m)	1:100 yr AEP + 20%CC Velocity (m/s)	1:100 yr AEP + 20%CC Depth (m)	1:100 yr AEP + 40%CC Velocity (m/s)	1:100 yr AEP + 40%CC Depth (m)	1:1000 yr AEP Velocity (m/s)	1:1000 yr AEP Depth (m)
DALA44	P	0.04	0	0.02	0	0.04	0	0.02	0	0.04	0
DALA45	L	0.14	2.64	0.14	2.67	0.14	2.70	0.14	2.70	0.14	2.70
DALA46	P	0.32	0.40	0.31	0.57	0.30	0.63	0.30	0.64	0.30	0.66
DALA47	P	0.05	0.47	0.05	0.64	0.05	0.70	0.05	0.71	0.05	0.73
DALA48	P	0.02	0	0.03	0	0.03	0	0.04	0	0.05	0
DALA49	P	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
DALA50	P	0.63	0.03	0.65	0.03	0.65	0.04	0.65	0.12	0.65	0.15

The peak pluvial flood depth maps (Figures 6.2 – 6.6 in Appendix A) show areas of pluvial flooding concentrated to the south of the Site (bounded by the A55 road) and to the west of the Site (bounded by the unnamed road from the Dalar Hir Interchange to Bodedern to the north). The pluvial flooding is directed to those areas which are low lying due to the local topography. Flood velocities presented in Table 6.1 and in Figures 6.12 to 6.16 show velocities peaking at just less than 0.7 m/s, with the highest velocities focusses on narrow tracts across the model area.

The model utilises the water level and flood velocity parameters to further output flood hazard¹ ratings across the TUFLOW grid that can be used to assess the level of flood hazard across the Site. The results of which are presented in Figures 6.21 to 6.25 in Appendix A. In all baseline runs from the 1:30 year AEP pluvial event to 1:1000 year AEP event flood hazard ratings mapping identifies the zones of 'Danger to some' or greater are concentrated to the south of the Site along the A55 corridor, and along the Dalar Hir Stream. The extent of the measured flood hazard increases through the return periods modelled. There are no areas which are considered to have a flood hazard rating above 2 (danger for all).

6.3 Fluvial results

The peak fluvial flood depths in Table 6.2 have been extracted from the TUFLOW model at PO lines and points, the locations of which are shown in Figure 4.1 (in Appendix A). For all baseline runs, the highest depth is across line DALA7 and at point DALA26 which are located between the A5 and A55 roads. As would be expected, the highest peak depth occurs at the 1:1,000 year AEP event, with a peak flood depth of 2.31 m and 2.27 m recorded at DALA7 and DALA26 respectively. Within the Site boundary the DALA5 and DALA6 lines have the highest recorded depths as water builds up behind the A55 road culvert. The deepest recorded water depth occurs in DALA5 during the 1:1000 year AEP event at 1.75 m.

The FCA document, to which this modelling report is an Annex, makes the selection of the flood depths which are used to form the basis of the assessment.

¹ Based on the DEFRA UK Hazard Formula - $D \cdot (V + 0.5) + DF$, where default Debris Factor (DF) in TUFLOW ('Conservative') is used; Debris Factor is 0.5 for flood depths up to 0.25m and 1 for flood depths over 0.25m.

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NOT PROTECTIVELY MARKED**Table 6.2 Baseline fluvial runs summary results – peak flood depth (m) across a line or at point**

Results ID	Point (P) or Line (L)	1:20 yr AEP Velocity (m/s)	1:20 yr AEP Depth (m)	1:100 yr AEP Velocity (m/s)	1:100 yr AEP Depth (m)	1:100 yr AEP + 30%CC Velocity (m/s)	1:100 yr AEP + 30%CC Depth (m)	1:1000 yr AEP Velocity (m/s)	1:1000 yr AEP Depth (m)
DALA1	L	0	1.13	0	1.23	0	1.28	0	1.47
DALA2	L	0	1.13	0	1.21	0	1.29	0.04	1.48
DALA3	L	0	0	0	0	0	0	0	0
DALA4	L	0	0.80	0	0.90	0	0.95	0	1.11
DALA5	L	0.18	1.18	0.20	1.31	0.22	1.55	0.24	1.75
DALA6	L	0	1.24	0	1.32	0	1.40	0	1.59
DALA7	L	0	1.42	0	1.86	0	2.12	0	2.31
DALA8	L	0	0.55	0	0.80	0	0.89	0	0.97
DALA9	L	0	1.14	0	1.19	0	1.31	0	1.50
DALA10	P	0.07	0.17	0.09	0.27	0.10	0.32	0.11	0.48
DALA11	P	0	0	0.03	0.06	0.05	0.11	0.07	0.27
DALA12	P	0.01	0.05	0.02	0.15	0.03	0.20	0.04	0.36
DALA13	P	0	0	0.01	0.02	0.03	0.07	0.08	0.23
DALA14	P	0	0	0	0	0.12	0.04	0.21	0.20
DALA15	P	0.06	0.04	0.11	0.12	0.16	0.20	0.22	0.39
DALA16	P	0	0	0.03	0.06	0.05	0.14	0.08	0.33
DALA17	P	0	0	0.01	0.06	0.06	0.13	0.09	0.32
DALA18	P	0.15	0.31	0.20	0.40	0.24	0.47	0.29	0.66
DALA19	P	0.13	0.78	0.14	0.86	0.18	0.94	0.23	1.13
DALA20	P	0.10	0.60	0.16	0.68	0.20	0.76	0.25	0.95
DALA21	P	0.15	0.76	0.16	0.84	0.20	0.92	0.26	1.11
DALA22	P	0.07	0.87	0.11	1.13	0.13	1.38	0.15	1.58
DALA23	P	0.07	0.84	0.15	1.10	0.16	1.36	0.19	1.55
DALA24	P	0.28	0.57	0.45	0.83	0.50	1.08	0.57	1.28
DALA25	P	0.04	0.67	0.04	0.93	0.07	1.19	0.07	1.38
DALA26	P	0.16	1.38	0.29	1.82	0.33	2.07	0.35	2.27
DALA27	P	0.10	1.37	0.22	1.81	0.24	2.06	0.20	2.26

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Results ID	Point (P) or Line (L)	1:20 yr AEP Velocity (m/s)	1:20 yr AEP Depth (m)	1:100 yr AEP Velocity (m/s)	1:100 yr AEP Depth (m)	1:100 yr AEP + 30%CC Velocity (m/s)	1:100 yr AEP + 30%CC Depth (m)	1:1000 yr AEP Velocity (m/s)	1:1000 yr AEP Depth (m)
DALA28	P	0	0	0.03	0.08	0.03	0.17	0.04	0.25
DALA29	P	0.23	0.49	0.23	0.73	0.23	0.83	0.22	0.91
DALA30	P	0.02	0.08	0.02	0.33	0.02	0.42	0.02	0.50
DALA31	P	0	0	0	0	0	0.08	0.01	0.28
DALA32	P	0.02	0.25	0.03	0.51	0.04	0.77	0.06	0.96
DALA33	P	0	0	0	0	0	0	0	0
DALA34	P	0	0	0	0	0	0	0.01	0.16
DALA35	P	0	0	0	0	0	0	0	0
DALA36	P	0	0	0	0	0	0	0	0
DALA37	P	0	0	0.03	0.04	0.12	0.08	0.19	0.25
DALA38	P	0	0	0	0	0	0	0.01	0.11
DALA39	P	0.02	0.28	0.03	0.54	0.04	0.80	0.05	1.00
DALA40	P	0	0	0	0	0	0	0.03	0.10
DALA41	P	0	0	0	0	0	0	0	0
DALA42	P	0	0	0	0	0	0	0	0
DALA43	P	0	0	0	0	0	0	0	0
DALA44	P	0	0	0	0	0	0	0	0
DALA45	L	0	0	0	0	0	0	0	0
DALA46	P	0	0	0	0	0	0	0	0
DALA47	P	0	0	0	0	0	0	0	0
DALA48	P	0	0	0	0	0	0	0	0
DALA49	P	0	0	0	0	0	0	0	0
DALA50	P	0.02	0.14	0.04	0.40	0.05	0.66	0.04	0.85

The peak fluvial flood depth maps (Figures 6.7 – 6.10 in Appendix A) show flooding along much of the upper and mid reaches of the Dalar Hir Stream modelled. The depth of water is highest between the A55 and A5 roads, and to the north of the A55. The fluvial flooding is directed to those areas which are low lying by local topography. Flood velocities presented in Table 6.2 and in Figures 6.17 to 6.20 show the highest velocities occurring in the northern upper reaches and as flow over the A55 under all baseline scenarios. The highest velocities occur in the 1:1,000 year AEP event, with velocities mapped peaking around up to 1 m/s. The model predicts a large area of ponding north of the A55, this results from the combination of the A55 being on an elevated embankment and the presence of a 600mm culvert/pipe through the embankment which

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conveys the Dalar Hir stream through the embankment. The capacity of this drain is exceeded in the return periods simulated and this results in the attenuation of flood water. For example, the baseline maximum water surface elevation calculated is about 16.42mAOD equivalent to a depth of 1.55 around the inlet area of the culvert under the A5 road corresponding to 1:100 AEP+30%CC event.

The model utilises the water level and flood velocity parameters to further output flood hazard ratings across the TUFLOW grid cells that can be used to assess the level of hazard at the Site. The results of which are presented in Figures 6.26 to 6.29 in Appendix A. In all baseline runs from the 1:20 year AEP pluvial event to 1:1,000 year AEP event flood hazard ratings mapping shows that there are areas considered to be a danger to some, and a danger to most. These are concentrated to the south of the Site along the A55 corridor, the area between the A5 and A55 roads and along the Dalar Hir Stream. The extent of the measure flood hazard increases through the return periods and includes areas with a Flood Hazard Rating above 2 “danger for all” in the 1:100 year AEP (plus climate change) and 1:1000 year AEP flood events.

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7. 'With development' model results

Analysis of the impact of the P&R Site on the flood risk and the change to the flood mechanism is discussed in this Section. Background to the inclusion of the infrastructure representation in the model and summary of the results obtained from the hydraulic modelling are discussed. Results are presented as water levels extracted from 1D nodes immediately upstream of the A5 and at key locations throughout the P&R Site and in difference grids illustrating the impact spatially across the Dalar Hir area.

Appendix A contains the following flood depths and extent maps which describe the bypass flood hazard:

Figure 7.1 Dalar Hir 'with development' peak fluvial flood depth 1:100 year AEP plus climate change (30%)

Figure 7.2 Dalar Hir 'with development' peak pluvial flood depth 1:100 year AEP plus climate change (40%)

Figure 7.3 Dalar Hir peak depth difference fluvial 1:100 year AEP plus climate change (30%)

Figure 7.4 Dalar Hir peak depth difference pluvial 1:100 year AEP plus climate change (40%)

Additional return period were not simulated as these were not required by the FCA.

7.1 Flood mechanism

Fluvial

Analysis of the 'with development' fluvial flood mechanism shows a similar behaviour as the baseline flood mechanism. Analysis of the flood propagation of the 100 year AEP event shows that flooding starts approximately 130m upstream of the A5, filling the lowered area to the north-west of the Dalar Hir Stream first. As the event progresses the lowered area to the north-east of the Dalar Hir Stream begins to flood next followed shortly by the car park to the south-east of the Dalar Hir Stream. And finally water floods both halves of the car park south-west of the Dalar Hir Stream, with water ponding in the southern half.

The lowered ground levels and voids under the car park areas (as represented in the hydraulic model by lowering the ground levels see Section 5 for further details of how the design was represented), delay the onset of flooding within the lower-lying areas of the P&R Site as well as upstream. This ultimately reduces the flood extent at the peak of the event as well.

Pluvial

Analysis of the 'with development' pluvial flood mechanism shows a similar behaviour as the baseline flood mechanism, outside the areas where ground levels are proposed to be lowered. Analysis of the flood propagation shows that surface water starts ponding in the lowered area to the north-west of the Dalar Hir Stream and the southern half of the car park to the south-west of the Dalar Hir Stream first. As the 1:100 year AEP event progresses, the flood depths in these areas increase; however there is no appreciable increase in the maximum flood depth in the other lowered areas and car parks.

7.2 Flood depths

The impact of the P&R Site on water levels and therefore flood depths is described in three ways:

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1. By means of change in depth of flooding at the 1D model cross section node upstream of the A5;
2. By means of depth of flooding at selected 2D model results points in the car parks; and
3. By mapping the difference in flood depths across the 2D domain for each scenario assessed.

1D Peak water levels

The impact of the car park and ride scheme on water levels in the Dalar Hir Stream immediately upstream of the A5 for both fluvial and pluvial flooding is shown in Table 7.1. Based on the ground levels represented in the hydraulic model there is a slight reduction in the peak water levels for the 1:100 year AEP event with climate change for both pluvial and fluvial flood events simulated.

Table 7.1 'With development' 1D peak water levels

Source	Event	Location	Baseline water surface elevation (mAOD)	'With development' water surface elevation (mAOD)	Depth Change (m)
Fluvial	1:100 year AEP + 30%	Upstream of A5	16.42	16.28	-0.14
Pluvial	1:100 year AEP + 40%	Upstream of A5	16.23	15.92	-0.31

Results ID is DALA01_0791

2D Peak water levels

Ground levels in some areas of the car park have been lowered to manage changes in flood risk associated with the P&R Site and. Flow depth and water surface levels of flooding in these areas are shown in Table 7.2 for fluvial flooding and in Table 7.3 for pluvial flooding. This shows limited flood depths in the south-western car park (north) associated with a 1:100 year AEP event with climate change appropriate to the flood source. Otherwise depths are up to 1.24m during a fluvial event and 0.43m during a pluvial event.

Table 7.2 'With development' fluvial peak water levels and depths

Results ID	Event	Location	'With development' water surface elevation (mAOD)	'With development' depth (m)	Baseline depth (m)
DALA42	1:100 year AEP + 30%	South-eastern car park	16.28	1.24	0.00
DALA39	1:100 year AEP + 30%	South-western car park (north)	16.02	0.03	0.80
DALA40	1:100 year AEP + 30%	South-western car park (north)	16.05	0.06	0.00
DALA25	1:100 year AEP + 30%	South-western car park (south)	16.02	0.98	1.19

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Table 7.3 'With development' pluvial peak water levels

Results ID	Event	Location	'With development' water surface elevation (mAOD)	'With development' depth (m)	Baseline depth (m)
DALA42	1:100 year AEP + 40%	South-eastern car park	15.15	0.11	0.00
DALA39	1:100 year AEP + 40%	South-western car park (north)	16.00	0.01	0.26
DALA40	1:100 year AEP + 40%	South-western car park (north)	16.00	0.01	0.00
DALA25	1:100 year AEP + 40%	South-western car park (south)	15.47	0.43	0.65

The impact of the proposed development on flood depths across the floodplain is shown in Figure 7.3 for fluvial flooding and Figure 7.4 pluvial flooding. The range of impact of the proposed development and embedded mitigation and the Site, on water levels across the floodplain (outside of the areas where ground levels have changed), is shown in Table 7.4. Outside of the areas where ground raising or lowering is proposed, the development including mitigation (as represented in the model), has generally resulted in a reduction of peak water surface elevation in the local floodplain.

Table 7.4 Range of impact from proposed development of the Site

Source	Event	Water level difference	
		Reduction in water surface elevation	Increase in water surface elevation
Fluvial	1:100 year AEP + 30%	-0.40m	0.00m
Pluvial	1:100 year AEP + 40%	-2.00m	+0.04m

7.3 Summary of P&R Site impact

- ▶ The inclusion of the P&R Site with areas of lowered ground reduces water levels for both the fluvial and pluvial events, apart from the pluvial event where the ground level has been raised.
- ▶ The water level immediately upstream of the A5 is reduced in the Dalar Hir Stream by 0.14m during a 1:100 year AEP fluvial event with 30% uplift representing climate change and by 0.31m during a 1:100 year AEP pluvial event with 40% uplift representing climate change.
- ▶ The flood mechanism is not significantly impacted by the P&R Site, although lowered areas fill quicker and delay flooding elsewhere on the P&R Site and upstream of the P&R Site. Flood depths in all car parks is up to 1.24m during a 1:100 year AEP fluvial event with 30% uplift representing climate change and 0.43m during a 1:100 year AEP pluvial event with 40% uplift representing climate change.

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8. Sensitivity testing

The objective of sensitivity testing is to test the validity of the underlying assumptions in the model, and ensure the model is behaving as expected. Sensitivity testing provides a means of assessing how sensitive the predicted flood depths are to changes in model parameters and assumptions. It is expected that if a parameter is changed then the resultant flood depth may change. The aim of the sensitivity testing is to highlight the potential degree of change associated with adjusted parameters so as to provide confidence in the value selected and to understand uncertainty.

Section 8.1 details the sensitivity tests undertaken and their application in the 1D-2D model domain. A discussion on the sensitivity testing results is in Section 8.2.

8.1 Sensitivity test method

Sensitivity tests have been undertaken to test various model parameters: Manning's roughness coefficients; downstream boundary changes; storm durations, inflow points and the potential impact of culvert blockages. Table 8.1 details the application of the sensitivity tests in the 1D-2D modelling for fluvial and pluvial tests. All tests have been applied to the 'critical' 6 hour storm duration for the 1:100 year AEP event pluvial events and 1:100 year AEP fluvial events.

Table 8.1 Sensitivity test methods

Scenario	Flood source	Description
Sensitivity Test 1: 2D Roughness Increase (fluvial)	Fluvial	Run to assess the degree of change resultant of the roughness in the 1D/2D model: Roughness increased by 50% in 1D and increased to the values below in 2D files Global edit to nodes to increase roughness by 50% (saved as DALA01_026.dat)
		Category Baseline Increased Manning's n (Materials_006)
		Grass/General surface 0.04 0.05
		Building/Glasshouse 0.3 0.5
		Rough Grassland/Scrub/Trees 0.08 0.11
		Inland Water 0.035 0.045
		Path/Roadside 0.025 0.03
		Road 0.015 0.017
Sensitivity Test 2: 2D Roughness Decrease (fluvial)	Fluvial	Run to assess the degree of change resultant of the roughness in the 1D/2D model: Roughness decreased by 50% in 1D and decreased to the values below in 2D files Global edit to nodes to decrease roughness by 50% (saved as DALA01_027.dat)
		Category Baseline Decrease Manning's n (Materials_007)
		Grass/General surface 0.04 0.03
		Building/Glasshouse 0.3 0.01

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Scenario	Flood source	Description																					
		<table> <tr> <td>Rough Grassland/Scrub/Trees</td><td>0.08</td><td>0.06</td></tr> <tr> <td>Inland Water</td><td>0.035</td><td>0.025</td></tr> <tr> <td>Path/Roadside</td><td>0.025</td><td>0.02</td></tr> <tr> <td>Road</td><td>0.015</td><td>0.013</td></tr> </table>	Rough Grassland/Scrub/Trees	0.08	0.06	Inland Water	0.035	0.025	Path/Roadside	0.025	0.02	Road	0.015	0.013									
Rough Grassland/Scrub/Trees	0.08	0.06																					
Inland Water	0.035	0.025																					
Path/Roadside	0.025	0.02																					
Road	0.015	0.013																					
Sensitivity Test 3: Downstream boundary (fluvial)	Fluvial	2D HT (Head Time) downstream boundary represented at final downstream 1D cross section set at level 12.36mAOD (bank top level 12.364mAOD) compared to a calculated maximum of 11.86mAOD for 1:100+CC event.																					
Sensitivity Test 4: A5 Culvert Blockage* (fluvial)	Fluvial	Blockages of 30%, 67% and 95% were run on the A5 culvert on the Dalar Hir Stream. Each blockage was run individually and described below as Test 4a, 4b and 4c respectively. Change to culvert blockage in 1D model added into DAL01_029.dat, DALA01_029b.dat and DALA01_29c.dat files respectively.																					
Sensitivity Test 5: 2D Roughness Increase (pluvial)	Pluvial	Run to assess the degree of change resultant of the roughness in the 1D/2D model: Roughness increased by 50% in 1D and increased to the values below in 2D files Global edit to nodes to increase roughness by 50% (saved as DALA01_026.dat) <table> <tr> <td>Category</td><td>Baseline</td><td>Increased Manning's n (Materials_006)</td></tr> <tr> <td>Grass/General surface</td><td>0.04</td><td>0.05</td></tr> <tr> <td>Building/Glasshouse</td><td>0.3</td><td>0.5</td></tr> <tr> <td>Rough Grassland/Scrub/Trees</td><td>0.08</td><td>0.11</td></tr> <tr> <td>Inland Water</td><td>0.035</td><td>0.045</td></tr> <tr> <td>Path/Roadside</td><td>0.025</td><td>0.03</td></tr> <tr> <td>Road</td><td>0.015</td><td>0.017</td></tr> </table>	Category	Baseline	Increased Manning's n (Materials_006)	Grass/General surface	0.04	0.05	Building/Glasshouse	0.3	0.5	Rough Grassland/Scrub/Trees	0.08	0.11	Inland Water	0.035	0.045	Path/Roadside	0.025	0.03	Road	0.015	0.017
Category	Baseline	Increased Manning's n (Materials_006)																					
Grass/General surface	0.04	0.05																					
Building/Glasshouse	0.3	0.5																					
Rough Grassland/Scrub/Trees	0.08	0.11																					
Inland Water	0.035	0.045																					
Path/Roadside	0.025	0.03																					
Road	0.015	0.017																					
Sensitivity Test 6: 2D Roughness Decrease (pluvial)	Pluvial	Run to assess the degree of change resultant of the roughness in the 1D/2D model: Roughness decreased by 50% in 1D and decreased to the values below in 2D files Global edit to nodes to decrease roughness by ` (saved as DALA01_027.dat) <table> <tr> <td>Category</td><td>Baseline</td><td>Decrease Manning's n (Materials_007)</td></tr> <tr> <td>Grass/General surface</td><td>0.04</td><td>0.03</td></tr> <tr> <td>Building/Glasshouse</td><td>0.3</td><td>0.01</td></tr> <tr> <td>Rough Grassland/Scrub/Trees</td><td>0.08</td><td>0.06</td></tr> <tr> <td>Inland Water</td><td>0.035</td><td>0.025</td></tr> <tr> <td>Path/Roadside</td><td>0.025</td><td>0.02</td></tr> <tr> <td>Road</td><td>0.015</td><td>0.013</td></tr> </table>	Category	Baseline	Decrease Manning's n (Materials_007)	Grass/General surface	0.04	0.03	Building/Glasshouse	0.3	0.01	Rough Grassland/Scrub/Trees	0.08	0.06	Inland Water	0.035	0.025	Path/Roadside	0.025	0.02	Road	0.015	0.013
Category	Baseline	Decrease Manning's n (Materials_007)																					
Grass/General surface	0.04	0.03																					
Building/Glasshouse	0.3	0.01																					
Rough Grassland/Scrub/Trees	0.08	0.06																					
Inland Water	0.035	0.025																					
Path/Roadside	0.025	0.02																					
Road	0.015	0.013																					
Sensitivity Test 7: Downstream boundary	Fluvial	Run to assess the sensitivity to a decrease in slope at the downstream boundary in the hydraulic model. One fluvial run has been undertaken using the 1% AEP baseline fluvial inflows.																					

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Scenario	Flood source	Description
Sensitivity Test 8: Critical fluvial and pluvial storm durations	Fluvial and Pluvial	Runs to assess the sensitivity of the model predictions to fluvial and pluvial storm durations. To improve confidence in the chosen critical durations. Four additional fluvial model runs, and four additional pluvial model runs, of differing durations have been simulated. The additional eight simulations apply the present day 1:100 year AEP pluvial and fluvial baseline inflows, modifying the duration only.
Sensitivity Test 9: Critical fluvial and pluvial seasonal profile	Fluvial and Pluvial	Runs to assess the sensitivity of the model output to the seasonal profile of the pluvial and fluvial inflows. A fluvial hydrograph and a pluvial hyetograph for the baseline present day 1:100 year AEP critical duration event will be derived using the winter profile (corresponding summer profiles are presented in Section 3). This will allow a comparison with the summer profile.
Sensitivity Test 10: Loss units applied to conduits	Fluvial	Run to assess to test the sensitivity of the model predictions to a more conservative approach to the hydraulic modelling approach by adding inlet and outlet loss units for the A5 culvert. The scenario tested is the present day 1:100 year AEP fluvial event.
Sensitivity Test 11: Additional 1D roughness change	Fluvial	Runs to assess the sensitivity of the model predictions to a higher 1D roughness set across the whole 1D model. The simulations tested are the baseline 1:100 year AEP and the 'with development' 1:100 year AEP plus climate change.
Sensitivity Test 12: The effect of the separation of fluvial and pluvial inflows	Pluvial	Runs to assess the sensitivity of the separation of fluvial and pluvial inflows, by pairing the 1:30 year AEP and 1:100 year AEP pluvial storms with fluvial inflows corresponding to the same events, and comparing the results to the same pluvial events paired with a fluvial baseflow. The same critical duration of 6 hours has been used for like-for-like comparison.
Sensitivity Test 13: Distribution of Inflows with the model	Fluvial	This test has been undertaken to test the sensitivity of the model predictions to the method of hydrograph application to the hydraulic model. This has been undertaken by applying the existing fluvial hydrograph for the 1:100 year AEP (present day) event, distributing laterally along the watercourse rather than 'lumped' at the upstream end of the model. The test has been run for the baseline and 'with development' scenarios. The lateral distribution of flows has been calculated based on contributing catchment area.

8.2 Sensitivity test results

This section discusses the results of the sensitivity tests, which are compared to baseline 1:100 year AEP event unless otherwise stated. Results are reported at locations within the site boundary, as per Figure 4.1b

Test 1: Fluvial Manning's n roughness increase

Modelled peak flood depths for Manning's roughness increase sensitivity test has a relatively small difference in absolute terms (up to a 6cm change with the majority of locations experiencing less than 2cm difference) when compared to the depths of the baseline 1:100 year AEP fluvial event (Table 8.2). Given the baseline fluvial flood depths the absolute changes for each of the point and lines is considered low. Where the percentage change is more than 10%, the absolute changes is still less than 10cm. The higher roughness is slightly attenuating flows upstream of the site resulting in small decreases in the flood depths at the site.

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Table 8.2 Sensitivity Test 1 Summary Results – Peak Flood Depth (m) and difference compared to baseline for the 1:100 year AEP fluvial event

Results ID	Baseline 1:100 year AEP event		Test 1 Results		Test 1 Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA1	0	1.23	0	1.22	0	-0.01
DALA2	0	1.21	0	1.22	0	0.01
DALA3	0	0	0	0	0	0
DALA4	0	0.9	0	0.88	0	-0.02
DALA5	0.2	1.31	0.19	1.29	-0.01	-0.02
DALA6	0	1.32	0	1.33	0	0.01
DALA7	0	1.86	0	1.84	0	-0.02
DALA8	0	0.8	0	0.74	0	-0.06
DALA9	0	1.19	0	1.19	0	0
DALA10	0.09	0.27	0.07	0.26	-0.02	-0.01
DALA11	0.03	0.06	0.01	0.05	-0.02	-0.01
DALA12	0.02	0.15	0.01	0.14	-0.01	-0.01
DALA13	0.01	0.02	0	0.01	-0.01	-0.01
DALA14	0	0	0	0	0	0
DALA15	0.11	0.12	0.04	0.11	-0.07	-0.01
DALA16	0.03	0.06	0.09	0.08	0.06	0.02
DALA17	0.01	0.06	0.05	0.07	0.04	0.01
DALA18	0.2	0.4	0.23	0.41	0.03	0.01
DALA19	0.14	0.86	0.18	0.87	0.04	0.01
DALA20	0.16	0.68	0.14	0.69	-0.02	0.01
DALA21	0.16	0.84	0.20	0.85	0.04	0.01
DALA22	0.11	1.13	0.08	1.11	-0.03	-0.02
DALA23	0.15	1.1	0.08	1.09	-0.07	-0.01
DALA24	0.45	0.83	0.36	0.81	-0.09	-0.02
DALA25	0.04	0.93	0.04	0.92	0	-0.01
DALA26	0.29	1.82	0.25	1.80	-0.04	-0.02
DALA27	0.22	1.81	0.21	1.79	-0.01	-0.02
DALA28	0.03	0.08	0.01	0.02	-0.02	-0.06
DALA29	0.23	0.73	0.23	0.68	0	-0.05
DALA30	0.02	0.33	0.03	0.27	0.01	-0.06
DALA31	0	0	0	0	0	0
DALA32	0.03	0.51	0.03	0.49	0	-0.02

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Results ID	Baseline 1:100 year AEP event		Test 1 Results		Test 1 Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA33	0	0	0	0	0	0
DALA34	0	0	0	0	0	0
DALA35	0	0	0	0	0	0
DALA36	0	0	0	0	0	0
DALA37	0.03	0.04	0.01	0.03	-0.02	-0.01
DALA38	0	0	0	0	0	0
DALA39	0.03	0.54	0.02	0.53	-0.01	-0.01
DALA40	0	0	0	0	0	0
DALA41	0	0	0	0	0	0
DALA42	0	0	0	0	0	0
DALA43	0	0	0	0	0	0
DALA44	0	0	0	0	0	0
DALA45	0	0	0	0	0	0
DALA46	0	0	0	0	0	0
DALA47	0	0	0	0	0	0
DALA48	0	0	0	0	0	0
DALA49	0	0	0	0	0	0
DALA50	0.04	0.4	0.03	0.38	-0.01	-0.02

Test 2: Fluvial Manning's n roughness decrease

Modelled peak flood depths for Manning's roughness decrease sensitivity test has a relatively small difference in absolute terms (with the majority of locations experiencing less than 1cm difference) when compared to the depths of the baseline 1:100 year AEP fluvial event (Table 8.3). Given the baseline fluvial flood depths the absolute changes for most of the point and lines is considered low. The exceptions to this occur downstream of the site boundary at DALA28 – DALA30 (points) and DALA8 (line) where the change is a 14cm increase in flood depth. This is to be expected as this is an area of ponding and with a reduction in manning's n roughness more water will be conveyed to these ponding locations. These also still represent a relatively low absolute change.

Table 8.3 Sensitivity Test 2 Summary Results – Peak Flood Depth (m) and difference compared to baseline for the 1:100 year AEP fluvial event

Results ID	Baseline 1:100 year AEP event		Test 1 Results		Test 1 Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA1	0	1.23	0.00	1.22	0.00	-0.01
DALA2	0	1.21	0.00	1.20	0.00	-0.01

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Results ID	Baseline 1:100 year AEP event		Test 1 Results		Test 1 Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA3	0	0	0.00	0.00	0.00	0.00
DALA4	0	0.9	0.00	0.90	0.00	0.00
DALA5	0.2	1.31	0.23	1.31	0.03	0.00
DALA6	0	1.32	0.00	1.31	0.00	-0.01
DALA7	0	1.86	0.00	1.87	0.00	0.01
DALA8	0	0.8	0.00	0.93	0.00	0.13
DALA9	0	1.19	0.00	1.19	0.00	0.00
DALA10	0.09	0.27	0.09	0.27	0.00	0.00
DALA11	0.03	0.06	0.05	0.06	0.02	0.00
DALA12	0.02	0.15	0.02	0.15	0.00	0.00
DALA13	0.01	0.02	0.01	0.02	0.00	0.00
DALA14	0	0	0.00	0.00	0.00	0.00
DALA15	0.11	0.12	0.19	0.12	0.08	0.00
DALA16	0.03	0.06	0.01	0.05	-0.02	-0.01
DALA17	0.01	0.06	0.03	0.05	0.02	-0.01
DALA18	0.2	0.4	0.26	0.38	0.06	-0.02
DALA19	0.14	0.86	0.19	0.85	0.05	-0.01
DALA20	0.16	0.68	0.17	0.67	0.01	-0.01
DALA21	0.16	0.84	0.29	0.83	0.13	-0.01
DALA22	0.11	1.13	0.14	1.14	0.03	0.01
DALA23	0.15	1.1	0.21	1.11	0.06	0.01
DALA24	0.45	0.83	0.62	0.84	0.17	0.01
DALA25	0.04	0.93	0.08	0.94	0.04	0.01
DALA26	0.29	1.82	0.34	1.83	0.05	0.01
DALA27	0.22	1.81	0.23	1.82	0.01	0.01
DALA28	0.03	0.08	0.05	0.22	0.02	0.14
DALA29	0.23	0.73	0.23	0.87	0.00	0.14
DALA30	0.02	0.33	0.02	0.47	0.00	0.14
DALA31	0	0	0.00	0.00	0.00	0.00
DALA32	0.03	0.51	0.03	0.52	0.00	0.01
DALA33	0	0	0.00	0.00	0.00	0.00
DALA34	0	0	0.00	0.00	0.00	0.00
DALA35	0	0	0.00	0.00	0.00	0.00
DALA36	0	0	0.00	0.00	0.00	0.00
DALA37	0.03	0.04	0.03	0.03	0.00	-0.01

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Results ID	Baseline 1:100 year AEP event		Test 1 Results		Test 1 Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA38	0	0	0.00	0.00	0.00	0.00
DALA39	0.03	0.54	0.06	0.55	0.03	0.01
DALA40	0	0	0.00	0.00	0.00	0.00
DALA41	0	0	0.00	0.00	0.00	0.00
DALA42	0	0	0.00	0.00	0.00	0.00
DALA43	0	0	0.00	0.00	0.00	0.00
DALA44	0	0	0.00	0.00	0.00	0.00
DALA45	0	0	0.00	0.00	0.00	0.00
DALA46	0	0	0.00	0.00	0.00	0.00
DALA47	0	0	0.00	0.00	0.00	0.00
DALA48	0	0	0.00	0.00	0.00	0.00
DALA49	0	0	0.00	0.00	0.00	0.00
DALA50	0.04	0.4	0.05	0.41	0.01	0.01

Test 3: Fluvial downstream boundary

Modelled peak flood depths for test 3 are very similar to those presented in the baseline results. The largest change is 1cm (Table 8.4).

Table 8.4 Sensitivity Test 3 Summary Results – Peak Flood Depth (m) and difference compared to baseline for the 1:100 year AEP fluvial event

Results ID	Baseline 1:100 year AEP event		Test 3 Results		Test 4a Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA1	0	1.23	0	1.23	0	0
DALA2	0	1.21	0	1.21	0	0
DALA3	0	0	0	0	0	0
DALA4	0	0.9	0.03	0.90	0.03	0
DALA5	0.2	1.31	0	1.31	-0.20	0
DALA6	0	1.32	0	1.32	0	0
DALA7	0	1.86	0	1.86	0	0
DALA8	0	0.8	0	0.79	0	-0.01
DALA9	0	1.19	0	1.19	0	0

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Results ID	Baseline 1:100 year AEP event		Test 3 Results		Test 4a Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA10	0.09	0.27	0.09	0.27	0	0
DALA11	0.03	0.06	0.03	0.06	0	0
DALA12	0.02	0.15	0.02	0.15	0	0
DALA13	0.01	0.02	0.01	0.02	0	0
DALA14	0	0	0	0	0	0
DALA15	0.11	0.12	0.11	0.12	0	0
DALA16	0.03	0.06	0.04	0.07	0.01	0.01
DALA17	0.01	0.06	0.01	0.06	0	0
DALA18	0.2	0.4	0.23	0.40	0.03	0
DALA19	0.14	0.86	0.14	0.86	0	0
DALA20	0.16	0.68	0.16	0.68	0	0
DALA21	0.16	0.84	0.16	0.84	0	0
DALA22	0.11	1.13	0.11	1.12	0	-0.01
DALA23	0.15	1.1	0.15	1.10	0	0
DALA24	0.45	0.83	0.45	0.82	0	-0.01
DALA25	0.04	0.93	0.04	0.93	0	0
DALA26	0.29	1.82	0.29	1.81	0	-0.01
DALA27	0.22	1.81	0.22	1.81	0	0
DALA28	0.03	0.08	0.03	0.08	0	0
DALA29	0.23	0.73	0.23	0.73	0	0
DALA30	0.02	0.33	0.02	0.33	0	0
DALA31	0	0	0	0	0	0
DALA32	0.03	0.51	0.03	0.51	0	0
DALA33	0	0	0	0	0	0
DALA34	0	0	0	0	0	0
DALA35	0	0	0	0	0	0
DALA36	0	0	0	0	0	0

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Results ID	Baseline 1:100 year AEP event		Test 3 Results		Test 4a Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA37	0.03	0.04	0.03	0.04	0	0
DALA38	0	0	0	0	0	0
DALA39	0.03	0.54	0.03	0.54	0	0
DALA40	0	0	0	0	0	0
DALA41	0	0	0	0	0	0
DALA42	0	0	0	0	0	0
DALA43	0	0	0	0	0	0
DALA44	0	0	0	0	0	0
DALA45	0	0	0	0	0	0
DALA46	0	0	0	0	0	0
DALA47	0	0	0	0	0	0
DALA48	0	0	0	0	0	0
DALA49	0	0	0	0	0	0
DALA50	0.04	0.4	0.04	0.40	0	0

Test 4: Fluvial A5 culvert blockages

Three modelled scenarios were undertaken to assess the impact of culvert blockage (of the existing culvert under the A5) at the Dalar Hir Park and Ride Site. These were dictated by the NRW guidance (2015) which suggested testing should incorporate culvert blockages of 30%, 67% and 95%.

Test 4a: 30% Blockage

A 30% blockage of the A5 culvert causes flood depths to increase slightly at some monitoring point such as DALA39, by up to 8cm (Table 8.5). The increase in depth is upstream of the culvert location which is as expected and not considered as significant, given the result check point being at some local depression point. In general, the overall depth increment is in proportion to the scenario as can be seen from the table.

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Table 8.5 Sensitivity Test 4a Summary Results – Peak Flood Depth (m) and difference compared to baseline for the 1:100 year AEP fluvial event

Results ID	Baseline 1:100 year AEP event		Test 4a Results		Test 4a Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA1	0	1.23	0	1.24	0	0.01
DALA2	0	1.21	0	1.23	0	0.02
DALA3	0	0	0	0	0	0
DALA4	0	0.9	0	0.91	0	0.01
DALA5	0.2	1.31	0.19	1.37	-0.01	0.06
DALA6	0	1.32	0	1.34	0	0.02
DALA7	0	1.86	0	1.93	0	0.07
DALA8	0	0.8	0	0.81	0	0.01
DALA9	0	1.19	0	1.19	0	0
DALA10	0.09	0.27	0.09	0.29	0	0.02
DALA11	0.03	0.06	0.03	0.07	0	0.01
DALA12	0.02	0.15	0.02	0.16	0	0.01
DALA13	0.01	0.02	0.02	0.03	0.01	0.01
DALA14	0	0	0.05	0	0.05	0
DALA15	0.11	0.12	0.12	0.14	0.01	0.02
DALA16	0.03	0.06	0.04	0.08	0.01	0.02
DALA17	0.01	0.06	0.03	0.08	0.02	0.02
DALA18	0.2	0.4	0.19	0.42	-0.01	0.02
DALA19	0.14	0.86	0.15	0.88	0.01	0.02
DALA20	0.16	0.68	0.16	0.70	0	0.02
DALA21	0.16	0.84	0.17	0.86	0.01	0.02
DALA22	0.11	1.13	0.11	1.20	0	0.07
DALA23	0.15	1.1	0.15	1.17	0	0.07
DALA24	0.45	0.83	0.46	0.90	0.01	0.07
DALA25	0.04	0.93	0.05	1.00	0.01	0.07
DALA26	0.29	1.82	0.31	1.89	0.02	0.07

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Results ID	Baseline 1:100 year AEP event		Test 4a Results		Test 4a Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA27	0.22	1.81	0.24	1.88	0.02	0.07
DALA28	0.03	0.08	0.03	0.10	0	0.02
DALA29	0.23	0.73	0.08	0.75	-0.15	0.02
DALA30	0.02	0.33	0.04	0.34	0.02	0.01
DALA31	0	0	0	0	0	0
DALA32	0.03	0.51	0.03	0.58	0	0.07
DALA33	0	0	0	0	0	0
DALA34	0	0	0	0	0	0
DALA35	0	0	0	0	0	0
DALA36	0	0	0	0	0	0
DALA37	0.03	0.04	0.04	0.05	0.01	0.01
DALA38	0	0	0	0	0	0
DALA39	0.03	0.54	0.03	0.62	0	0.08
DALA40	0	0	0	0	0	0
DALA41	0	0	0	0	0	0
DALA42	0	0	0	0	0	0
DALA43	0	0	0	0	0	0
DALA44	0	0	0	0	0	0
DALA45	0	0	0	0	0	0
DALA46	0	0	0	0	0	0
DALA47	0	0	0	0	0	0
DALA48	0	0	0	0	0	0
DALA49	0	0	0	0	0	0
DALA50	0.04	0.4	0.04	0.47	0	0.07

Test 4b: 67% Blockage

A 67% blockage at the A5 culvert causes flood depths to increase slightly at some monitoring points such as DALA39, by up to 11cm (Table 8.6). The increase in depth is upstream of the culvert location which is as expected and not considered as significant, given the result check point being at a local depression point. In

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general, the overall depth increment is in proportion to the scenario considered as can be seen from the table.

Table 8.6 Sensitivity Test 4b Summary Results – Peak Flood Depth (m) and difference compared to baseline for the 1:100 year AEP fluvial event

Results ID	Baseline 1:100 year AEP event		Test 4b Results		Test 4b Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA1	0	1.23	0	1.25	0	0.02
DALA2	0	1.21	0	1.24	0	0.03
DALA3	0	0	0	0	0	0
DALA4	0	0.9	0.03	0.91	0.03	0.01
DALA5	0.2	1.31	0	1.40	-0.20	0.09
DALA6	0	1.32	0	1.35	0	0.03
DALA7	0	1.86	0	1.96	0	0.10
DALA8	0	0.8	0	0.82	0	0.02
DALA9	0	1.19	0	1.19	0	0
DALA10	0.09	0.27	0.09	0.29	0	0.02
DALA11	0.03	0.06	0.03	0.08	0	0.02
DALA12	0.02	0.15	0.02	0.17	0	0.02
DALA13	0.01	0.02	0.02	0.04	0.01	0.02
DALA14	0	0	0.07	0.01	0.07	0.01
DALA15	0.11	0.12	0.12	0.15	0.01	0.03
DALA16	0.03	0.06	0.05	0.09	0.02	0.03
DALA17	0.01	0.06	0.04	0.09	0.03	0.03
DALA18	0.2	0.4	0.22	0.43	0.02	0.03
DALA19	0.14	0.86	0.15	0.89	0.01	0.03
DALA20	0.16	0.68	0.16	0.71	0	0.03
DALA21	0.16	0.84	0.17	0.87	0.01	0.03
DALA22	0.11	1.13	0.12	1.23	0.01	0.10
DALA23	0.15	1.1	0.13	1.21	-0.02	0.11
DALA24	0.45	0.83	0.45	0.93	0	0.10

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Results ID	Baseline 1:100 year AEP event		Test 4b Results		Test 4b Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA25	0.04	0.93	0.05	1.04	0.01	0.11
DALA26	0.29	1.82	0.31	1.92	0.02	0.10
DALA27	0.22	1.81	0.24	1.91	0.02	0.10
DALA28	0.03	0.08	0.03	0.10	0	0.02
DALA29	0.23	0.73	0.33	0.76	0.10	0.03
DALA30	0.02	0.33	0.04	0.35	0.02	0.02
DALA31	0	0	0	0	0	0
DALA32	0.03	0.51	0.03	0.61	0	0.10
DALA33	0	0	0	0	0	0
DALA34	0	0	0	0	0	0
DALA35	0	0	0	0	0	0
DALA36	0	0	0	0	0	0
DALA37	0.03	0.04	0.06	0.05	0.03	0.01
DALA38	0	0	0	0	0	0
DALA39	0.03	0.54	0.03	0.65	0	0.11
DALA40	0	0	0	0	0	0
DALA41	0	0	0	0	0	0
DALA42	0	0	0	0	0	0
DALA43	0	0	0	0	0	0
DALA44	0	0	0	0	0	0
DALA45	0	0	0	0	0	0
DALA46	0	0	0	0	0	0
DALA47	0	0	0	0	0	0
DALA48	0	0	0	0	0	0
DALA49	0	0	0	0	0	0
DALA50	0.04	0.4	0.04	0.50	0	0.10

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NOT PROTECTIVELY MARKED**Test 4c: 95% Blockage**

Modelled peak flood depths increase at a number of locations by up to 14 cm in proportion to the scenario considered. The largest percentage changes occur where minimal flooding was seen in the baseline modelling (less than 5 cm), with the largest absolute changes corresponding to low percentage increases within the Site boundary towards the A55 and in the tract of land between the A55 and A5 where a local ditch is accumulating water. The results of a 95% blockage scenario are shown in Table 8.7.

Table 8.7 Sensitivity Test 4c Summary Results – Peak Flood Depth (m) and difference compared to baseline for the 1:100 year AEP fluvial event

Results ID	Baseline 1:100 year AEP event		Test 4c Results		Test 4c Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA1	0	1.23	0	1.26	0	0.03
DALA2	0	1.21	0	1.25	0	0.04
DALA3	0	0	0	0	0	0
DALA4	0	0.9	0.03	0.92	0.03	0.02
DALA5	0.2	1.31	0	1.43	-0.20	0.12
DALA6	0	1.32	0	1.35	0	0.03
DALA7	0	1.86	0	2.00	0	0.14
DALA8	0	0.8	0	0.83	0	0.03
DALA9	0	1.19	0	1.21	0	0.02
DALA10	0.09	0.27	0.08	0.30	-0.01	0.03
DALA11	0.03	0.06	0.03	0.08	0	0.02
DALA12	0.02	0.15	0.02	0.17	0	0.02
DALA13	0.01	0.02	0.02	0.04	0.01	0.02
DALA14	0	0	0.07	0.01	0.07	0.01
DALA15	0.11	0.12	0.12	0.16	0.01	0.04
DALA16	0.03	0.06	0.06	0.10	0.03	0.04
DALA17	0.01	0.06	0.05	0.10	0.04	0.04
DALA18	0.2	0.4	0.22	0.43	0.02	0.03
DALA19	0.14	0.86	0.15	0.90	0.01	0.04
DALA20	0.16	0.68	0.16	0.71	0	0.03
DALA21	0.16	0.84	0.17	0.88	0.01	0.04

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Results ID	Baseline 1:100 year AEP event		Test 4c Results		Test 4c Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA22	0.11	1.13	0.11	1.26	0	0.13
DALA23	0.15	1.1	0.08	1.24	-0.07	0.14
DALA24	0.45	0.83	0.40	0.96	-0.05	0.13
DALA25	0.04	0.93	0.05	1.07	0.01	0.14
DALA26	0.29	1.82	0.32	1.95	0.03	0.13
DALA27	0.22	1.81	0.25	1.94	0.03	0.13
DALA28	0.03	0.08	0.03	0.11	0	0.03
DALA29	0.23	0.73	0.34	0.77	0.11	0.04
DALA30	0.02	0.33	0.04	0.36	0.02	0.03
DALA31	0	0	0	0	0	0
DALA32	0.03	0.51	0.03	0.65	0	0.14
DALA33	0	0	0	0	0	0
DALA34	0	0	0	0	0	0
DALA35	0	0	0	0	0	0
DALA36	0	0	0	0	0	0
DALA37	0.03	0.04	0.07	0.06	0.04	0.02
DALA38	0	0	0	0	0	0
DALA39	0.03	0.54	0.03	0.68	0	0.14
DALA40	0	0	0	0	0	0
DALA41	0	0	0	0	0	0
DALA42	0	0	0	0	0	0
DALA43	0	0	0	0	0	0
DALA44	0	0	0	0	0	0
DALA45	0	0	0	0	0	0
DALA46	0	0	0	0	0	0
DALA47	0	0	0	0	0	0
DALA48	0	0	0	0	0	0

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Results ID	Baseline 1:100 year AEP event		Test 4c Results		Test 4c Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA49	0	0	0	0	0	0
DALA50	0.04	0.4	0.04	0.54	0	0.14

Test 5: Pluvial Run Manning's roughness (n) increase

Modelled peak flood depths for Manning's roughness increase sensitivity test has a relatively small difference in absolute terms (up to a 7cm change) when compared to the depths of the baseline 1:100 year AEP fluvial event (Table 8.8). When the baseline fluvial flood depths are considered, the absolute changes for each of the monitor point and lines is considered to be small confirming that the model predictions at the site are not very sensitive to surface roughness.

Table 8.8 Sensitivity Test 5 Summary Results – Peak Flood Depth (m) and difference compared to baseline for the 1:100 year AEP fluvial event

Results ID	Baseline 1:100 year AEP event		Test 5 Results		Test 5 Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA1	0	1.66	0	1.71	0	0.05
DALA2	0.01	1.81	0.01	1.81	0	0
DALA3	0.49	0.75	0.41	0.76	-0.08	0
DALA4	0.06	0.74	0.05	0.73	-0.01	-0.01
DALA5	0.18	0.81	0.19	0.82	0.01	0
DALA6	0	2.09	0	2.10	0	0.01
DALA7	0.04	1.23	0.03	1.23	-0.01	0
DALA8	0.01	0.82	0.01	0.77	0	-0.05
DALA9	0.02	1.85	0.02	1.92	0	0.06
DALA10	0.08	0.06	0.08	0.05	0	-0.01
DALA11	0.03	0	0.01	0	-0.01	0
DALA12	0.13	0.01	0.12	0.01	-0.01	0
DALA13	0.07	0	0.06	0.01	-0.01	0
DALA14	0.03	0.01	0.03	0.01	-0.01	0
DALA15	0.01	0	0.01	0	0	0

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Results ID	Baseline 1:100 year AEP event		Test 5 Results		Test 5 Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA16	0.04	0	0.04	0	0	0
DALA17	0.01	0	0.01	0	0	0
DALA18	0.12	0.21	0.13	0.22	0	0.01
DALA19	0.12	0.68	0.10	0.69	-0.02	0.01
DALA20	0.08	0.50	0.08	0.51	0	0.01
DALA21	0.14	0.66	0.12	0.67	-0.02	0.01
DALA22	0.03	0.55	0.02	0.56	-0.01	0.01
DALA23	0.02	0.53	0.02	0.53	0	0.01
DALA24	0.03	0.25	0.05	0.26	0.02	0.01
DALA25	0.02	0.36	0.03	0.36	0.01	0.01
DALA26	0.05	0.70	0.04	0.70	-0.01	0
DALA27	0.01	0.69	0.02	0.69	0.01	0
DALA28	0.03	0	0.03	0	-0.01	0
DALA29	0.04	0.52	0.04	0.45	0.01	-0.07
DALA30	0.09	0.11	0.10	0.04	0.01	-0.07
DALA31	0.05	0	0.06	0	0.01	0
DALA32	0.03	0	0.03	0	0	0
DALA33	0.10	0.01	0.09	0.01	-0.01	0
DALA34	0.06	0.03	0.05	0.03	0	0
DALA35	0.03	0	0.05	0	0.02	0
DALA36	0.06	0.01	0.08	0.01	0.01	0
DALA37	0	0	0.01	0	0.01	0
DALA38	0.01	0	0.01	0	0	0
DALA39	0.05	0	0.05	0	0	0
DALA40	0.02	0	0.02	0	0	0
DALA41	0.17	0.01	0.16	0.01	-0.01	0
DALA42	0.03	0	0.02	0	0	0
DALA43	0.02	0	0.02	0	0	0

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Results ID	Baseline 1:100 year AEP event		Test 5 Results		Test 5 Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA44	0.02	0	0.01	0	0	0
DALA45	0.14	2.67	0.13	2.68	-0.01	0
DALA46	0.31	0.57	0.27	0.57	-0.04	0
DALA47	0.05	0.64	0.05	0.64	0	0
DALA48	0.03	0	0.03	0	0	0
DALA49	0.02	0.02	0.01	0.02	-0.01	0
DALA50	0.65	0.03	0.56	0.04	-0.09	0.01

Test 6: Pluvial Run Manning's roughness (n) decrease

Modelled peak flood depths for Manning's roughness decrease sensitivity test has a relatively small difference in absolute terms (up to an 8cm reduction) when compared to the depths of the baseline 1:100 year AEP fluvial event (Table 8.9). When the baseline fluvial flood depths are considered, the absolute changes for each of the monitor point and lines is considered to be small confirming that the model predictions at the site are not very sensitive to surface roughness. The exceptions to this occur downstream of the site boundary at DALA29 and DALA30 (points) where the change is a 10cm increase in flood depth which is not unexpected because the points lie on a depression and has only localised effect. The result is considered consistent with what would be expected from this test, in which lower surface roughness promotes a less restrictive conveyance of water from the upstream to downstream reaches.

Table 8.9 Sensitivity Test 6 Summary Results – Peak Flood Depth (m) and difference compared to baseline for the 1:100 year AEP fluvial event

Results ID	Baseline 1:100 year AEP event		Test 6 Results		Test 6 Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA1	0	1.66	0.01	1.66	0	0
DALA2	0.01	1.81	0.02	1.81	0	0
DALA3	0.49	0.75	0.41	0.75	-0.07	0
DALA4	0.06	0.74	0.08	0.76	0.02	0.02
DALA5	0.18	0.81	0.16	0.82	-0.02	0
DALA6	0	2.09	0	2.10	0	0
DALA7	0.04	1.23	0.05	1.24	0.01	0
DALA8	0.01	0.82	0.02	0.90	0	0.08

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Results ID	Baseline 1:100 year AEP event		Test 6 Results		Test 6 Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA9	0.02	1.85	0.02	1.83	0	-0.02
DALA10	0.08	0.06	0.09	0.09	0.01	0.02
DALA11	0.03	0	0.03	0	0.01	0
DALA12	0.13	0.01	0.14	0	0	0
DALA13	0.07	0	0.08	0	0.01	0
DALA14	0.03	0.01	0.03	0.01	0	0
DALA15	0.01	0	0.02	0	0.01	0
DALA16	0.04	0	0.04	0	0	0
DALA17	0.01	0	0.01	0	0	0
DALA18	0.12	0.21	0.09	0.22	-0.04	0
DALA19	0.12	0.68	0.18	0.68	0.06	0
DALA20	0.08	0.50	0.14	0.50	0.06	0
DALA21	0.14	0.66	0.26	0.66	0.12	0
DALA22	0.03	0.55	0.02	0.56	-0.01	0
DALA23	0.02	0.53	0.03	0.53	0.01	0
DALA24	0.03	0.25	0.03	0.26	0	0
DALA25	0.02	0.36	0.03	0.36	0.01	0
DALA26	0.05	0.70	0.06	0.70	0.01	0
DALA27	0.01	0.69	0.01	0.69	0	0
DALA28	0.03	0	0.04	0	0.01	0
DALA29	0.04	0.52	0.06	0.61	0.02	0.10
DALA30	0.09	0.11	0.05	0.21	-0.04	0.10
DALA31	0.05	0	0.04	0	-0.01	0
DALA32	0.03	0	0.05	0	0.01	0
DALA33	0.10	0.01	0.10	0.01	0	0
DALA34	0.06	0.03	0.06	0.02	0	0
DALA35	0.03	0	0.03	0	0.01	0
DALA36	0.06	0.01	0.05	0	-0.02	0

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Results ID	Baseline 1:100 year AEP event		Test 6 Results		Test 6 Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA37	0	0	0	0	0	0
DALA38	0.01	0	0.01	0	0	0
DALA39	0.05	0	0.04	0	0	0
DALA40	0.02	0	0.03	0	0	0
DALA41	0.17	0.01	0.18	0.01	0.01	0
DALA42	0.03	0	0.02	0	0	0
DALA43	0.02	0	0.03	0	0	0
DALA44	0.02	0	0.04	0	0.02	0
DALA45	0.14	2.67	0.16	2.68	0.02	0
DALA46	0.31	0.57	0.37	0.57	0.06	0
DALA47	0.05	0.64	0.02	0.64	-0.03	0
DALA48	0.03	0	0.03	0	0	0
DALA49	0.02	0.02	0.03	0.01	0.01	-0.01
DALA50	0.65	0.03	0.77	0.03	0.12	0

Test 7: Additional downstream boundary sensitivity test

This test has been completed by decreasing the definition of the slope of the downstream boundary of the hydraulic model (by 20%) in the hydraulic model. The baseline boundary condition was decreased by 20% and represented as normal depth boundary in both the 1D and 2D components. This represents a more conservative hydraulic modelling approach. The 1:100 year AEP event fluvial hydrology for the present day was applied in this sensitivity test.

Modelled peak flood depths for the change to the slope of the downstream outflow boundary test show a localised increase in water level near the downstream boundary whereas there was negligible change to the water depths and velocities at all other upstream locations when compared to the baseline 1:100 year AEP fluvial event (Table 8.10 Table 8.20).

Table 8.10 Sensitivity Test 7 Summary Results – Peak Flood Depth (m) and difference compared to baseline for the 1:100 year AEP fluvial event

Results ID	Baseline 1:100 year AEP event		Test 7 Results		Test 7 Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA1	0	1.23	0	1.23	0	0

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Results ID	Baseline 1:100 year AEP event		Test 7 Results		Test 7 Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA2	0	1.21	0	1.21	0	0
DALA3	0	0	0	0	0	0
DALA4	0	0.9	0	0.9	0	0
DALA5	0.2	1.31	0.21	1.31	0.01	0
DALA6	0	1.32	0	1.32	0	0
DALA7	0	1.86	0	1.86	0	0
DALA8	0	0.8	0	0.8	0	0
DALA9	0	1.19	0	1.19	0	0
DALA10	0.09	0.27	0.09	0.27	0	0
DALA11	0.03	0.06	0.03	0.06	0	0
DALA12	0.02	0.15	0.02	0.15	0	0
DALA13	0.01	0.02	0.01	0.02	0	0
DALA14	0	0	0	0	0	0
DALA15	0.11	0.12	0.11	0.12	0	0
DALA16	0.03	0.06	0.03	0.06	0	0
DALA17	0.01	0.06	0.01	0.06	0	0
DALA18	0.2	0.4	0.20	0.4	0	0
DALA19	0.14	0.86	0.14	0.86	0	0
DALA20	0.16	0.68	0.16	0.68	0	0
DALA21	0.16	0.84	0.16	0.84	0	0
DALA22	0.11	1.13	0.11	1.13	0	0
DALA23	0.15	1.1	0.15	1.1	0	0
DALA24	0.45	0.83	0.45	0.83	0	0
DALA25	0.04	0.93	0.04	0.93	0	0
DALA26	0.29	1.82	0.29	1.82	0	0
DALA27	0.22	1.81	0.22	1.81	0	0
DALA28	0.03	0.08	0.03	0.08	0	0
DALA29	0.23	0.73	0.23	0.73	0	0

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Results ID	Baseline 1:100 year AEP event		Test 7 Results		Test 7 Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA30	0.02	0.33	0.02	0.33	0	0
DALA31	0	0	0	0	0	0
DALA32	0.03	0.51	0.03	0.51	0	0
DALA33	0	0	0	0	0	0
DALA34	0	0	0	0	0	0
DALA35	0	0	0	0	0	0
DALA36	0	0	0	0	0	0
DALA37	0.03	0.04	0.03	0.04	0	0
DALA38	0	0	0	0	0	0
DALA39	0.03	0.54	0.03	0.54	0	0
DALA40	0	0	0	0	0	0
DALA41	0	0	0	0	0	0
DALA42	0	0	0	0	0	0
DALA43	0	0	0	0	0	0
DALA44	0	0	0	0	0	0
DALA45	0	0	0	0	0	0
DALA46	0	0	0	0	0	0
DALA47	0	0	0	0	0	0
DALA48	0	0	0	0	0	0
DALA49	0	0	0	0	0	0
DALA50	0.04	0.4	0.04	0.4	0	0

Test 8: Additional sensitivity testing to storm duration

This test was undertaken to provide greater granularity to the storm duration testing undertaken previously in Section 3. In Section 3.1, the critical pluvial storm duration assessment used the 1:100 year AEP event and a range of durations (0.5, 1, 3, 6 and 24 hours) and the 6 hour duration storm was taken as critical. The critical fluvial storm duration was taken to be 5.5 hours for the 1:100 year AEP event.

In this test, the assessments have been added for 4, 5 and 7 and 8 hour duration pluvial storms to compare with the values obtained from 6 hour pluvial duration. Similarly, additional fluvial runs have been carried out for four other storm durations: 3.5, 4.5, 6.5 and 7.5 hours and the results have been compared with those from the adopted critical duration to test the sensitivity to the storm durations on the model predictions.

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A total of eight runs were undertaken; four additional fluvial 1D-2D baseline runs and four pluvial 1D-2D baseline runs each testing different storm durations, building on the previous critical duration assessments in Section 3. This sensitivity test included the following runs:

- ▶ Fluvial testing: completed by generating an additional four fluvial hydrographs for the 1:100 year AEP event (present day storm) of differing durations and then running them through the 1D-2D hydraulic model:
 - ▶ Test 8a – fluvial baseline model run with 3.5 hour summer storm duration hydrograph;
 - ▶ Test 8b – fluvial baseline model run with 4.5 hour summer storm duration hydrograph;
 - ▶ Test 8c – fluvial baseline model run with 6.5 hour summer storm duration hydrograph; and
 - ▶ Test 8d – fluvial baseline model run with 7.5 hour summer storm duration hydrograph.
- ▶ Pluvial testing: completed by generating an additional four pluvial hyetographs for the 1:100 year AEP event (present day storm) of differing durations (e.g. 4, 5, 7, 8 hour) and running them through the 1D-2D hydraulic model.
 - ▶ Test 8e – pluvial baseline model run with 4 hour summer storm hyetograph;
 - ▶ Test 8f – pluvial baseline model run with 5 hour summer storm hyetograph;
 - ▶ Test 8g – pluvial baseline model run with 7 hour summer storm hyetograph; and
 - ▶ Test 8h – pluvial baseline model run with 8 hour summer storm hyetograph.

Modelled peak flood depths for the changes to the storm duration testing shows very little change to modelled water depths in both the fluvial and pluvial tests (up to a maximum of $\pm 10\text{cm}$). The depth changes at the critical locations are presented in Table 8.11a (fluvial runs Task 8.2a to 8.2d) and Table 8.11b (pluvial runs Task 8.2e to 8.2h) against the appropriate baseline model. The runs are summarised as follows:

- ▶ Test 8.2a: Very small changes using the 3.5 hour summer storm hydrograph compared to the baseline fluvial 1D-2D hydraulic model run (1:100 year AEP). The water depths at critical locations show a maximum increase of 1cm at some locations, with a decrease of up to 9cm at other locations;
- ▶ Test 8.2b: Very small changes using the 4.5 hour summer storm hydrograph compared to the baseline fluvial 1D-2D hydraulic model run (1:100 year AEP). The water depths at critical locations show a maximum increase of up to 1cm at some locations, with a decrease of up to 4cm at other locations;
- ▶ Test 8.2c: Very small changes using the 6.5 hour summer storm hydrograph compared to the baseline fluvial 1D-2D hydraulic model run (1:100 year AEP). The water depths at critical locations show a maximum increase of up to 3cm at some locations;
- ▶ Test 8.2d: Very small changes using the 7.5 hour summer storm hydrograph compared to the baseline fluvial 1D-2D hydraulic model run (1:100 year AEP). The water depths at critical locations show a maximum increase of up to 5cm at some locations, with a decrease up to 5cm at other locations;
- ▶ Test 8.2e: Very small changes using the 4 hour summer storm hyetograph compared to the baseline pluvial 1D-2D hydraulic model run (1:100 year AEP). The water depths at critical locations show a maximum increase of up to 2cm at some locations, with a decrease of up to 5cm at other locations;
- ▶ Test 8.2f: Very small changes using the 5 hour summer storm hyetograph compared to the baseline pluvial 1D-2D hydraulic model run (1:100 year AEP). The water depths at critical

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locations show a maximum increase of up to 1cm at some locations, with a decrease of up to 2cm at other locations;

- Test 8.2g: Very small changes using the 7 hour summer storm hyetograph compared to the baseline pluvial 1D-2D hydraulic model run (1:100 year AEP). The water depths at critical locations show a maximum increase of up to 2cm at some locations, with a decrease of up to 1cm at other locations; and

Test 8.2h: Very small changes using the 8 hour summer storm hyetograph compared to the baseline pluvial 1D-2D hydraulic model run (1:100 year AEP). The water depths at critical locations show a maximum increase of up to 5cm at some locations, with a decrease of up to 2cm at other locations.

The results indicate that the model is not sensitive to storm duration. The results of the testing presented here confirms that the critical storm durations of 5.5 hours for the fluvial and 6 hours for the pluvial 1:100 year AEP events as reported in Section 3 are appropriate. The sensitivity testing presents only very small relative changes to maximum water depths for the range storm durations tested, indicating that the model is not sensitive to storm duration in this range.

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Table 8.11a Sensitivity Tests 8a to d Summary Results – Peak Flood Depth (m) and difference compared to baseline for the 1:100 year AEP fluvial event

Results	Baseline 1:100 year AEP Event		Test 8a Results		Test 8a Results minus Baseline		Test 8b Results		Test 8b Results minus Baseline		Test 8c Results		Test 8c Results minus Baseline		Test 8d Results		Test 8d Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA1	0	1.23	0	1.22	0	-0.01	0	1.23	0	0	0	1.23	0	0	0	1.23	0	0
DALA2	0	1.21	0	1.2	0	-0.01	0	1.21	0	0	0	1.21	0	0	0	1.21	0	0
DALA3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DALA4	0	0.9	0	0.89	0	-0.01	0	0.9	0	0	0	0.9	0	0	0	0.89	0	-0.01
DALA5	0.2	1.31	0.21	1.23	0.01	-0.08	0.21	1.27	0.01	-0.04	0.2	1.33	0	0.02	0.2	1.35	0	0.04
DALA6	0	1.32	0	1.31	0	-0.01	0	1.32	0	0	0	1.32	0	0	0	1.32	0	0
DALA7	0	1.86	0	1.77	0	-0.09	0	1.82	0	-0.04	0	1.89	0	0.03	0	1.9	0	0.04
DALA8	0	0.8	0	0.77	0	-0.03	0	0.78	0	-0.02	0	0.8	0	0	0	0.81	0	0.01
DALA9	0	1.19	0	1.2	0	0.01	0	1.2	0	0.01	0	1.19	0	0	0	1.19	0	0
DALA10	0.09	0.27	0.09	0.27	0	0	0.09	0.27	0	0	0.09	0.27	0	0	0.09	0.27	0	0
DALA11	0.03	0.06	0.02	0.05	-0.01	-0.01	0.03	0.06	0	0	0.03	0.06	0	0	0.03	0.06	0	0
DALA12	0.02	0.15	0.02	0.14	0	-0.01	0.02	0.15	0	0	0.02	0.15	0	0	0.02	0.15	0	0
DALA13	0.01	0.02	0.01	0.01	0	-0.01	0.01	0.02	0	0	0.01	0.02	0	0	0.01	0.02	0	0
DALA14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DALA15	0.11	0.12	0.11	0.12	0	0	0.11	0.12	0	0	0.11	0.12	0	0	0.11	0.12	0	0
DALA16	0.03	0.06	0.03	0.06	0	0	0.03	0.06	0	0	0.03	0.06	0	0	0.03	0.06	0	0
DALA17	0.01	0.06	0.01	0.06	0	0	0.01	0.06	0	0	0.01	0.06	0	0	0.01	0.06	0	0
DALA18	0.2	0.4	0.19	0.39	-0.01	-0.01	0.2	0.4	0	0	0.2	0.4	0	0	0.2	0.4	0	0
DALA19	0.14	0.86	0.14	0.85	0	-0.01	0.14	0.86	0	0	0.14	0.86	0	0	0.14	0.86	0	0
DALA20	0.16	0.68	0.15	0.67	-0.01	-0.01	0.16	0.68	0	0	0.16	0.68	0	0	0.16	0.68	0	0
DALA21	0.16	0.84	0.16	0.83	0	-0.01	0.16	0.84	0	0	0.16	0.84	0	0	0.16	0.84	0	0
DALA22	0.11	1.13	0.11	1.04	0	-0.09	0.11	1.09	0	-0.04	0.11	1.16	0	0.03	0.1	1.17	-0.01	0.04
DALA23	0.15	1.1	0.16	1.01	0.01	-0.09	0.16	1.06	0.01	-0.04	0.15	1.13	0	0.03	0.14	1.15	-0.01	0.05
DALA24	0.45	0.83	0.46	0.74	0.01	-0.09	0.46	0.79	0.01	-0.04	0.44	0.85	-0.01	0.02	0.43	0.87	-0.02	0.04
DALA25	0.04	0.93	0.05	0.84	0.01	-0.09	0.05	0.89	0.01	-0.04	0.05	0.96	0.01	0.03	0.05	0.98	0.01	0.05
DALA26	0.29	1.82	0.28	1.73	-0.01	-0.09	0.29	1.78	0	-0.04	0.29	1.85	0	0.03	0.29	1.86	0	0.04
DALA27	0.22	1.81	0.21	1.72	-0.01	-0.09	0.22	1.77	0	-0.04	0.22	1.84	0	0.03	0.21	1.85	-0.01	0.04

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Results	Baseline 1:100 year AEP Event		Test 8a Results		Test 8a Results minus Baseline		Test 8b Results		Test 8b Results minus Baseline		Test 8c Results		Test 8c Results minus Baseline		Test 8d Results		Test 8d Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA28	0.03	0.08	0.02	0.05	-0.01	-0.03	0.02	0.07	-0.01	-0.01	0.03	0.09	0	0.01	0.03	0.09	0	0.01
DALA29	0.23	0.73	0.23	0.71	0	-0.02	0.22	0.72	-0.01	-0.01	0.23	0.74	0	0.01	0.23	0.75	0	0.02
DALA30	0.02	0.33	0.02	0.3	0	-0.03	0.02	0.32	0	-0.01	0.02	0.34	0	0.01	0.02	0.34	0	0.01
DALA31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DALA32	0.03	0.51	0.03	0.42	0	-0.09	0.03	0.47	0	-0.04	0.02	0.54	-0.01	0.03	0.03	0.55	0	0.04
DALA33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DALA34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DALA35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DALA36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DALA37	0.03	0.04	0.02	0.03	-0.01	-0.01	0.03	0.03	0	-0.01	0.03	0.04	0	0	0.02	0.03	-0.01	-0.01
DALA38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DALA39	0.03	0.54	0.03	0.46	0	-0.08	0.03	0.5	0	-0.04	0.03	0.57	0	0.03	0.03	0.59	0	0.05
DALA40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DALA41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DALA42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DALA43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DALA44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DALA45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DALA46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DALA47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DALA48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DALA49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DALA50	0.04	0.4	0.04	0.31	0	-0.09	0.04	0.36	0	-0.04	0.04	0.43	0	0.03	0.04	0.44	0	0.04

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Table 8.12b Sensitivity Tests 8e to h Summary Results – Peak Flood Depth (m) and difference compared to baseline for the 1:100 year AEP pluvial event

Results	Baseline 1:100 year AEP Pluvial event with 6 hour storm duration		Test 8e Results		Test 8e Results minus Baseline		Test 8f Results		Test 8f Results minus Baseline		Test 8g Results		Test 8g Results minus Baseline		Test 8h Results		Test 8h Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA1	0	1.66	0.01	1.65	0.01	-0.01	0.01	1.66	0.01	0	0.01	1.66	0.01	0	0.01	1.67	0.01	0.01
DALA2	0.01	1.81	0.01	1.81	0	0	0.01	1.81	0	0	0.01	1.81	0	0	0.01	1.81	0	0
DALA3	0.49	0.75	0.49	0.76	0	0.01	0.49	0.76	0	0.01	0.48	0.75	-0.01	0	0.33	0.75	-0.16	0
DALA4	0.06	0.74	0.06	0.75	0	0.01	0.06	0.74	0	0	0.06	0.73	0	-0.01	0.06	0.72	0	-0.02
DALA5	0.18	0.81	0.20	0.78	0.02	-0.03	0.2	0.8	0.02	-0.01	0.15	0.81	-0.03	0	0.12	0.81	-0.06	0
DALA6	0	2.09	0	2.09	0	0	0	2.1	0	0.01	0	2.1	0	0.01	0	2.09	0	0
DALA7	0.04	1.23	0.04	1.21	0	-0.02	0.04	1.22	0	-0.01	0.04	1.25	0	0.02	0.04	1.25	0	0.02
DALA8	0.01	0.82	0.02	0.82	0.01	0	0.02	0.82	0.01	0	0.01	0.82	0	0	0.01	0.82	0	0
DALA9	0.02	1.85	0.02	1.84	0	-0.01	0.02	1.83	0	-0.02	0.02	1.87	0	0.02	0.02	1.9	0	0.05
DALA10	0.08	0.06	0.09	0.08	0.01	0.02	0.08	0.07	0	0.01	0.08	0.05	0	-0.01	0.08	0.05	0	-0.01
DALA11	0.03	0	0.03	0	0	0	0.03	0	0	0	0.03	0	0	0	0.03	0	0	0
DALA12	0.13	0.01	0.14	0.01	0.01	0	0.14	0.01	0.01	0	0.13	0.01	0	0	0.13	0.01	0	0
DALA13	0.07	0	0.08	0.01	0.01	0.01	0.08	0.01	0.01	0.01	0.07	0	0	0	0.06	0	-0.01	0
DALA14	0.03	0.01	0.03	0.01	0	0	0.03	0.01	0	0	0.03	0.01	0	0	0.03	0.01	0	0
DALA15	0.01	0	0.04	0	0.03	0	0.04	0	0.03	0	0.04	0	0.03	0	0.02	0	0.01	0
DALA16	0.04	0	0.04	0	0	0	0.04	0	0	0	0.04	0	0	0	0.03	0	-0.01	0
DALA17	0.01	0	0.01	0	0	0	0.01	0	0	0	0.01	0	0	0	0	0	-0.01	0
DALA18	0.12	0.21	0.13	0.23	0.01	0.02	0.13	0.22	0.01	0.01	0.12	0.2	0	-0.01	0.11	0.2	-0.01	-0.01
DALA19	0.12	0.68	0.13	0.7	0.01	0.02	0.13	0.69	0.01	0.01	0.12	0.67	0	-0.01	0.12	0.66	0	-0.02
DALA20	0.08	0.5	0.09	0.51	0.01	0.01	0.08	0.51	0	0.01	0.08	0.49	0	-0.01	0.07	0.48	-0.01	-0.02
DALA21	0.14	0.66	0.15	0.68	0.01	0.02	0.14	0.67	0	0.01	0.14	0.65	0	-0.01	0.14	0.64	0	-0.02
DALA22	0.03	0.55	0.04	0.54	0.01	-0.01	0.03	0.55	0	0	0.03	0.55	0	0	0.02	0.55	-0.01	0
DALA23	0.02	0.53	0.03	0.52	0.01	-0.01	0.02	0.52	0	-0.01	0.02	0.52	0	-0.01	0.02	0.52	0	-0.01
DALA24	0.03	0.25	0.04	0.24	0.01	-0.01	0.04	0.25	0.01	0	0.03	0.25	0	0	0.03	0.25	0	0
DALA25	0.02	0.36	0.03	0.35	0.01	-0.01	0.03	0.35	0.01	-0.01	0.03	0.36	0.01	0	0.03	0.35	0.01	-0.01
DALA26	0.05	0.7	0.06	0.65	0.01	-0.05	0.05	0.68	0	-0.02	0.05	0.72	0	0.02	0.05	0.73	0	0.03
DALA27	0.01	0.69	0.02	0.64	0.01	-0.05	0.02	0.67	0.01	-0.02	0.02	0.71	0.01	0.02	0.01	0.72	0	0.03

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Results	Baseline 1:100 year AEP Pluvial event with 6 hour storm duration		Test 8e Results		Test 8e Results minus Baseline		Test 8f Results		Test 8f Results minus Baseline		Test 8g Results		Test 8g Results minus Baseline		Test 8h Results		Test 8h Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA28	0.03	0	0.03	0	0	0	0.03	0	0	0	0.03	0	0	0	0.03	0	0	0
DALA29	0.04	0.52	0.07	0.52	0.03	0	0.05	0.52	0.01	0	0.04	0.52	0	0	0.03	0.51	-0.01	-0.01
DALA30	0.09	0.11	0.13	0.11	0.04	0	0.11	0.11	0.02	0	0.08	0.11	-0.01	0	0.08	0.11	-0.01	0
DALA31	0.05	0	0.06	0	0.01	0	0.05	0	0	0	0.04	0	-0.01	0	0.04	0	-0.01	0
DALA32	0.03	0	0.04	0	0.01	0	0.04	0	0.01	0	0.03	0	0	0	0.03	0	0	0
DALA33	0.1	0.01	0.13	0.01	0.03	0	0.11	0.01	0.01	0	0.09	0.01	-0.01	0	0.09	0.01	-0.01	0
DALA34	0.06	0.03	0.07	0.03	0.01	0	0.06	0.03	0	0	0.05	0.02	-0.01	-0.01	0.05	0.02	-0.01	-0.01
DALA35	0.03	0	0.03	0	0	0	0.03	0	0	0	0.02	0	-0.01	0	0.02	0	-0.01	0
DALA36	0.06	0.01	0.07	0.01	0.01	0	0.07	0.01	0.01	0	0.06	0	0	-0.01	0.05	0	-0.01	-0.01
DALA37	0	0	0.01	0	0.01	0	0.01	0	0.01	0	0	0	0	0	0	0	0	0
DALA38	0.01	0	0.01	0	0	0	0.01	0	0	0	0.01	0	0	0	0.01	0	0	0
DALA39	0.05	0	0.06	0	0.01	0	0.05	0	0	0	0.04	0	-0.01	0	0.04	0	-0.01	0
DALA40	0.02	0	0.02	0	0	0	0.02	0	0	0	0.02	0	0	0	0.02	0	0	0
DALA41	0.17	0.01	0.20	0.01	0.03	0	0.19	0.01	0.02	0	0.16	0.01	-0.01	0	0.15	0.01	-0.02	0
DALA42	0.03	0	0.03	0	0	0	0.03	0	0	0	0.03	0	0	0	0.03	0	0	0
DALA43	0.02	0	0.03	0	0.01	0	0.02	0	0	0	0.02	0	0	0	0.02	0	0	0
DALA44	0.02	0	0.04	0	0.02	0	0.04	0	0.02	0	0.04	0	0.02	0	0.03	0	0.01	0
DALA45	0.14	2.67	0.14	2.67	0	0	0.14	2.67	0	0	0.14	2.69	0	0.02	0.14	2.69	0	0.02
DALA46	0.31	0.57	0.37	0.52	0.06	-0.05	0.33	0.55	0.02	-0.02	0.28	0.58	-0.03	0.01	0.27	0.59	-0.04	0.02
DALA47	0.05	0.64	0.06	0.59	0.01	-0.05	0.06	0.62	0.01	-0.02	0.05	0.65	0	0.01	0.04	0.66	-0.01	0.02
DALA48	0.03	0	0.04	0	0.01	0	0.03	0	0	0	0.03	0	0	0	0.02	0	-0.01	0
DALA49	0.02	0.02	0.02	0.02	0	0	0.02	0.02	0	0	0.02	0.02	0	0	0.02	0.02	0	0
DALA50	0.65	0.03	0.65	0.04	0	0.01	0.65	0.04	0	0.01	0.65	0.03	0	0	0.65	0.03	0	0

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This test has been completed by applying a winter profile to the fluvial hydrograph for the 1:100 year AEP (present day) event and a winter profile to the pluvial hyetograph for the 1% AEP (present day) event and running through the baseline 1D-2D fluvial and pluvial model respectively.

Modelled peak flood depths for the winter storm hydrograph Test 9a have been compared to the depths of the baseline 1:100 year AEP fluvial event (which used the summer profile) in Table 8.12a. The results show a decrease in flood depths at most locations. The decrease in flood depth is up to 29cm.

Modelled peak flood depths for the winter storm hyetograph Test 9b run have been compared to the depths of the baseline 1:100 year AEP pluvial event (summer profile) in Table 8.12b. The results show a mixed output with increases at some locations up to 4cm, and elsewhere decreases of up to 22cm. The exception to this occurs as a localised depression at DALA9 where an apparent increase of 27cm is observed however it is not considered to be significant because other monitoring points in this vicinity show a decrease in depth. The overall results for majority of site indicate that, the summer storm profile is critical.

Table 8.13a Sensitivity Test 9a Summary Results – Peak Flood Depth (m) and difference compared to baseline for the 1:100 year AEP fluvial event

Results ID	Baseline 1:100 year AEP event		Test 9a Results		Test 9a Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA1	0	1.23	0	1.17	0	-0.06
DALA2	0	1.21	0	1.16	0	-0.05
DALA3	0	0	0	0	0	0
DALA4	0	0.9	0	0.84	0	-0.06
DALA5	0.2	1.31	0.20	1.18	0	-0.13
DALA6	0	1.32	0	1.27	0	-0.05
DALA7	0	1.86	0	1.57	0	-0.29
DALA8	0	0.8	0	0.69	0	-0.11
DALA9	0	1.19	0	1.17	0	-0.02
DALA10	0.09	0.27	0.07	0.22	-0.02	-0.05
DALA11	0.03	0.06	0	0	-0.03	-0.06
DALA12	0.02	0.15	0.01	0.09	-0.01	-0.06
DALA13	0.01	0.02	0	0	-0.01	-0.02
DALA14	0	0	0	0	0	0
DALA15	0.11	0.12	0.07	0.07	-0.04	-0.05
DALA16	0.03	0.06	0.00	0.01	-0.03	-0.05

NOT PROTECTIVELY MARKED

NOT PROTECTIVELY MARKED

Results ID	Baseline 1:100 year AEP event		Test 9a Results		Test 9a Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA17	0.01	0.06	0.00	0.01	-0.01	-0.05
DALA18	0.2	0.4	0.16	0.35	-0.04	-0.05
DALA19	0.14	0.86	0.13	0.81	-0.01	-0.05
DALA20	0.16	0.68	0.12	0.63	-0.04	-0.05
DALA21	0.16	0.84	0.15	0.79	-0.01	-0.05
DALA22	0.11	1.13	0.08	0.89	-0.03	-0.24
DALA23	0.15	1.1	0.09	0.86	-0.06	-0.24
DALA24	0.45	0.83	0.34	0.59	-0.11	-0.24
DALA25	0.04	0.93	0.06	0.69	0.02	-0.24
DALA26	0.29	1.82	0.23	1.53	-0.06	-0.29
DALA27	0.22	1.81	0.16	1.52	-0.06	-0.29
DALA28	0.03	0.08	0	0	-0.03	-0.08
DALA29	0.23	0.73	0.23	0.63	0	-0.1
DALA30	0.02	0.33	0.02	0.23	0	-0.1
DALA31	0	0	0	0	0	0
DALA32	0.03	0.51	0.03	0.27	0	-0.24
DALA33	0	0	0	0	0	0
DALA34	0	0	0	0	0	0
DALA35	0	0	0	0	0	0
DALA36	0	0	0	0	0	0
DALA37	0.03	0.04	0	0	-0.03	-0.04
DALA38	0	0	0	0	0	0
DALA39	0.03	0.54	0.04	0.31	0.01	-0.23
DALA40	0	0	0	0	0	0
DALA41	0	0	0	0	0	0
DALA42	0	0	0	0	0	0
DALA43	0	0	0	0	0	0

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Results ID	Baseline 1:100 year AEP event		Test 9a Results		Test 9a Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA44	0	0	0	0	0	0
DALA45	0	0	0	0	0	0
DALA46	0	0	0	0	0	0
DALA47	0	0	0	0	0	0
DALA48	0	0	0	0	0	0
DALA49	0	0	0	0	0	0
DALA50	0.04	0.4	0.04	0.16	0	-0.24

Table 8.14b Sensitivity Test 9b Summary Results – Peak Flood Depth (m) and difference compared to baseline for the 1:100 year AEP pluvial event

Results ID	Baseline 1:100 year AEP Pluvial event with 6 hour storm duration		Test 9b Results		Test 9b Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA1	0	1.66	0.01	1.7	0.01	0.04
DALA2	0.01	1.81	0.01	1.82	0	0.01
DALA3	0.49	0.75	0.24	0.74	-0.25	-0.01
DALA4	0.06	0.74	0.06	0.67	0	-0.07
DALA5	0.18	0.81	0.17	0.65	-0.01	-0.16
DALA6	0	2.09	0	2.11	0	0.02
DALA7	0.04	1.23	0.04	1.17	0	-0.06
DALA8	0.01	0.82	0.01	0.79	0	-0.03
DALA9	0.02	1.85	0.02	2.12	0	0.27
DALA10	0.08	0.06	0.06	0	-0.02	-0.06
DALA11	0.03	0	0.03	0	0	0
DALA12	0.13	0.01	0.10	0	-0.03	-0.01
DALA13	0.07	0	0.04	0	-0.03	0
DALA14	0.03	0.01	0.02	0	-0.01	-0.01

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Results ID	Baseline 1:100 year AEP Pluvial event with 6 hour storm duration		Test 9b Results		Test 9b Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA15	0.01	0	0.01	0	0	0
DALA16	0.04	0	0.02	0	-0.02	0
DALA17	0.01	0	0.00	0	-0.01	0
DALA18	0.12	0.21	0.08	0.1	-0.04	-0.11
DALA19	0.12	0.68	0.12	0.57	0	-0.11
DALA20	0.08	0.5	0.07	0.39	-0.01	-0.11
DALA21	0.14	0.66	0.14	0.55	0	-0.11
DALA22	0.03	0.55	0.02	0.33	-0.01	-0.22
DALA23	0.02	0.53	0.01	0.31	-0.01	-0.22
DALA24	0.03	0.25	0.02	0.03	-0.01	-0.22
DALA25	0.02	0.36	0.02	0.14	0	-0.22
DALA26	0.05	0.7	0.05	0.54	0	-0.16
DALA27	0.01	0.69	0.01	0.53	0	-0.16
DALA28	0.03	0	0.03	0	0	0
DALA29	0.04	0.52	0.04	0.48	0	-0.04
DALA30	0.09	0.11	0.06	0.07	-0.03	-0.04
DALA31	0.05	0	0.02	0	-0.03	0
DALA32	0.03	0	0.03	0	0	0
DALA33	0.1	0.01	0.06	0.01	-0.04	0
DALA34	0.06	0.03	0.04	0.02	-0.02	-0.01
DALA35	0.03	0	0.02	0	-0.01	0
DALA36	0.06	0.01	0.03	0	-0.03	-0.01
DALA37	0	0	0.00	0	0	0
DALA38	0.01	0	0.01	0	0	0
DALA39	0.05	0	0.03	0	-0.02	0
DALA40	0.02	0	0.02	0	0	0
DALA41	0.17	0.01	0.10	0.01	-0.07	0

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Results ID	Baseline 1:100 year AEP Pluvial event with 6 hour storm duration		Test 9b Results		Test 9b Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA42	0.03	0	0.02	0	-0.01	0
DALA43	0.02	0	0.02	0	0	0
DALA44	0.02	0	0.03	0	0.01	0
DALA45	0.14	2.67	0.14	2.64	0	-0.03
DALA46	0.31	0.57	0.29	0.44	-0.02	-0.13
DALA47	0.05	0.64	0.05	0.51	0	-0.13
DALA48	0.03	0	0.02	0	-0.01	0
DALA49	0.02	0.02	0.01	0.01	-0.01	-0.01
DALA50	0.65	0.03	0.55	0.02	-0.1	-0.01

Test 10: Sensitivity testing of inlet and outlet loss units on the A5 culvert crossing

This test has been completed by incorporating inlet and outlet loss units for the A5 culvert into the existing fluvial hydrograph for the 1:100 year AEP (present day) and running the 1D-2D model.

Modelled peak flood depths for the loss units test increases flood depths slightly at locations upstream of the culvert crossing (up to a 3cm increase in flood depths is observed in the fluvial test) when compared to the depths of the baseline 1:100 year AEP fluvial event (Table 8.13). The absolute change in water level is comparatively small which demonstrates that the hydraulic model is not sensitive to this change and as such the model set up presented in Section 4 remains valid.

Table 8.15 Sensitivity Test 10 Summary Results – Peak Flood Depth (m) and difference compared to baseline for the 1:100 year AEP fluvial event

Results ID	Baseline 1:100 year AEP event		Test 10 Results		Test 10 Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA1	0	1.23	0	1.23	0	0
DALA2	0	1.21	0	1.22	0	0.01
DALA3	0	0	0	0	0	0
DALA4	0	0.9	0	0.9	0	0
DALA5	0.2	1.31	0.20	1.33	0	0.02
DALA6	0	1.32	0	1.33	0	0.01

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Results ID	Baseline 1:100 year AEP event		Test 10 Results		Test 10 Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA7	0	1.86	0	1.89	0	0.03
DALA8	0	0.8	0	0.8	0	0
DALA9	0	1.19	0	1.19	0	0
DALA10	0.09	0.27	0.09	0.28	0	0.01
DALA11	0.03	0.06	0.03	0.06	0	0
DALA12	0.02	0.15	0.02	0.15	0	0
DALA13	0.01	0.02	0.02	0.02	0.01	0
DALA14	0	0	0	0	0	0
DALA15	0.11	0.12	0.12	0.13	0.01	0.01
DALA16	0.03	0.06	0.04	0.07	0.01	0.01
DALA17	0.01	0.06	0.02	0.07	0.01	0.01
DALA18	0.2	0.4	0.20	0.41	0	0.01
DALA19	0.14	0.86	0.14	0.87	0	0.01
DALA20	0.16	0.68	0.16	0.69	0	0.01
DALA21	0.16	0.84	0.16	0.85	0	0.01
DALA22	0.11	1.13	0.11	1.16	0	0.03
DALA23	0.15	1.1	0.15	1.13	0	0.03
DALA24	0.45	0.83	0.46	0.86	0.01	0.03
DALA25	0.04	0.93	0.05	0.96	0.01	0.03
DALA26	0.29	1.82	0.30	1.85	0.01	0.03
DALA27	0.22	1.81	0.23	1.84	0.01	0.03
DALA28	0.03	0.08	0.03	0.08	0	0
DALA29	0.23	0.73	0.21	0.74	-0.02	0.01
DALA30	0.02	0.33	0.04	0.33	0.02	0
DALA31	0	0	0	0	0	0
DALA32	0.03	0.51	0.03	0.54	0	0.03
DALA33	0	0	0	0	0	0

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Results ID	Baseline 1:100 year AEP event		Test 10 Results		Test 10 Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA34	0	0	0	0	0	0
DALA35	0	0	0	0	0	0
DALA36	0	0	0	0	0	0
DALA37	0.03	0.04	0.03	0.04	0	0
DALA38	0	0	0	0	0	0
DALA39	0.03	0.54	0.03	0.57	0	0.03
DALA40	0	0	0	0	0	0
DALA41	0	0	0	0	0	0
DALA42	0	0	0	0	0	0
DALA43	0	0	0	0	0	0
DALA44	0	0	0	0	0	0
DALA45	0	0	0	0	0	0
DALA46	0	0	0	0	0	0
DALA47	0	0	0	0	0	0
DALA48	0	0	0	0	0	0
DALA49	0	0	0	0	0	0
DALA50	0.04	0.4	0.04	0.43	0	0.03

Test 11: Additional sensitivity testing of 1D roughness values

This test has been completed by applying a higher 1D roughness (0.07) across the 1:100 year AEP (present day) (Test 11a) and 1:100 year AEP with climate change and with development (Test 11b) 1D-2D models.

These tests are in addition to the testing performed in Tests 1 and 2, to explore the sensitivity of larger increases in roughness of the 1D model elements to represent very heavily vegetated unmaintained conditions.

The increase to the 1D roughness in the baseline model (Test 11a) has resulted in an increase in the modelled peak flood depths at a number of locations (by up to a 9cm) when compared to the depths of the baseline 1:100 year AEP fluvial event (Table 8.14a).

The increase to the 1D roughness in the development model (Test 11b) has resulted in an increase in the modelled peak flood depths at a number of locations (up to a 8cm) when compared to the depths of the development 1:100 year AEP fluvial event (Table 8.14b). The model is performing as expected under these more extreme roughness tests, (more extreme than the tests reported in Test 1 and 2), the results do not require changes to be made to the baseline model set up detailed in Section 4.

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Table 8.16a Sensitivity Test 11a Summary Results – Peak Flood Depth (m) and difference compared to baseline for the 1:100 year AEP fluvial event

Results ID	Baseline 1:100 year AEP event		Test 11a Results		Test 11a Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA1	0	1.23	0	1.24	0	0.01
DALA2	0	1.21	0	1.21	0	0
DALA3	0	0	0	0	0	0
DALA4	0	0.9	0	0.91	0	0.01
DALA5	0.2	1.31	0.22	1.32	0.02	0.01
DALA6	0	1.32	0	1.32	0	0
DALA7	0	1.86	0	1.87	0	0.01
DALA8	0	0.8	0	0.88	0	0.08
DALA9	0	1.19	0	1.2	0	0.01
DALA10	0.09	0.27	0.09	0.29	0	0.02
DALA11	0.03	0.06	0.02	0.07	-0.01	0.01
DALA12	0.02	0.15	0.02	0.16	0	0.01
DALA13	0.01	0.02	0.02	0.03	0.01	0.01
DALA14	0	0	0.06	0	0.06	0
DALA15	0.11	0.12	0.15	0.13	0.04	0.01
DALA16	0.03	0.06	0.02	0.07	-0.01	0.01
DALA17	0.01	0.06	0.02	0.06	0.01	0
DALA18	0.2	0.4	0.20	0.4	0	0
DALA19	0.14	0.86	0.15	0.86	0.01	0
DALA20	0.16	0.68	0.16	0.68	0	0
DALA21	0.16	0.84	0.21	0.84	0.05	0
DALA22	0.11	1.13	0.11	1.14	0	0.01
DALA23	0.15	1.1	0.16	1.11	0.01	0.01
DALA24	0.45	0.83	0.46	0.84	0.01	0.01
DALA25	0.04	0.93	0.05	0.94	0.01	0.01
DALA26	0.29	1.82	0.29	1.83	0	0.01

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Results ID	Baseline 1:100 year AEP event		Test 11a Results		Test 11a Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA27	0.22	1.81	0.22	1.82	0	0.01
DALA28	0.03	0.08	0.03	0.16	0	0.08
DALA29	0.23	0.73	0.22	0.82	-0.01	0.09
DALA30	0.02	0.33	0.02	0.41	0	0.08
DALA31	0	0	0	0	0	0
DALA32	0.03	0.51	0.03	0.52	0	0.01
DALA33	0	0	0	0	0	0
DALA34	0	0	0	0	0	0
DALA35	0	0	0	0	0	0
DALA36	0	0	0	0	0	0
DALA37	0.03	0.04	0.05	0.05	0.02	0.01
DALA38	0	0	0	0	0	0
DALA39	0.03	0.54	0.03	0.55	0	0.01
DALA40	0	0	0	0	0	0
DALA41	0	0	0	0	0	0
DALA42	0	0	0	0	0	0
DALA43	0	0	0	0	0	0
DALA44	0	0	0	0	0	0
DALA45	0	0	0	0	0	0
DALA46	0	0	0	0	0	0
DALA47	0	0	0	0	0	0
DALA48	0	0	0	0	0	0
DALA49	0	0	0	0	0	0
DALA50	0.04	0.4	0.04	0.41	0	0.01

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Table 8.17b Sensitivity Test 11b Summary Results – Peak Flood Depth (m) and difference compared to development for the 1:100 year AEP (plus climate change) fluvial event

Results ID	Mitigation 1:100 year AEP event		Test 11b Results		Test 11b Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA1	0	1.26	0	1.26	0	0
DALA2	0.36	1.21	0.38	1.21	0.02	0
DALA3	0	0	0	0	0	0
DALA4	0	0.79	0	0.8	0	0.01
DALA5	0.29	1.35	0.28	1.35	-0.01	0
DALA6	0	1.26	0	1.26	0	0
DALA7	0	1.73	0	1.74	0	0.01
DALA8	0	0.74	0	0.82	0	0.08
DALA9	0	1.19	0	1.19	0	0
DALA10	0.07	0.17	0.08	0.18	0.01	0.01
DALA11	0	0	0	0	0	0
DALA12	0.1	1.27	0.12	1.27	0.02	0
DALA13	0.08	1.27	0.09	1.27	0.01	0
DALA14	0.09	1.27	0.09	1.27	0	0
DALA15	0.02	0.06	0.04	0.07	0.02	0.01
DALA16	0.77	1.26	0.48	1.26	-0.29	0
DALA17	0.19	0.02	0.28	0.03	0.09	0.01
DALA18	0.45	0.34	0.45	0.34	0	0
DALA19	0.13	0.8	0.14	0.81	0.01	0.01
DALA20	0.13	0.62	0.14	0.62	0.01	0
DALA21	0.12	0.78	0.21	0.78	0.09	0
DALA22	0.12	0.99	0.11	1.01	-0.01	0.02
DALA23	0.13	0.98	0.13	1	0	0.02
DALA24	0.17	0.98	0.17	1	0	0.02
DALA25	0.28	0.99	0.28	1	0	0.01
DALA26	0.29	1.68	0.30	1.7	0.01	0.02

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Results ID	Mitigation 1:100 year AEP event		Test 11b Results		Test 11b Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA27	0.22	1.67	0.22	1.69	0	0.02
DALA28	0.02	0.03	0.03	0.1	0.01	0.07
DALA29	0.19	0.68	0.23	0.76	0.04	0.08
DALA30	0.02	0.28	0.02	0.35	0	0.07
DALA31	0	0	0	0	0	0
DALA32	0.09	0.03	0.10	0.04	0.01	0.01
DALA33	0	0	0	0	0	0
DALA34	0	0	0	0	0	0
DALA35	0	0	0	0	0	0
DALA36	0	0	0	0	0	0
DALA37	0.07	1.26	0.07	1.26	0	0
DALA38	0	0	0	0	0	0
DALA39	0.1	0.03	0.10	0.04	0	0.01
DALA40	0.27	0.06	0.29	0.06	0.02	0
DALA41	0	0	0	0	0	0
DALA42	0.22	1.24	0.22	1.25	0	0.01
DALA43	0.19	1.24	0.19	1.25	0	0.01
DALA44	0.22	1.24	0.21	1.25	-0.01	0.01
DALA45	0	0	0	0	0	0
DALA46	0	0	0	0	0	0
DALA47	0	0	0	0	0	0
DALA48	0	0	0	0	0	0
DALA49	0	0	0	0	0	0
DALA50	0.06	0.27	0.06	0.28	0	0.01

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Test 12: Additional sensitivity testing to synchronising of pluvial and fluvial inflow domains

In Section 3 of this report the hydrological assessment presents the pluvial hydrology estimates being paired with a fluvial baseflow. In this test the effect of pairing the pluvial storm with the fluvial flow that would be representative of the same storm is investigated – essentially testing the sensitivity of the pluvial predictions to higher river flows. The test was conducted by generating additional fluvial hydrographs for the 1:30 year AEP and 1:100 year AEP (present day) events for a 6 hour storm (the equivalent critical pluvial storm duration presented in Section 3) and running these hydrographs combined with the equivalent pluvial hyetograph (for the same event) through the baseline 1D-2D model. Double counting of inflows was avoided by ensuring that the fluvial inflows for each storm were only calculated for the area of the catchment outside of the domain where rainfall was directly applied in InfoWorks.

Modelled peak flood depths in this test, in the 1:100 year AEP event (Test 12a), are higher than the baseline at a large number of locations (generally up to a 20cm increase in depth) when compared to the depths of the baseline 1:100 year AEP pluvial event (Table 8.15a). There are isolated large increases in depth, such as at DALA26 and DALA27, which show a 0.97m increase in flood depth. The increased flood volume causes overtopping of the A5, filling the area between the A5 and A55. Results points DALA26 and DALA27 are located in the localised ponds situated between the A55 and A5, and so the very large increase in depth is considered to be due to low spots in the topography representing the ponds. Large increases up to 0.43m in depth are also seen at DALA22 to DALA25 in the vicinity of the channel located at the upstream end of the A5 culvert. The higher depths are caused by the backing up of flow behind the A5 and A55 culverts. These increases are attributed to the high water in the channels applied as 1D flow component to study a worst case scenario when stream channel is already swollen and the rainfall is added to 2D grids.

Modelled peak flood depths in this test, in the 1:30 year AEP event (Test 12b), are higher than the baseline at the same locations identified in Test 12a. The comparison is presented in (Table 8.15b). The same mechanisms of overtopping of the A5, and subsequent backing up at the A5 and A55 culverts causes increases of around 0.57m at DALA22-25, and up to 0.82m at the DALA26 and DALA27 ponds.

These increases indicate that the model is behaving appropriately in response to the increased fluvial flow contribution being applied at the fluvial boundary, compared to the baseflow applied in the baseline.

Table 8.18a Sensitivity Test 12a Summary Results – Peak Flood Depth (m) and difference compared to baseline for the 1:100 year AEP pluvial event

Results ID	Baseline 1:100 year AEP Pluvial event with 6 hour storm duration		Test 12a Results		Test 12a Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA1	0	1.66	0	1.64	0	-0.02
DALA2	0.01	1.81	0.01	1.77	0	-0.04
DALA3	0.49	0.75	0.49	0.75	0	0
DALA4	0.06	0.74	0.06	0.87	0	0.13
DALA5	0.18	0.81	0.18	1.19	0	0.38
DALA6	0	2.09	0	2.02	0	-0.07
DALA7	0.04	1.23	0.04	1.72	0	0.49
DALA8	0.01	0.82	0.01	0.83	0	0.01
DALA9	0.02	1.85	0.02	1.87	0	0.02

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Results ID	Baseline 1:100 year AEP Pluvial event with 6 hour storm duration		Test 12a Results		Test 12a Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA10	0.08	0.06	0.08	0.22	0	0.16
DALA11	0.03	0	0.03	0.01	0	0.01
DALA12	0.13	0.01	0.13	0.1	0	0.09
DALA13	0.07	0	0.07	0	0	0
DALA14	0.03	0.01	0.03	0.01	0	0
DALA15	0.01	0	0.08	0.08	0.07	0.08
DALA16	0.04	0	0.04	0.02	0	0.02
DALA17	0.01	0	0.01	0.01	0	0.01
DALA18	0.12	0.21	0.17	0.35	0.05	0.14
DALA19	0.12	0.68	0.12	0.81	0	0.13
DALA20	0.08	0.5	0.12	0.63	0.04	0.13
DALA21	0.14	0.66	0.15	0.79	0.01	0.13
DALA22	0.03	0.55	0.04	0.98	0.01	0.43
DALA23	0.02	0.53	0.07	0.96	0.05	0.43
DALA24	0.03	0.25	0.04	0.68	0.01	0.43
DALA25	0.02	0.36	0.02	0.79	0	0.43
DALA26	0.05	0.7	0.05	1.67	0	0.97
DALA27	0.01	0.69	0.10	1.66	0.09	0.97
DALA28	0.03	0	0.03	0.04	0	0.04
DALA29	0.04	0.52	0.04	0.69	0	0.17
DALA30	0.09	0.11	0.09	0.29	0	0.18
DALA31	0.05	0	0.05	0	0	0
DALA32	0.03	0	0.03	0.37	0	0.37
DALA33	0.1	0.01	0.10	0.01	0	0
DALA34	0.06	0.03	0.06	0.03	0	0
DALA35	0.03	0	0.03	0	0	0
DALA36	0.06	0.01	0.06	0.01	0	0
DALA37	0	0	0.00	0	0	0
DALA38	0.01	0	0.01	0	0	0
DALA39	0.05	0	0.05	0.4	0	0.4
DALA40	0.02	0	0.02	0	0	0
DALA41	0.17	0.01	0.17	0.01	0	0
DALA42	0.03	0	0.03	0	0	0

NOT PROTECTIVELY MARKED

NOT PROTECTIVELY MARKED

Results ID	Baseline 1:100 year AEP Pluvial event with 6 hour storm duration		Test 12a Results		Test 12a Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA43	0.02	0	0.02	0	0	0
DALA44	0.02	0	0.02	0	0	0
DALA45	0.14	2.67	0.14	2.68	0	0.01
DALA46	0.31	0.57	0.31	0.57	0	0
DALA47	0.05	0.64	0.05	0.64	0	0
DALA48	0.03	0	0.03	0	0	0
DALA49	0.02	0.02	0.02	0.02	0	0
DALA50	0.65	0.03	0.65	0.26	0	0.23

Table 8.19b Sensitivity Test 12b Summary Results – Peak Flood Depth (m) and difference compared to baseline for the 1:30 year AEP pluvial event

Results ID	Baseline 1:30 year AEP Pluvial event with 6 hour storm duration		Test 12b Results		Test 12b Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA1	0.01	1.68	0.01	1.64	0	-0.04
DALA2	0.01	1.81	0.01	1.77	0	-0.04
DALA3	0.29	0.73	0.29	0.73	0	0
DALA4	0.06	0.66	0.06	0.8	0	0.14
DALA5	0.19	0.63	0.19	1.07	0	0.44
DALA6	0	2.1	0	2.02	0	-0.08
DALA7	0.04	1.15	0.04	1.35	0	0.2
DALA8	0.01	0.79	0.01	0.79	0	0
DALA9	0.02	2.09	0.02	1.85	0	-0.24
DALA10	0.07	0	0.07	0.15	0	0.15
DALA11	0.03	0	0.03	0	0	0
DALA12	0.12	0.01	0.12	0.02	0	0.01
DALA13	0.05	0	0.05	0	0	0
DALA14	0.02	0	0.02	0	0	0
DALA15	0.04	0	0.06	0.02	0.02	0.02
DALA16	0.03	0	0.03	0	0	0
DALA17	0.01	0	0.01	0	0	0

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Results ID	Baseline 1:30 year AEP Pluvial event with 6 hour storm duration		Test 12b Results		Test 12b Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA18	0.08	0.09	0.13	0.29	0.05	0.2
DALA19	0.12	0.56	0.13	0.76	0.01	0.2
DALA20	0.07	0.38	0.08	0.57	0.01	0.19
DALA21	0.14	0.54	0.15	0.74	0.01	0.2
DALA22	0.03	0.3	0.04	0.86	0.01	0.56
DALA23	0.02	0.27	0.05	0.84	0.03	0.57
DALA24	0.03	0	0.04	0.56	0.01	0.56
DALA25	0.03	0.1	0.03	0.67	0	0.57
DALA26	0.05	0.49	0.05	1.31	0	0.82
DALA27	0.02	0.48	0.03	1.3	0.01	0.82
DALA28	0.03	0	0.03	0	0	0
DALA29	0.04	0.47	0.04	0.48	0	0.01
DALA30	0.07	0.06	0.07	0.07	0	0.01
DALA31	0.03	0	0.03	0	0	0
DALA32	0.03	0	0.03	0.24	0	0.24
DALA33	0.08	0.01	0.08	0.01	0	0
DALA34	0.04	0.02	0.04	0.02	0	0
DALA35	0.02	0	0.02	0	0	0
DALA36	0.04	0	0.04	0	0	0
DALA37	0	0	0.00	0	0	0
DALA38	0.01	0	0.01	0	0	0
DALA39	0.04	0	0.04	0.28	0	0.28
DALA40	0.02	0	0.02	0	0	0
DALA41	0.13	0.01	0.13	0.01	0	0
DALA42	0.03	0	0.03	0	0	0
DALA43	0.02	0	0.02	0	0	0
DALA44	0.04	0	0.04	0	0	0
DALA45	0.14	2.64	0.14	2.64	0	0
DALA46	0.32	0.4	0.32	0.4	0	0
DALA47	0.05	0.47	0.05	0.47	0	0
DALA48	0.02	0	0.02	0	0	0
DALA49	0.01	0.01	0.01	0.01	0	0
DALA50	0.63	0.03	0.63	0.13	0	0.1

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NOT PROTECTIVELY MARKED**Test 13: Distribution of Inflows within the model**

This test has been completed by applying the existing fluvial hydrograph for the 1:100 year AEP (present day) event laterally along the watercourse and running this revised set-up through the baseline 1D-2D model. The lateral distribution of flows has been proportioned along the channel reach based on contributing catchment area. In the baseline simulation (as reported in section 5.2), 100% of the inflow was applied upstream of A5 and in this distribution approach, that proportion is 62 %. This adds confidence to a reasonable conservatism applied in the baseline simulation.

Modelled peak flood depths for the change in the distribution of inflows test decreases flood depth at a large number of locations (up to a 45cm reduction in flood depths) when compared to the depths of the baseline 1:100 year AEP fluvial event (Table 8.20).

Table 8.20 Sensitivity Test 13 Summary Results – Peak Flood Depth (m) and difference compared to baseline for the 1:100 year AEP fluvial event

Results ID	Baseline 1:100 year AEP event		Test 13 Results		Test 13 Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA1	0	1.23	0	1.12	0	-0.11
DALA2	0	1.21	0	1.13	0	-0.08
DALA3	0	0	0	0	0	0
DALA4	0	0.9	0	0.79	0	-0.11
DALA5	0.2	1.31	0.18	1.18	-0.02	-0.13
DALA6	0	1.32	0	1.24	0	-0.08
DALA7	0	1.86	0	1.41	0	-0.45
DALA8	0	0.8	0	0.77	0	-0.03
DALA9	0	1.19	0	1.14	0	-0.05
DALA10	0.09	0.27	0.07	0.17	-0.02	-0.1
DALA11	0.03	0.06	0	0	-0.03	-0.06
DALA12	0.02	0.15	0.01	0.04	-0.01	-0.11
DALA13	0.01	0.02	0	0	-0.01	-0.02
DALA14	0	0	0	0	0	0
DALA15	0.11	0.12	0.06	0.04	-0.05	-0.08
DALA16	0.03	0.06	0	0	-0.03	-0.06
DALA17	0.01	0.06	0	0	-0.01	-0.06
DALA18	0.2	0.4	0.15	0.31	-0.05	-0.09
DALA19	0.14	0.86	0.13	0.78	-0.01	-0.08
DALA20	0.16	0.68	0.10	0.6	-0.06	-0.08
DALA21	0.16	0.84	0.16	0.76	0	-0.08
DALA22	0.11	1.13	0.06	0.87	-0.05	-0.26
DALA23	0.15	1.1	0.07	0.84	-0.08	-0.26

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Results ID	Baseline 1:100 year AEP event		Test 13 Results		Test 13 Results minus Baseline	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
DALA24	0.45	0.83	0.27	0.57	-0.18	-0.26
DALA25	0.04	0.93	0.04	0.67	0	-0.26
DALA26	0.29	1.82	0.16	1.37	-0.13	-0.45
DALA27	0.22	1.81	0.10	1.36	-0.12	-0.45
DALA28	0.03	0.08	0.03	0.05	0	-0.03
DALA29	0.23	0.73	0.24	0.71	0.01	-0.02
DALA30	0.02	0.33	0.03	0.3	0.01	-0.03
DALA31	0	0	0	0	0	0
DALA32	0.03	0.51	0.02	0.25	-0.01	-0.26
DALA33	0	0	0	0	0	0
DALA34	0	0	0	0	0	0
DALA35	0	0	0	0	0	0
DALA36	0	0	0	0	0	0
DALA37	0.03	0.04	0	0	-0.03	-0.04
DALA38	0	0	0	0	0	0
DALA39	0.03	0.54	0.02	0.28	-0.01	-0.26
DALA40	0	0	0	0	0	0
DALA41	0	0	0	0	0	0
DALA42	0	0	0	0	0	0
DALA43	0	0	0	0	0	0
DALA44	0	0	0	0	0	0
DALA45	0	0	0	0	0	0
DALA46	0	0	0	0	0	0
DALA47	0	0	0	0	0	0
DALA48	0	0	0	0	0	0
DALA49	0	0	0	0	0	0
DALA50	0.04	0.4	0.03	0.14	-0.01	-0.26

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8.3 Sensitivity test conclusions

Sensitivity Testing (Tests 1 – 6)

Summary results for the sensitivity tests undertaken indicate the model is responding appropriately and as expected to the sensitivity tests, with water level differences proportionate to the existing hazard, thus not causing a significant impact on flood results in the study area. It is therefore concluded that the roughness values taken as typical for the channel vegetation condition and surrounding area, and the downstream boundary adopted for the hydraulic model are appropriate.

Blockage sensitivity testing indicate an increase in water levels on site of up to 0.14m corresponding to a worst case of 95% culvert blockage scenario.

Sensitivity Testing (Tests 7 – 13)

These additional sensitivity tests were performed to provide greater granularity to the existing testing undertaken in the Rev0.1 report. The tests were carried out to add information and model sensitivity to a range of storm duration, seasonal criticality, change of roughness, inclusion of inlet and outlet loss units and distribution of inflows etc. The results in these additional sensitivity tests add confidence and support the selection of parameters and approaches detailed in Section 4 of the report.

The results show minimal changes in flood depths and confirms the criticality of the reported storm duration and seasonal rainfall profile in Section 3. The tests also show that the model results at the development site are not sensitive to the change in downstream boundary slope. The performance of model is reasonably sensitive to a blockage of culvert crossing under the A5, but that does not require the baseline model set up reported in Section 4 to be modified. When the fluvial hydrograph is applied as a distributed inflow hydrograph (rather than the 'lumped approach'), the flood depths are predicted to decrease at the development site giving a confidence that the model results presented in Sections 6 and 7 are conservative.

The test results with the separation of pluvial and fluvial zones represents a pluvial scenario when there is already high fluvial flow causing floodplain flooding (Test 12a). The average depths are higher by about 15cm when compared it with 1:100 AEP baseline fluvial simulation results in the vicinity of channel and at the local ditch south of the A5. At other monitoring locations, the results are higher. The results are as expected for the local ditches and near-channel banks where localised depressions are located. The majority of monitoring point/lines results show that the impact is not significant by the pluvial/fluvial zone separation.

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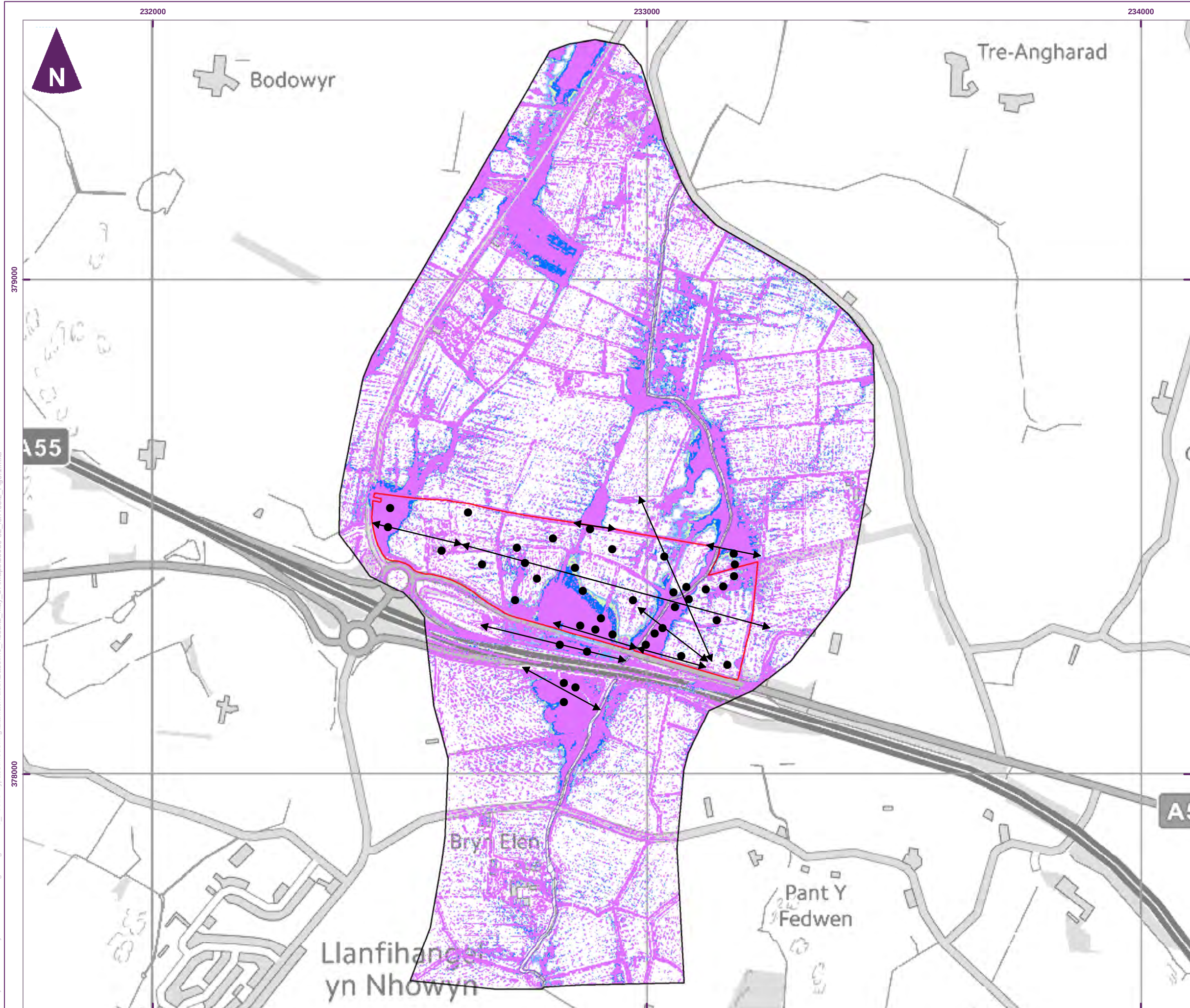
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Key

**Baseline puvial
Peak flood extents (>0.01m depth)**

1:30 Year AEP

1:100 year AEP

1:100 year AEP - plus
20% climate change

1:100 year AEP - plus
40% climate change

1:1000 year AEP

Model boundary

1D Model Domain

Site Boundary

Results Point

Results Line

OS Mapping

0100200300400 m

Scale at A3

Wylfa Newydd
Associated
Developments
Hydraulic Modelling



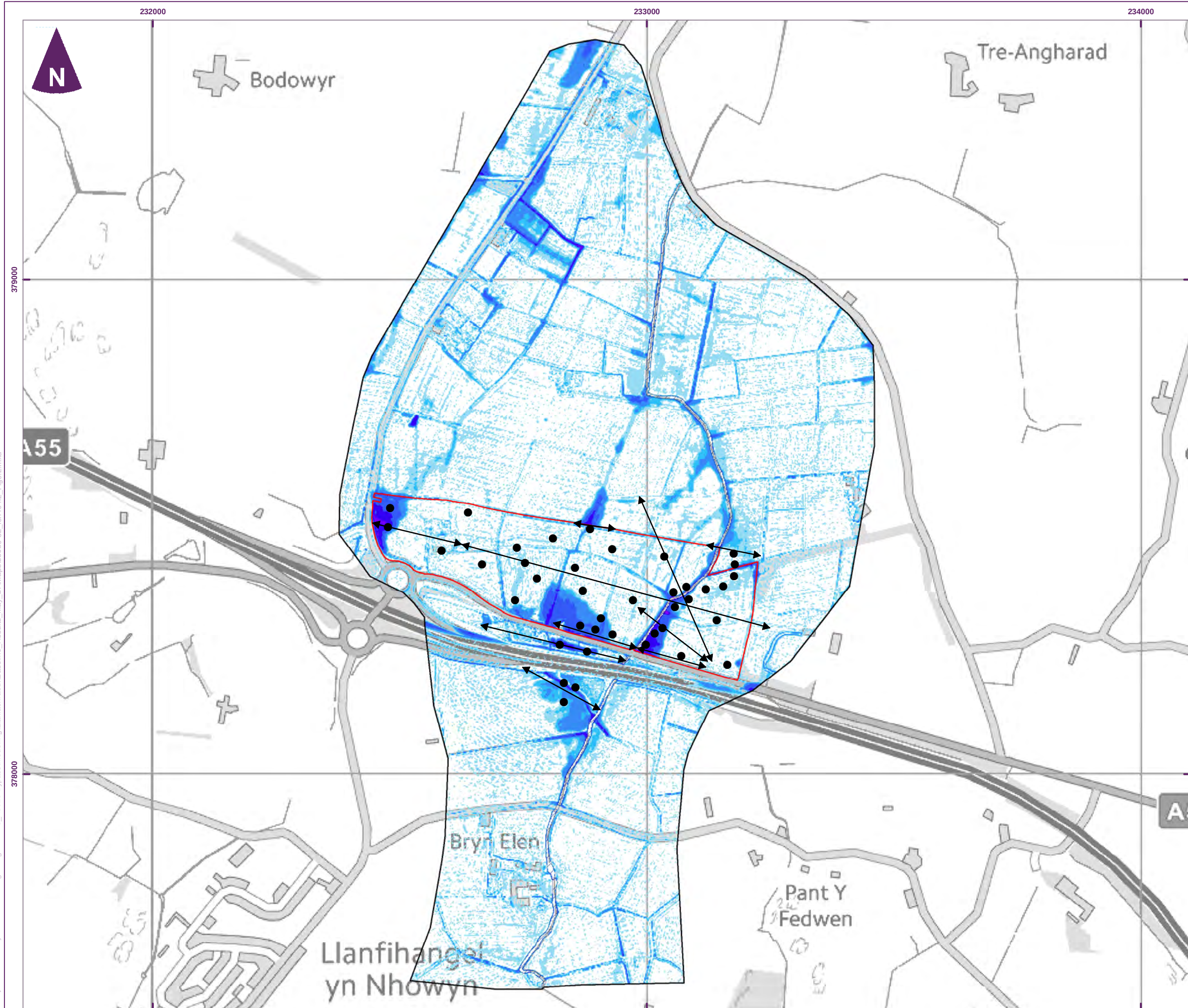
Figure 6.1
Dalar Hir baseline peak pluvial flood
extents

May 2017

35989_Lon463i2_jamek

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Key

Peak flood depth (m)
Baseline
1:30 year AEP pluvial
Present day

0.01 - 0.05
0.05 - 0.10
0.10 - 0.25
0.25 - 0.50
0.50 - 0.75
0.75 - 1.00
1.00 - 1.50
1.50 - 2.00
> 2.00

Model boundary
1D Model Domain
Site Boundary
Results Point
Results Line
OS Mapping

Notes:
The depths represent the maximum depth achieved. The flood prediction does not represent a moment in time as maximum depths can be achieved at different times.
Model run date: 22/04/2017
Corresponding data: 35989-C1338_Base_Pluvial_R30_360m.xlsx

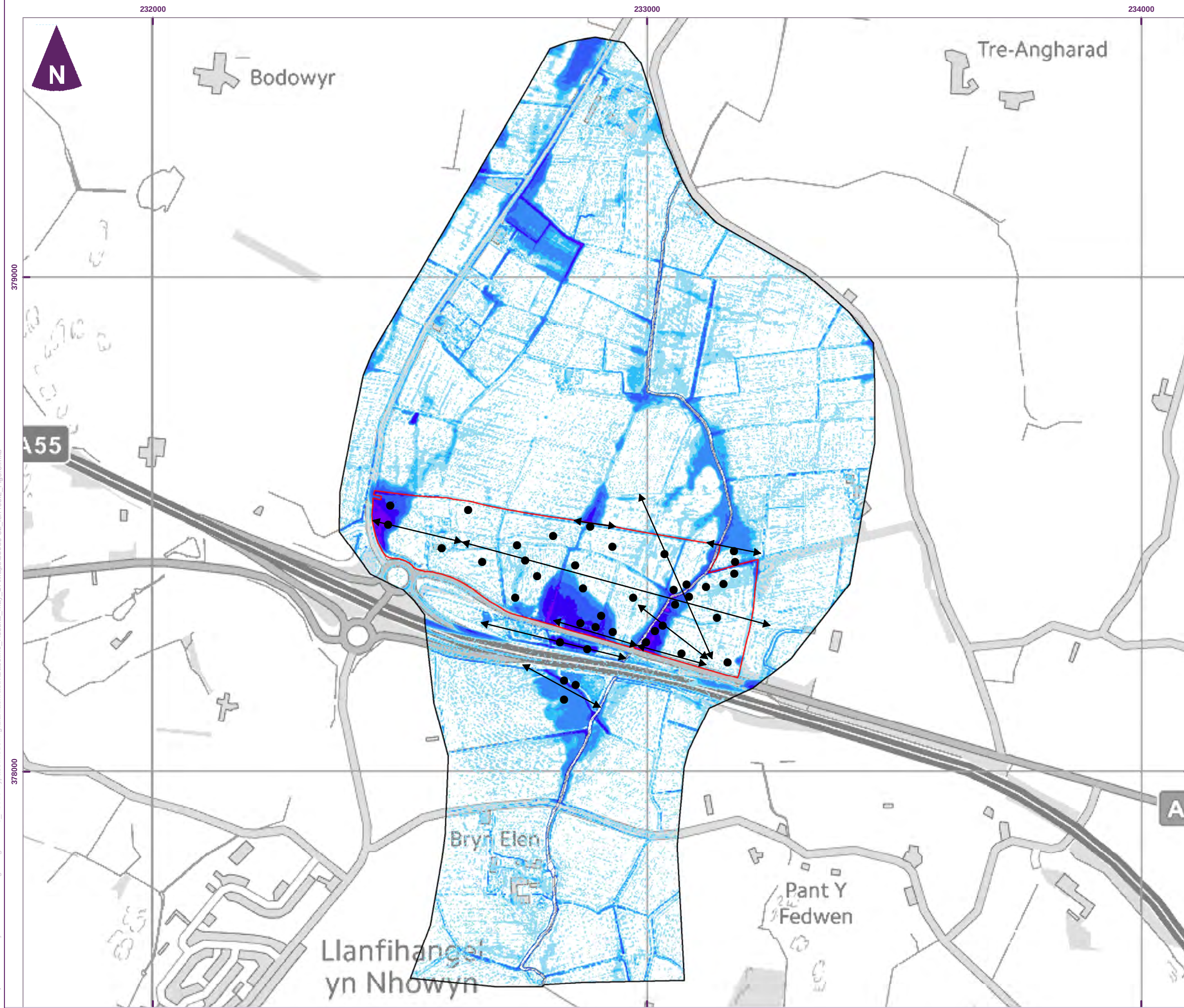
0 100 200 300 400 m
Scale at A3

Wylfa Newydd
Associated
Developments
Hydraulic Modelling

amec
foster
wheeler

Figure 6.2
Dalar Hir baseline peak pluvial flood
depth 1:30 year AEP present day (6
hour storm event)

May 2017 35989_Lon464i2 jamek



Key

Peak flood depth (m)
Baseline
1:100 year AEP pluvial
Present day

0.01 - 0.05
0.05 - 0.10
0.10 - 0.25
0.25 - 0.50
0.50 - 0.75
0.75 - 1.00
1.00 - 1.50
1.50 - 2.00
> 2.00

Model boundary
1D Model Domain
Site Boundary
Results Point
Results Line
OS Mapping

Notes:
The depths represent the maximum depth achieved. The flood prediction does not represent a moment in time as maximum depths can be achieved at different times.
Model run date: 22/04/2017
Corresponding data: 35989-C1339_Base_Pluvial_R100_360m.xlsx

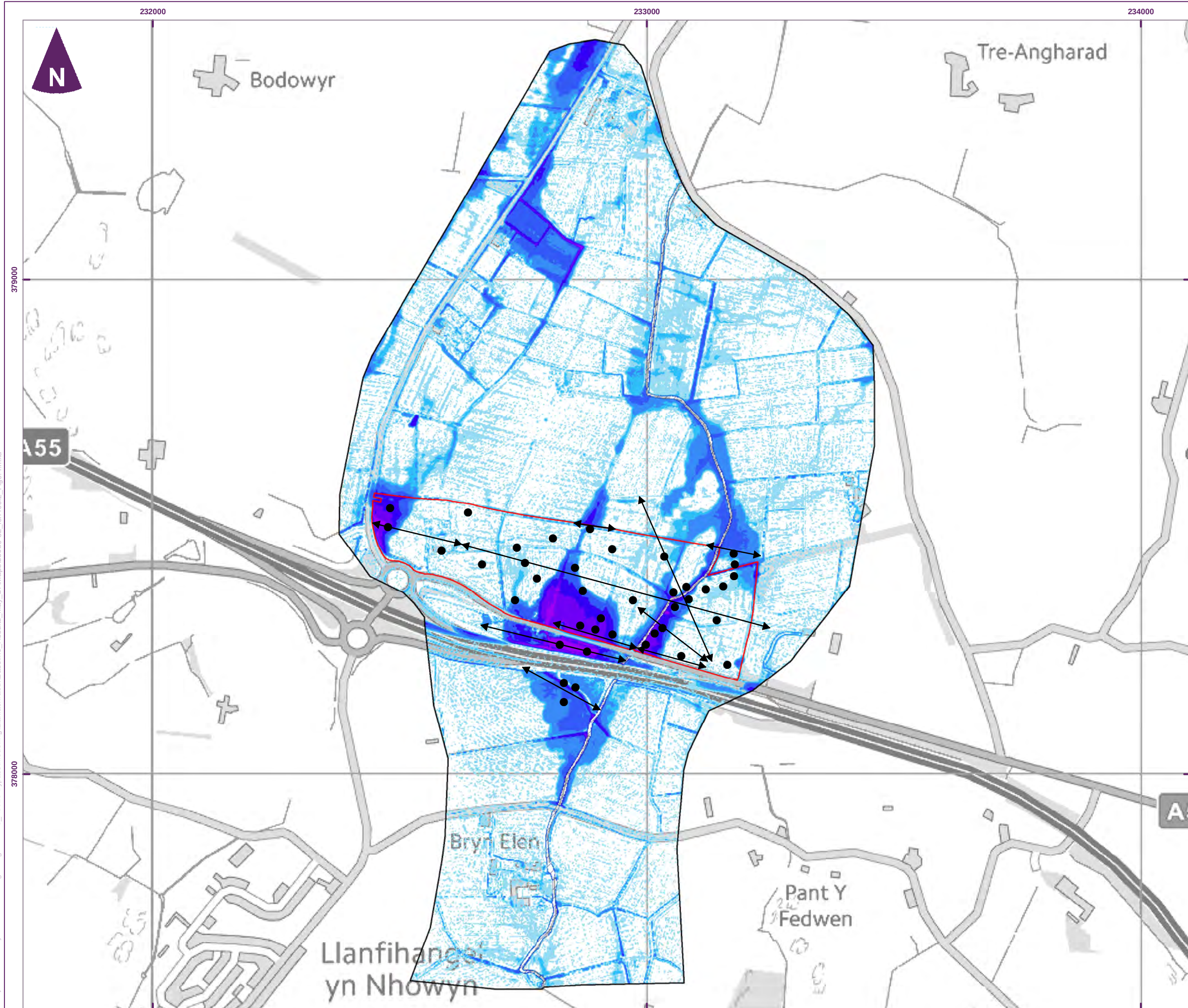
0 100 200 300 400 m
Scale at A3

Wylfa Newydd
Associated
Developments
Hydraulic Modelling

amec
foster
wheeler

Figure 6.3
Dalar Hir baseline peak pluvial flood
depth 1:100 year AEP present day (6
hour storm event)

May 2017 35989_Lon465i2_jamek



Key

Peak flood depth (m)
Baseline
1:1000 year AEP pluvial
Present day

0.01 - 0.05
0.05 - 0.10
0.10 - 0.25
0.25 - 0.50
0.50 - 0.75
0.75 - 1.00
1.00 - 1.50
1.50 - 2.00
> 2.00

Model boundary
1D Model Domain
Site Boundary
Results Point
Results Line
OS Mapping

Notes:
The depths represent the maximum depth achieved. The flood prediction does not represent a moment in time as maximum depths can be achieved at different times.
Model run date: 22/04/2017
Corresponding data: 35989-C1340_Base_Pluvial_R1000_360m.xlsx

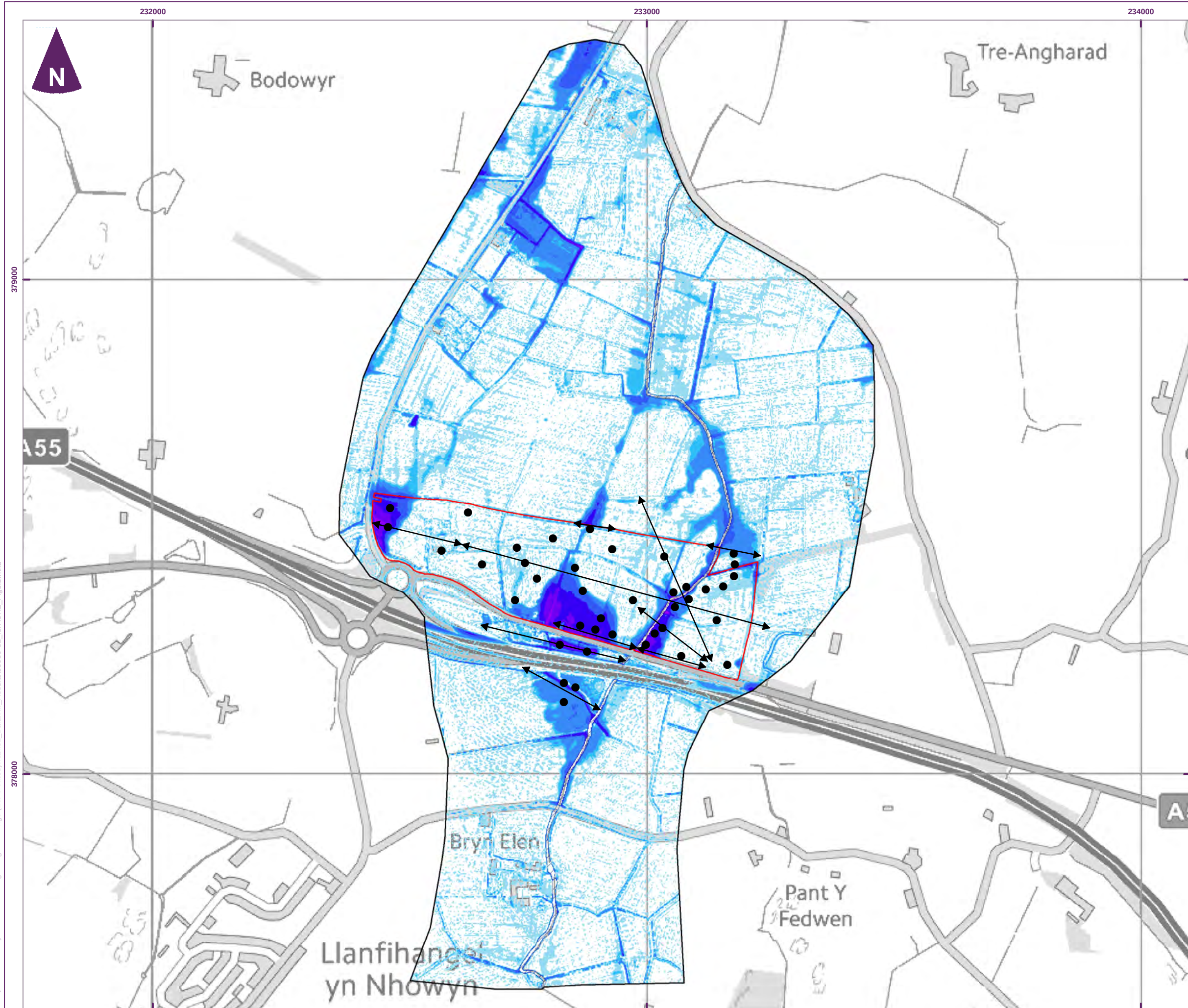
0 100 200 300 400 m
Scale at A3

Wylfa Newydd
Associated
Developments
Hydraulic Modelling

amec
foster
wheeler

Figure 6.4
Dalar Hir baseline peak pluvial flood
depth 1:1000 year AEP present day
(6 hour storm event)

May 2017 35989_Lon466i2 jamek



Key

Peak flood depth (m)
Baseline
1:100 year AEP pluvial
Climate change (20%)

0.01 - 0.05
0.05 - 0.10
0.10 - 0.25
0.25 - 0.50
0.50 - 0.75
0.75 - 1.00
1.00 - 1.50
1.50 - 2.00
> 2.00

Model boundary
1D Model Domain
Site Boundary
Results Point
Results Line
OS Mapping

Notes:
The depths represent the maximum depth achieved. The flood prediction does not represent a moment in time as maximum depths can be achieved at different times.
Model run date: 22/04/2017
Corresponding data:
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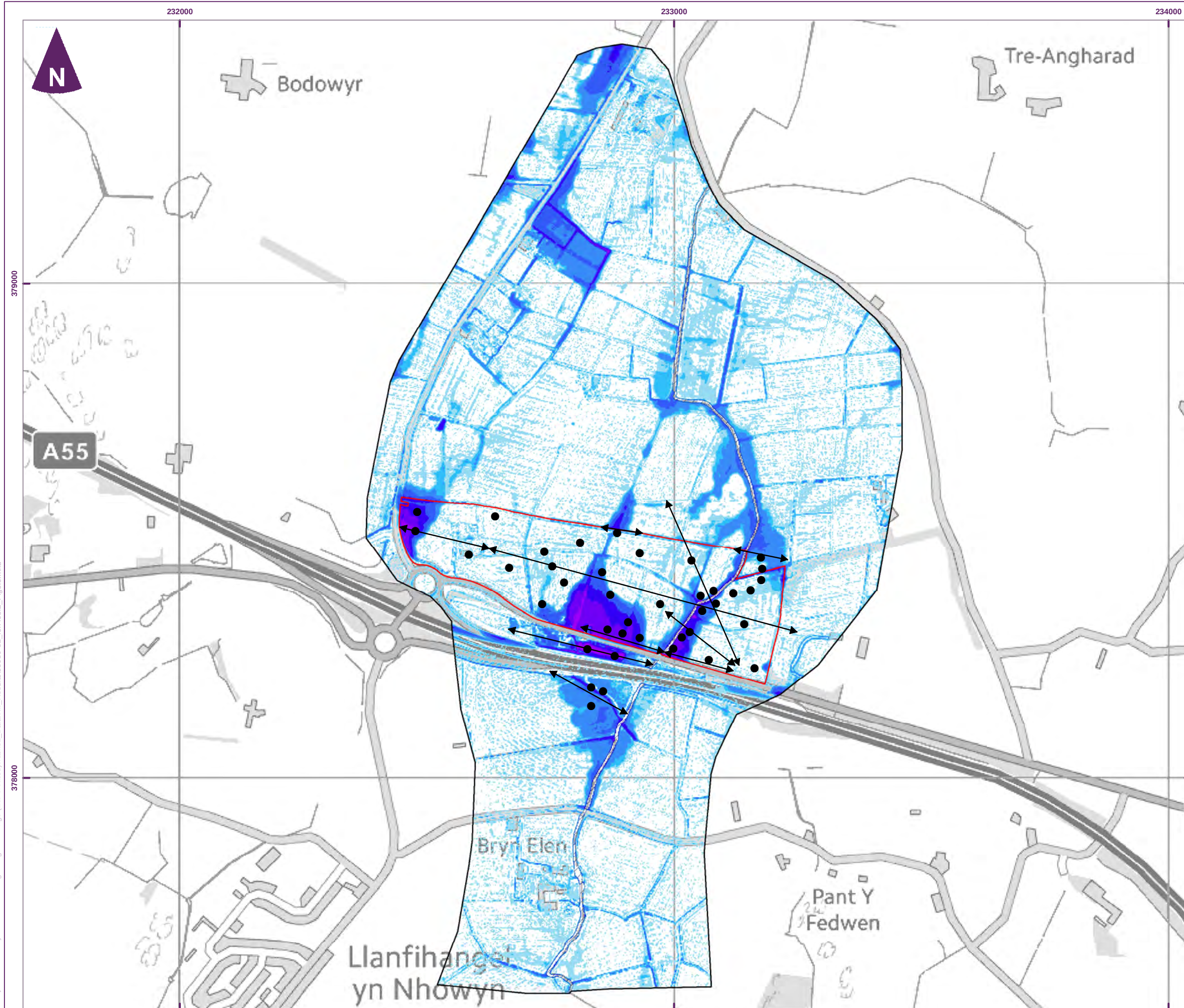
0 100 200 300 400 m
Scale at A3

Wylfa Newydd
Associated
Developments
Hydraulic Modelling

amec
foster
wheeler

Figure 6.5
Dalar Hir baseline peak pluvial flood
depth 1:100 year AEP (6 hour storm
event) plus climate change (20%)

May 2017 35989_Lon46712 jamek



Key

Peak flood depth (m)
Baseline
1:100 year AEP pluvial
Climate change (40%)

0.01 - 0.05
0.05 - 0.10
0.10 - 0.25
0.25 - 0.50
0.50 - 0.75
0.75 - 1.00
1.00 - 1.50
1.50 - 2.00
> 2.00

- Model boundary
- 1D Model Domain
- Site Boundary
- Results Point
- Results Line
- OS Mapping

Notes:
 The depths represent the maximum depth achieved. The flood prediction does not represent a moment in time as maximum depths can be achieved at different times.

Model run date: 22/04/2017
 Corresponding data:
 35989-C1342_Base_Pluvial_R100cc_360m.xlsx

0 100 200 300 400 m
 Scale at A3

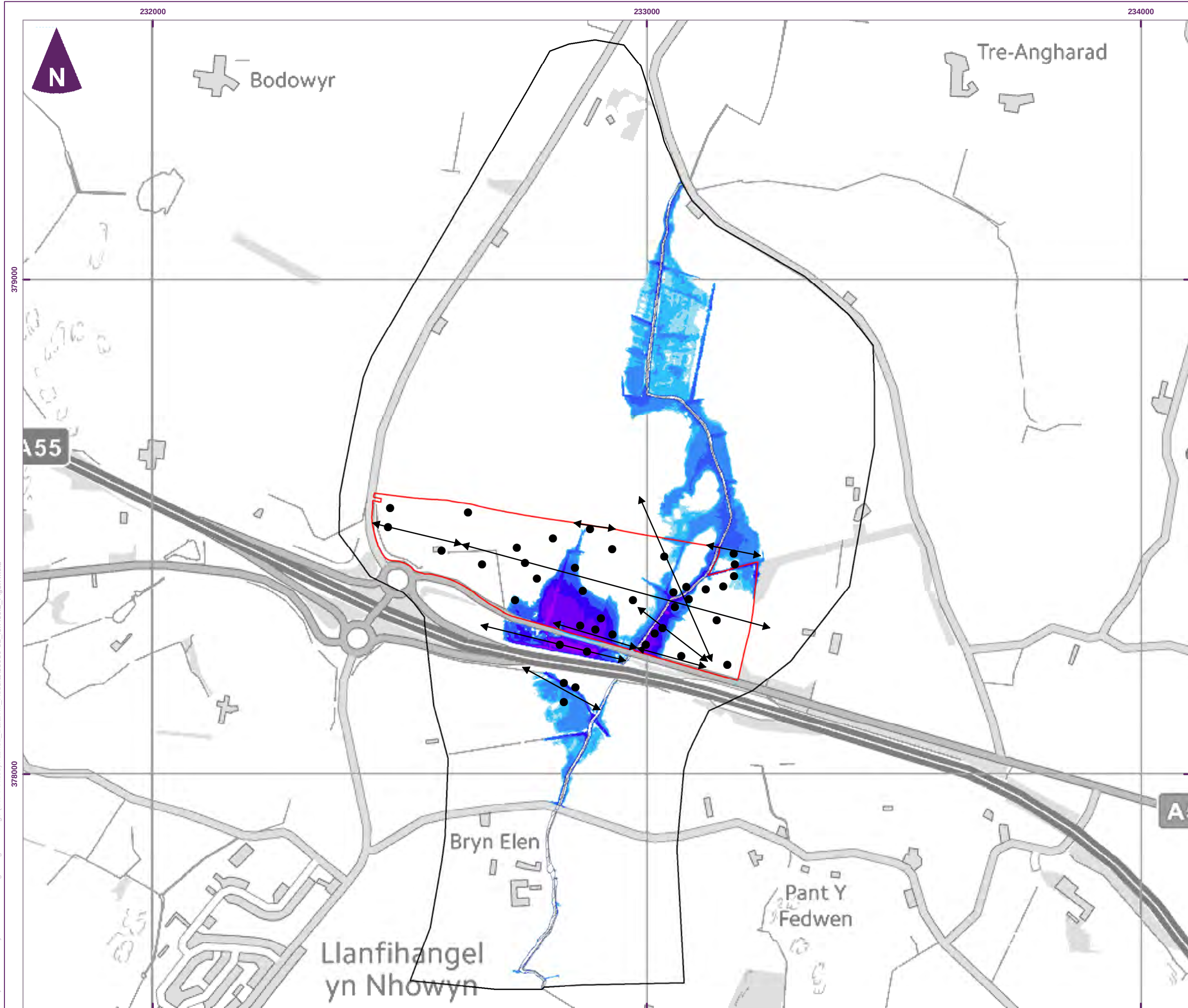
Wylfa Newydd
 Associated
 Developments
 Hydraulic Modelling

amec
 foster
 wheeler

Figure 6.6
Dalar Hir baseline peak pluvial flood
depth 1:100 year AEP (6 hour storm
event) plus climate change (20%)

May 2017

35989_Lon468i2 jamek



Key

Peak flood depth (m)
Baseline
1:20 year AEP fluvial
Present day

	0.01 - 0.05
	0.05 - 0.10
	0.10 - 0.25
	0.25 - 0.50
	0.50 - 0.75
	0.75 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	> 2.00

Model boundary

1D Model Domain

Site Boundary

Results Point

Results Line

OS Mapping

Notes:
The depths represent the maximum depth achieved. The flood prediction does not represent a moment in time as maximum depths can be achieved at different times.

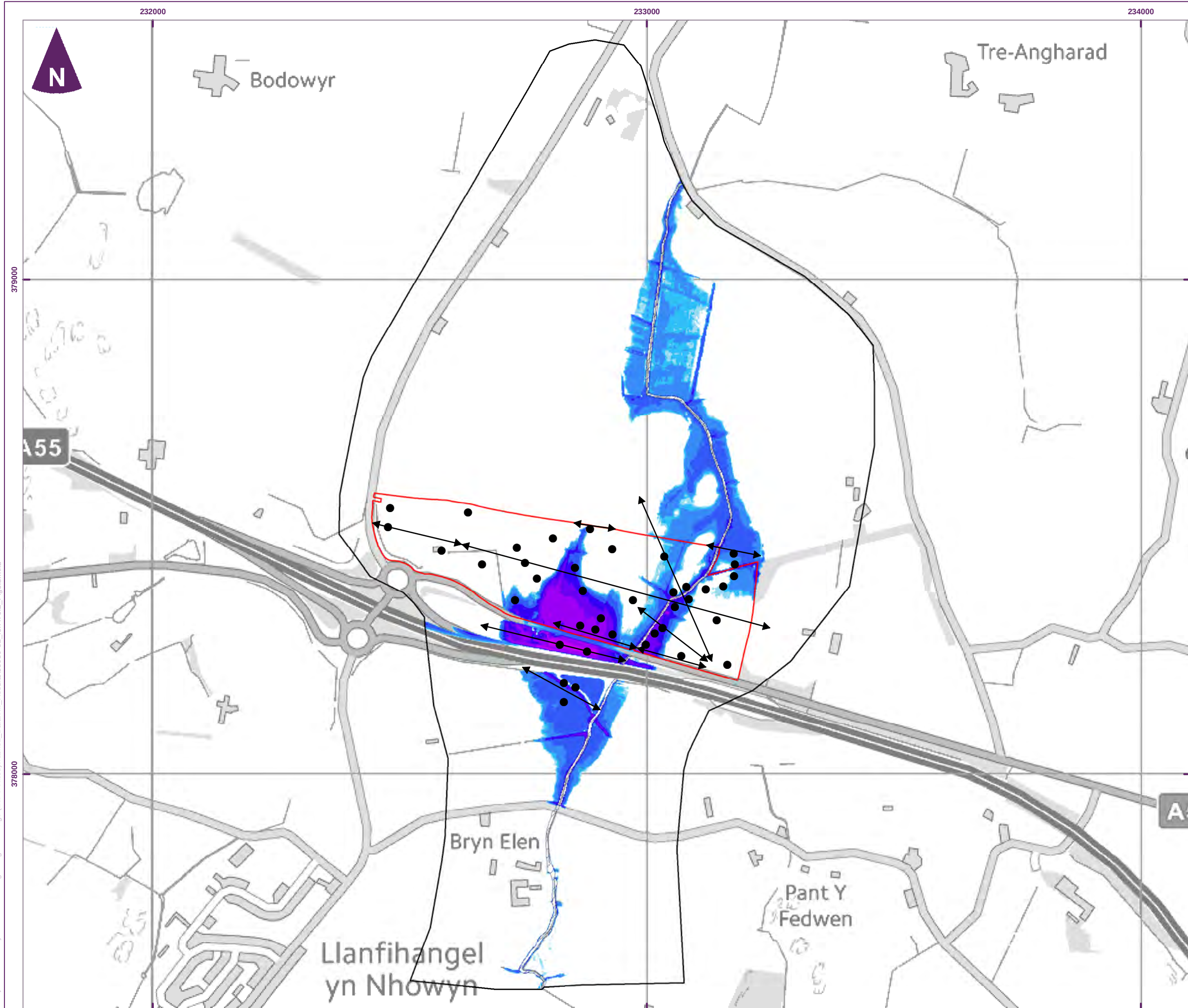
Model run date: 22/04/2017
Corresponding data:
35989-C1344_Base_Fluvial_F20.xlsx

0 100 200 300 400 m
Scale at A3

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Associated
Developments
Hydraulic Modelling

Figure 6.7
Dalar Hir baseline peak fluvial flood
depth 1:20 year AEP present day

May 2017 35989_Lon469i2 jamek



Key

Peak flood depth (m)
Baseline
1:100 year AEP fluvial
Present day

	0.01 - 0.05
	0.05 - 0.10
	0.10 - 0.25
	0.25 - 0.50
	0.50 - 0.75
	0.75 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	> 2.00

Model boundary

1D Model Domain

Site Boundary

Results Point

Results Line

OS Mapping

Notes:
The depths represent the maximum depth achieved. The flood prediction does not represent a moment in time as maximum depths can be achieved at different times.

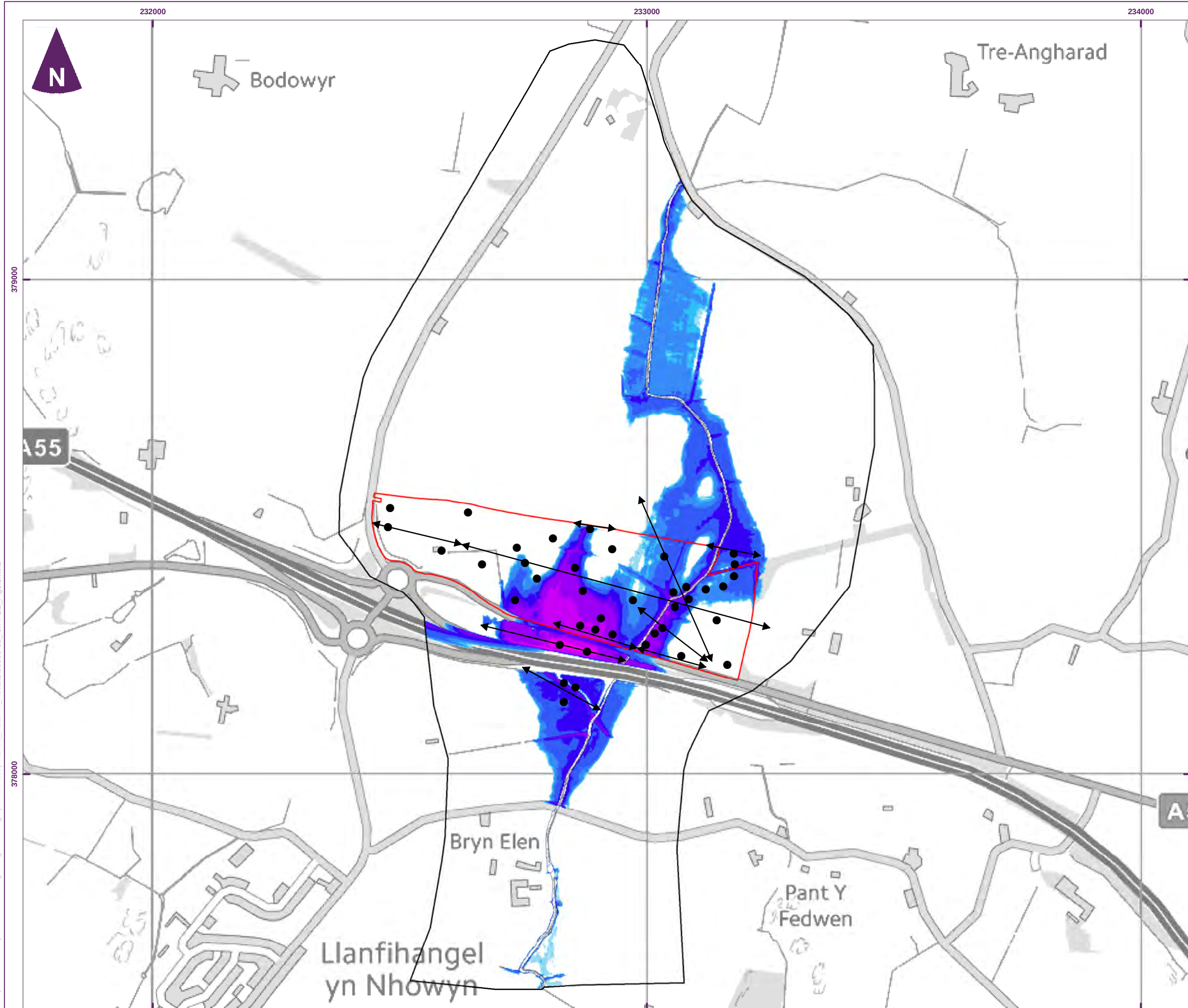
Model run date: 22/04/2017
Corresponding data:
35989-C1345_Base_Fluvial_F100.xlsx

0 100 200 300 400 m
Scale at A3

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Associated
Developments
Hydraulic Modelling

Figure 6.8
Dalar Hir baseline peak fluvial flood
depth 1:100 year AEP present day

May 2017 35989_Lon470i2 jamek



Key

Peak flood depth (m)
Baseline
1:1000 year AEP fluvial
Present day

0.01 - 0.05
0.05 - 0.10
0.10 - 0.25
0.25 - 0.50
0.50 - 0.75
0.75 - 1.00
1.00 - 1.50
1.50 - 2.00
> 2.00

Model boundary
1D Model Domain
Site Boundary
Results Point
Results Line
OS Mapping

Notes:
The depths represent the maximum depth achieved. The flood prediction does not represent a moment in time as maximum depths can be achieved at different times.

Model run date: 22/04/2017
Corresponding data:
35989-C1346_Base_Fluvial_F1000.xlsx

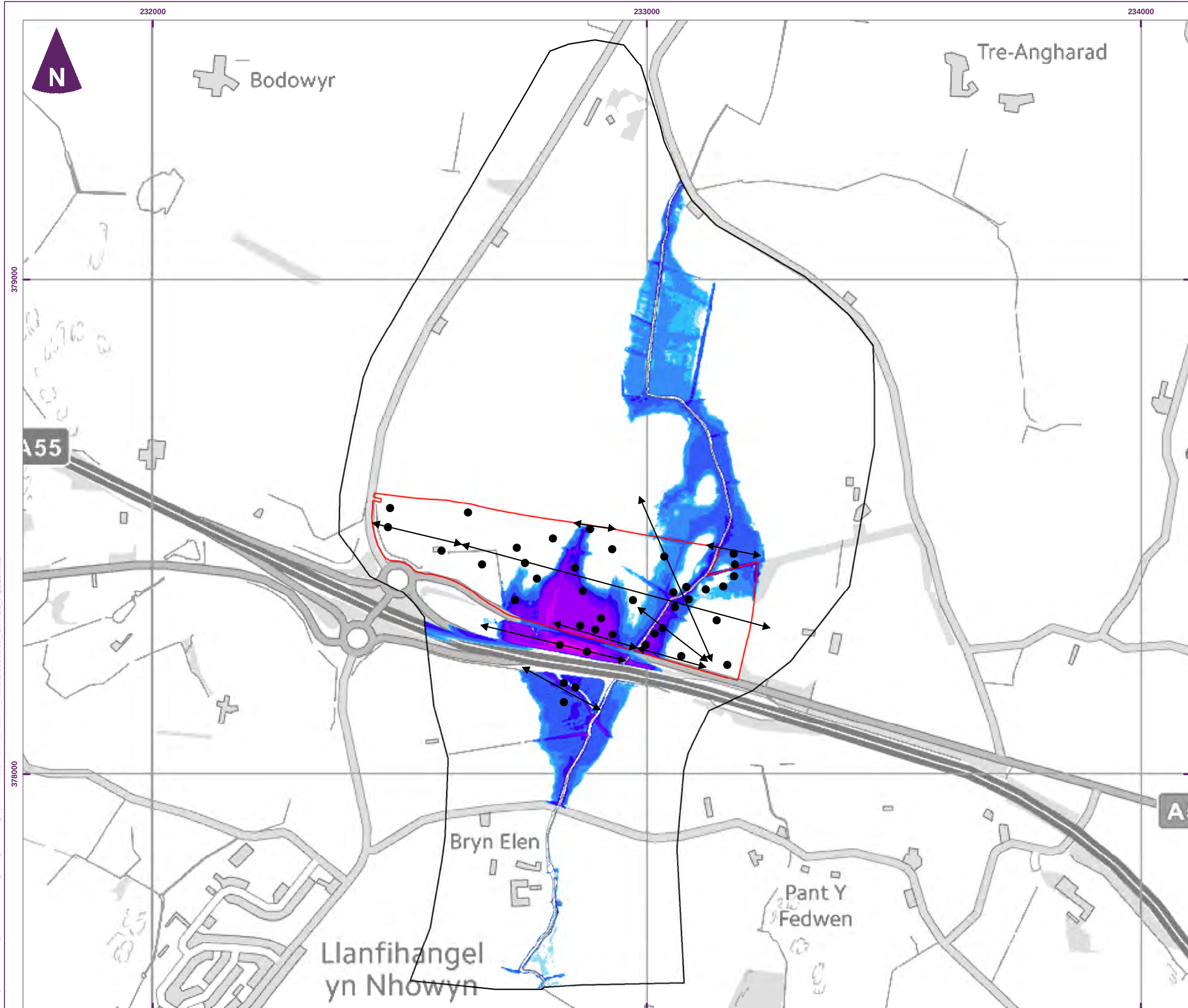
0 100 200 300 400 m
Scale at A3

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Associated
Developments
Hydraulic Modelling

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Figure 6.9
Dalar Hir baseline peak fluvial flood
depth 1:1000 year AEP present day

May 2017 35989_Lon471i2 jamek



Key

Peak flood depth (m)
Baseline
1:100 year AEP fluvial
Climate change (30%)

	0.01 - 0.05
	0.05 - 0.10
	0.10 - 0.25
	0.25 - 0.50
	0.50 - 0.75
	0.75 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	> 2.00

Model boundary

1D Model Domain

Site Boundary

Results Point

Results Line

OS Mapping

Notes:
The depths represent the maximum depth achieved. The flood prediction does not represent a moment in time as maximum depths can be achieved at different times.

Model run date: 22/04/2017
Corresponding data:
35989-C1347_Base_Fluvial_F100cc.xlsx

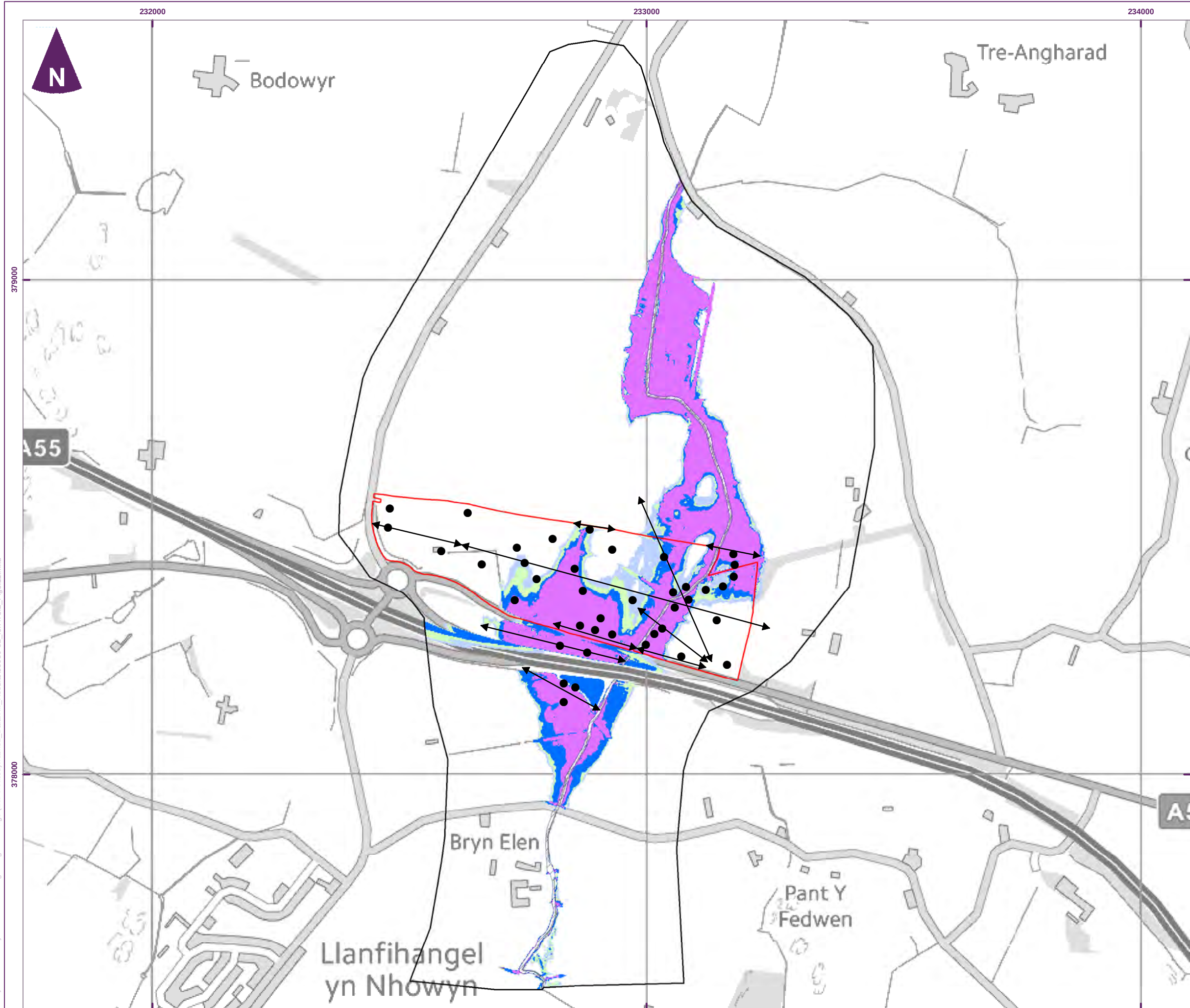
0 100 200 300 400 m
Scale at A3

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Figure 6.10
Dalar Hir baseline peak fluvial flood
depth 1:100 year AEP plus climate
change (30%)

May 2017

35989_Lon472i2 jamek



Key

Baseline fluvial Peak flood extents

- 1:30 Year AEP
- 1:100 year AEP
- 1:100 year AEP - plus 30% climate change
- 1:1000 year AEP
- Model boundary
- 1D Model Domain
- Site Boundary
- Results Point
- Results Line
- OS Mapping

0 100 200 300 400 m
Scale at A3

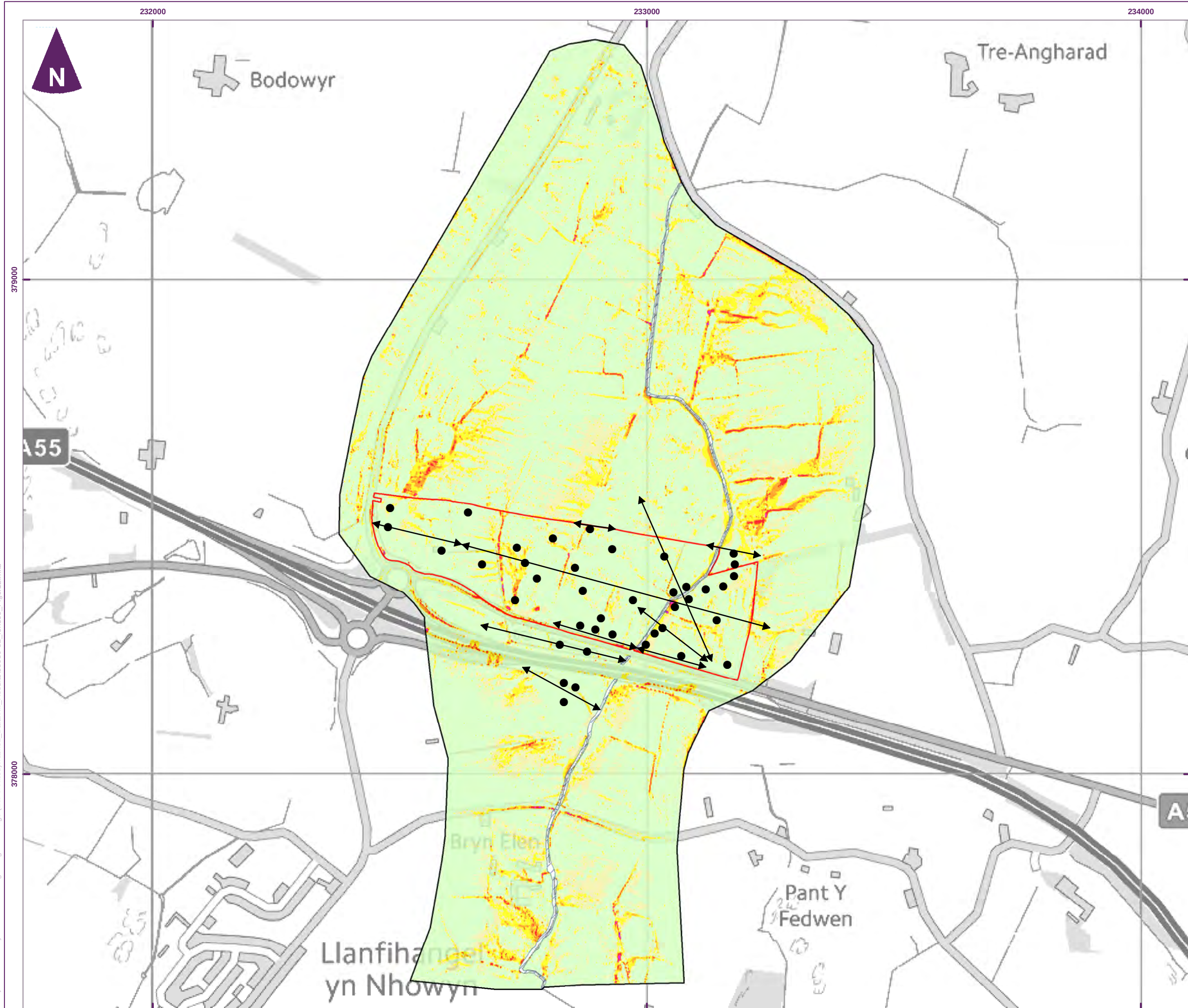
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Figure 6.11
Dalar Hir baseline peak fluvial flood
extents

July 2017 35989_Lon475i2 jamek

file: H:\Projects\35989 Wylfa NNB Modelling\DesignDrawings (E&I created)\Task32_DalarHir_Results\35989-32_Lon475i2_Fig6.11.mxd



Key

Peak flood velocity (m/s)
Baseline
1:30 year AEP pluvial
Present day

< 0.05
0.05 - 0.10
0.10 - 0.20
0.20 - 0.30
0.30 - 0.50
0.50 - 0.75
0.75 - 1.00
1.00 - 1.50
> 1.50

Model boundary
1D Model Domain
Site Boundary
Results Point
Results Line
OS Mapping

Notes:
The velocities represent the maximum velocity achieved. The flood prediction does not represent a moment in time as maximum velocities can be achieved at different times.

Model run date: 22/04/2017
Corresponding data:
35989-C1338_Base_Pluvial_R30_360m.xlsx

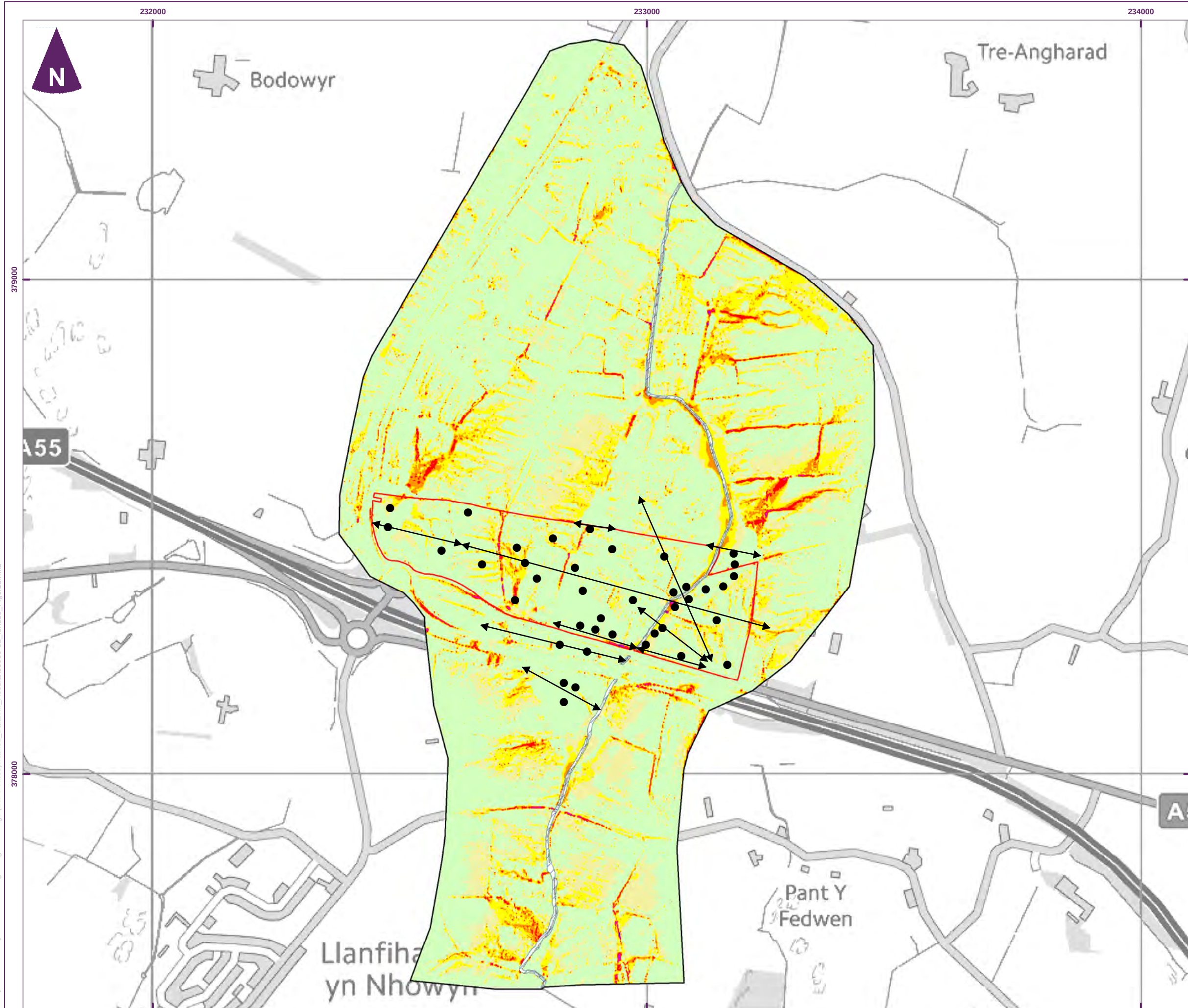
0 100 200 300 400 m
Scale at A3

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Figure 6.12
Dalar Hir baseline peak pluvial flood
velocity 1:30 year AEP present day
(6 hour storm event)

May 2017 35989_Lon509 jamek



Key

Peak flood velocity (m/s)
Baseline
1:100 year AEP pluvial
Present day

	< 0.05
	0.05 - 0.10
	0.10 - 0.20
	0.20 - 0.30
	0.30 - 0.50
	0.50 - 0.75
	0.75 - 1.00
	1.00 - 1.50
	> 1.50

Model boundary
 1D Model Domain
 Site Boundary
 Results Point
 Results Line
 OS Mapping

Notes:
The velocities represent the maximum velocity achieved. The flood prediction does not represent a moment in time as maximum velocities can be achieved at different times.

Model run date: 22/04/2017
Corresponding data:
35989-C1339_Base_Pluvial_R100_360m.xlsx

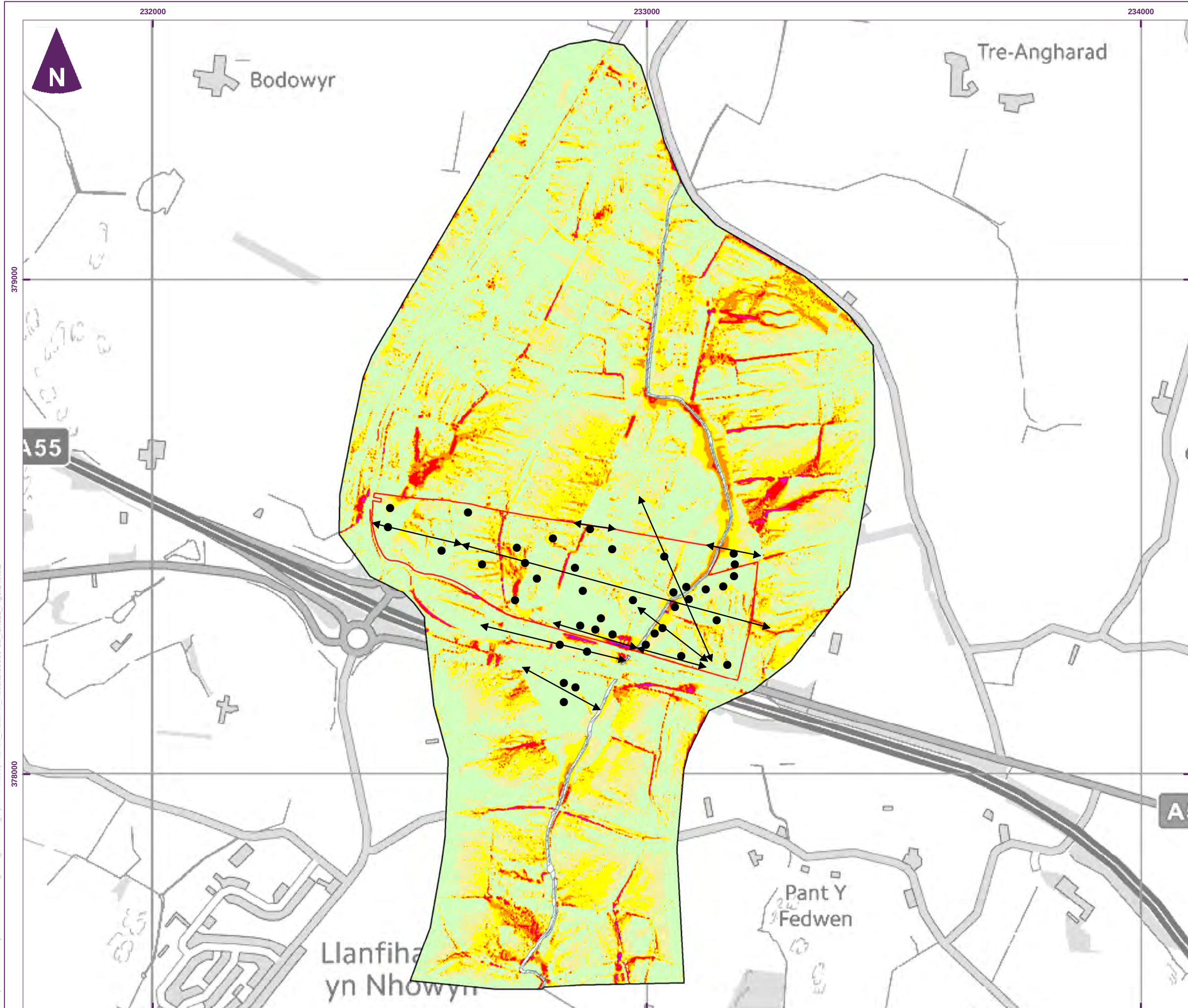
0 100 200 300 400 m
Scale at A3

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Figure 6.13
Dalar Hir baseline peak pluvial flood
velocity 1:100 year AEP present day
(6 hour storm event)

May 2017

35989_Lon510 jamek



Key

Peak flood velocity (m/s)
Baseline
1:1000 year AEP pluvial
Present day

< 0.05
0.05 - 0.10
0.10 - 0.20
0.20 - 0.30
0.30 - 0.50
0.50 - 0.75
0.75 - 1.00
1.00 - 1.50
> 1.50

Model boundary
1D Model Domain
Site Boundary
Results Point
Results Line
OS Mapping

Notes:
The velocities represent the maximum velocity achieved. The flood prediction does not represent a moment in time as maximum velocities can be achieved at different times.

Model run date: 22/04/2017
Corresponding data:
35989-C1340_Base_Pluvial_R1000_360m.xlsx

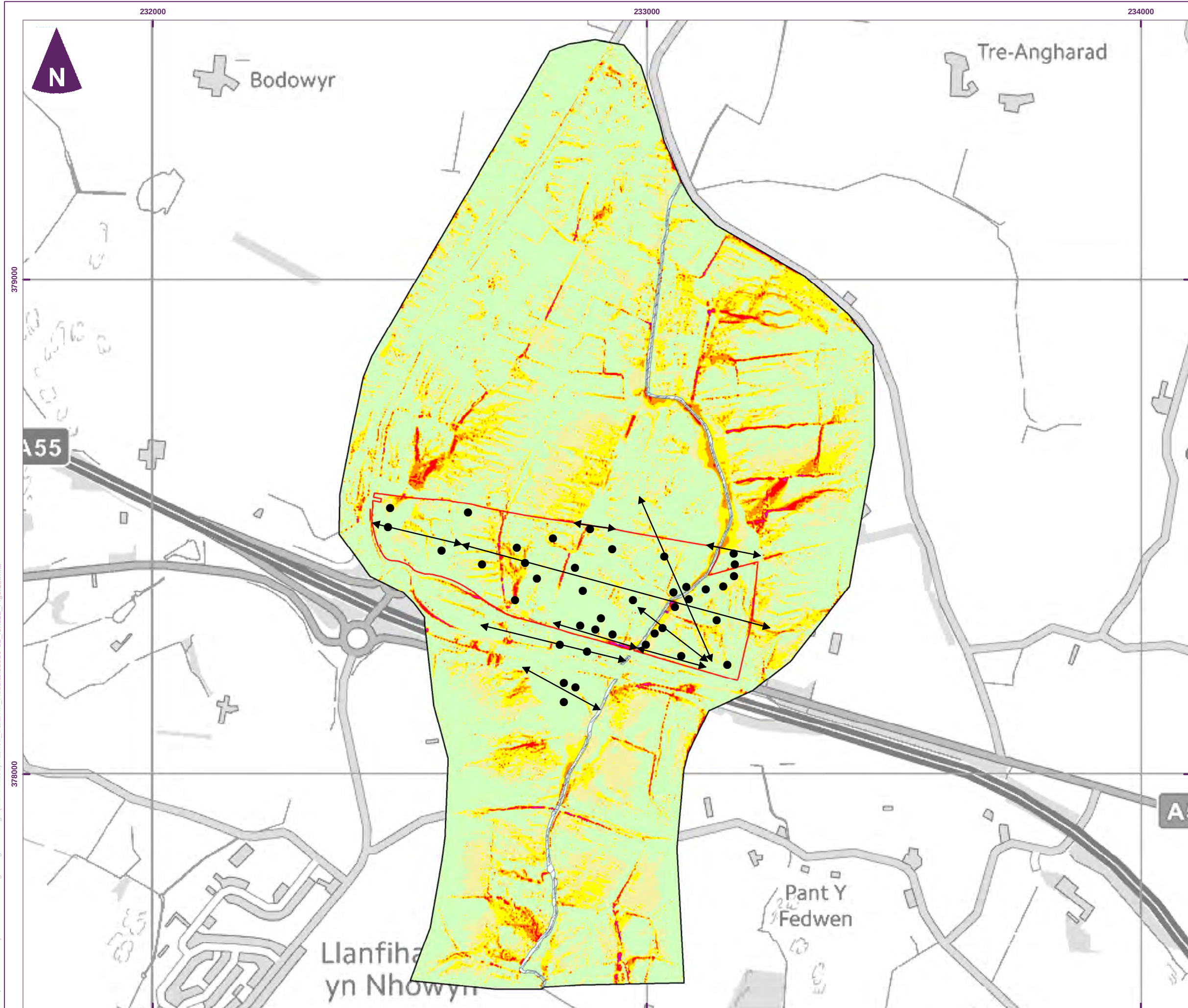
0 100 200 300 400 m
Scale at A3

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Hydraulic Modelling

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foster
wheeler

Figure 6.14
Dalar Hir baseline peak pluvial flood
velocity 1:1000 year AEP present day
(6 hour storm event)

May 2017 35989_Lon511 jamek



Key

Peak flood velocity (m/s)
Baseline
1:100 year AEP pluvial
Climate change (20%)

	< 0.05
	0.05 - 0.10
	0.10 - 0.20
	0.20 - 0.30
	0.30 - 0.50
	0.50 - 0.75
	0.75 - 1.00
	1.00 - 1.50
	> 1.50

Model boundary
 1D Model Domain
 Site Boundary
 Results Point
 Results Line
 OS Mapping

Notes:
The velocities represent the maximum velocity achieved. The flood prediction does not represent a moment in time as maximum velocities can be achieved at different times.

Model run date: 22/04/2017
Corresponding data:
35989-C1341_Base_Pluvial_R100cc_360m.xlsx

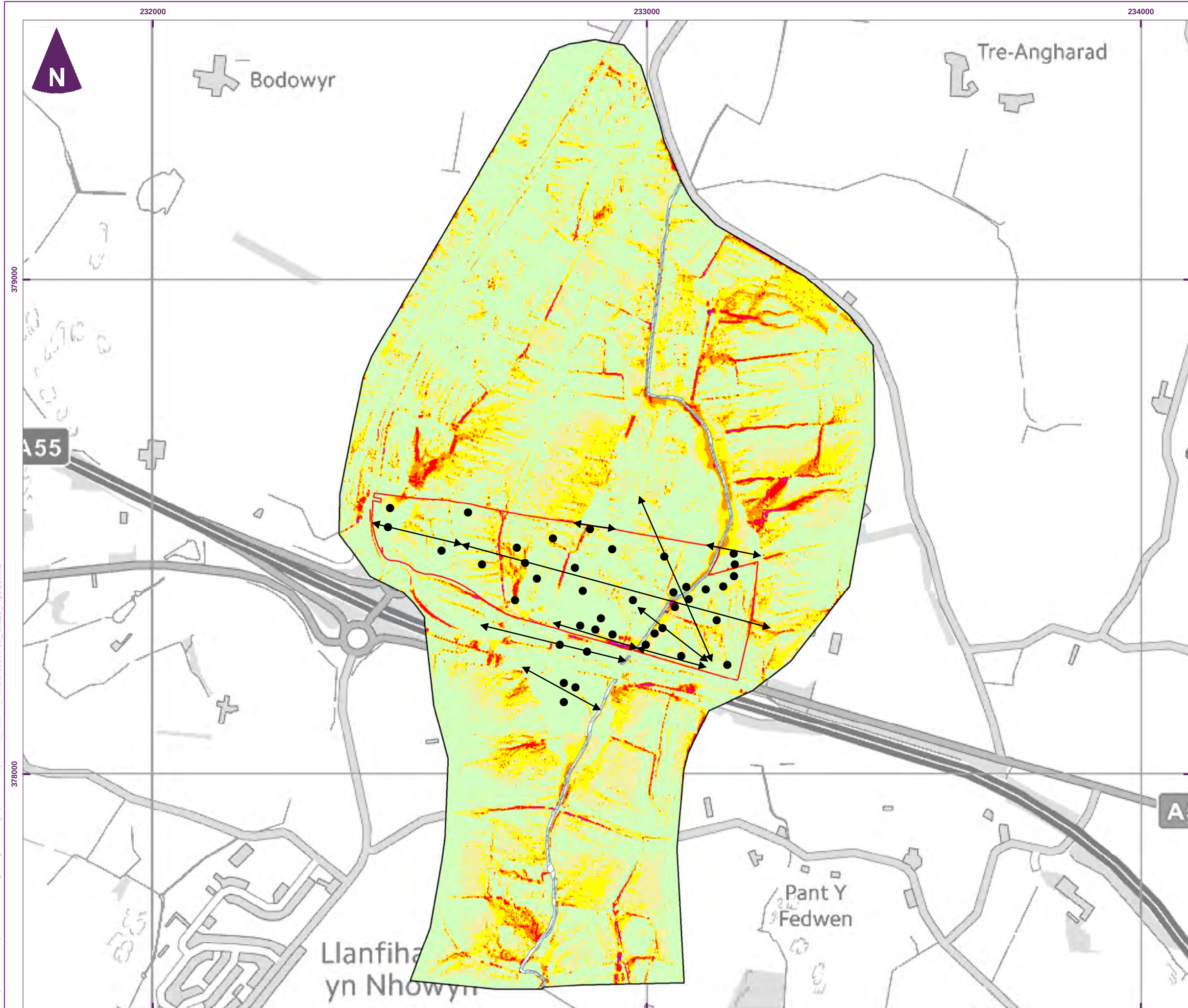
0 100 200 300 400 m
Scale at A3

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Figure 6.15
Dalar Hir baseline peak pluvial flood
velocity 1:100 year AEP (6 hour
storm event) plus climate change
(20%)

May 2017 35989_Lon512_jamek



Key

Peak flood velocity (m/s)
Baseline
1:100 year AEP pluvial
Climate change (40%)

	< 0.05
	0.05 - 0.10
	0.10 - 0.20
	0.20 - 0.30
	0.30 - 0.50
	0.50 - 0.75
	0.75 - 1.00
	1.00 - 1.50
	> 1.50

Model boundary

1D Model Domain

Site Boundary

Results Point

Results Line

OS Mapping

Notes:
The velocities represent the maximum velocity achieved. The flood prediction does not represent a moment in time as maximum velocities can be achieved at different times.

Model run date: 22/04/2017
Corresponding data:
35989-C1342_Base_Pluvial_R100cc_360m.xlsx

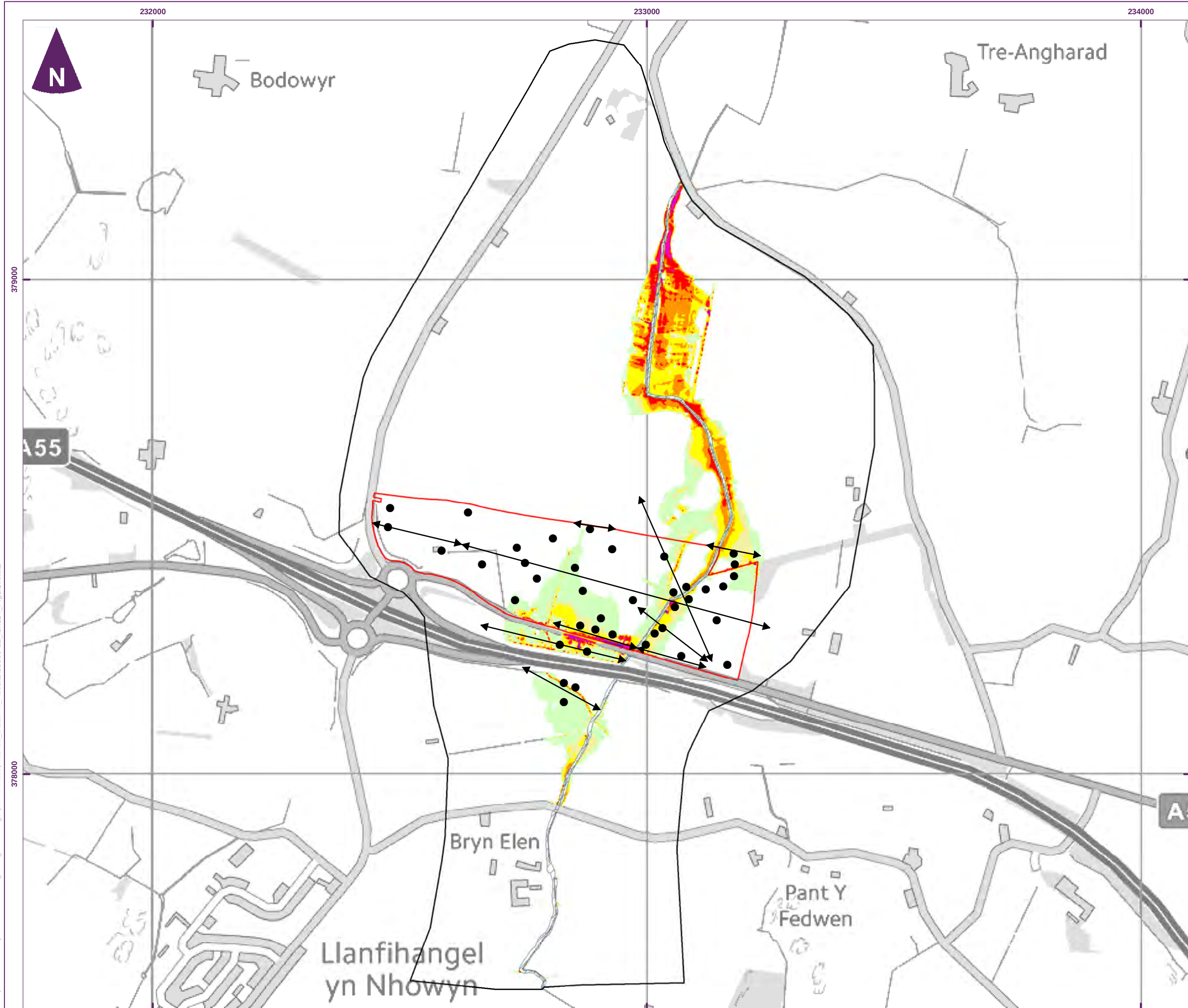
0 100 200 300 400 m
Scale at A3

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Figure 6.16
Dalar Hir baseline peak pluvial flood
velocity 1:100 year AEP (6 hour
storm event) plus climate change
(40%)

May 2017

35989_Lon513_jamek



Key

Peak flood velocity (m/s)
Baseline
1:20 year AEP fluvial
Present day

	< 0.05
	0.05 - 0.10
	0.10 - 0.20
	0.20 - 0.30
	0.30 - 0.50
	0.50 - 0.75
	0.75 - 1.00
	1.00 - 1.50
	> 1.50

Model boundary
 1D Model Domain
 Site Boundary
 Results Point
 Results Line
 OS Mapping

Notes:
The velocities represent the maximum velocity achieved. The flood prediction does not represent a moment in time as maximum velocities can be achieved at different times.

Model run date: 22/04/2017
Corresponding data:
35989-C1344_Base_Fluvial_F20.xlsx

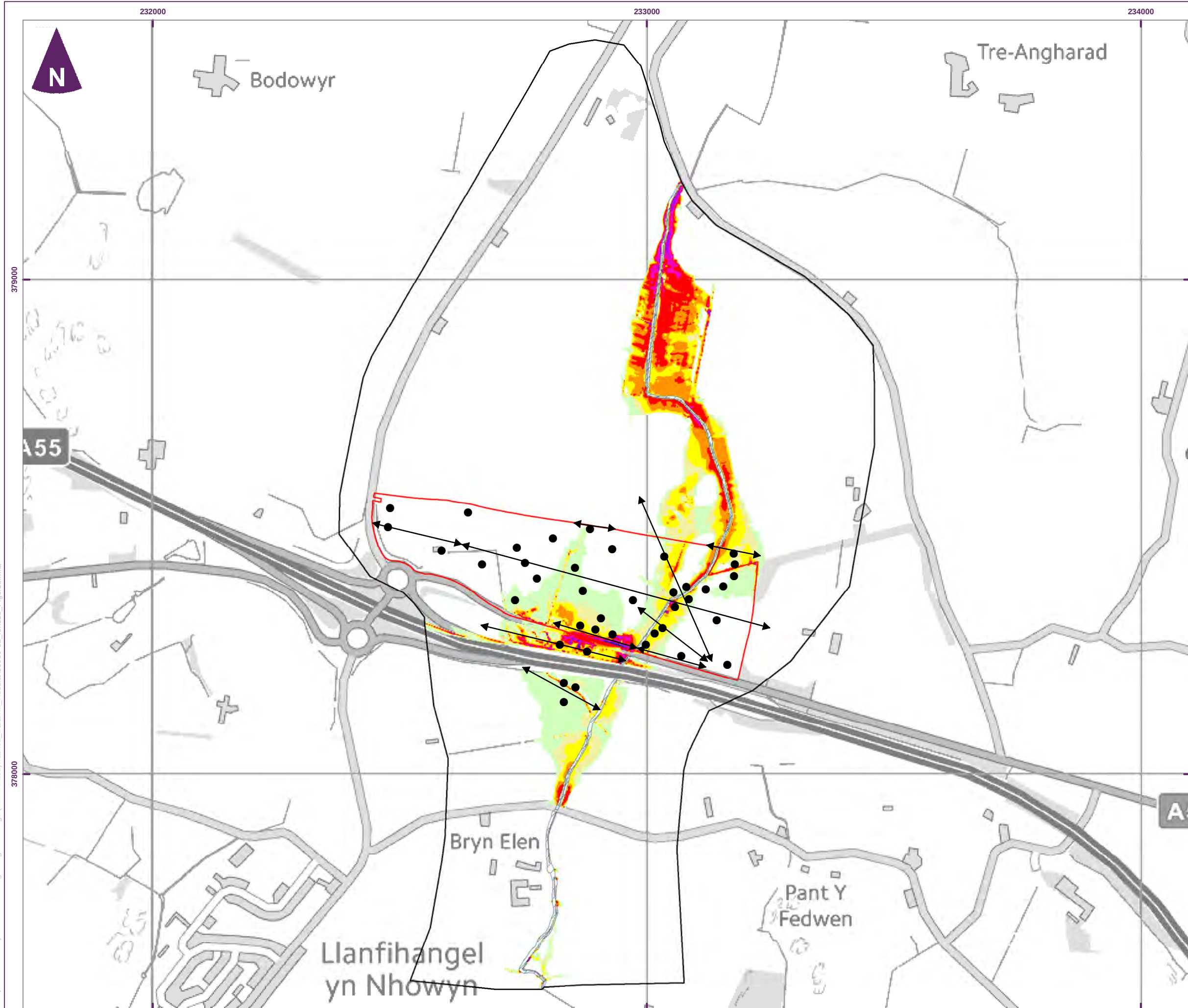
0 100 200 300 400 m
Scale at A3

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Figure 6.17
Dalar Hir baseline peak fluvial flood
velocity 1:20 year AEP present day

May 2017 35989_Lon514 jamek



Key

Peak flood velocity (m/s)
Baseline
1:100 year AEP fluvial
Present day

	< 0.05
	0.05 - 0.10
	0.10 - 0.20
	0.20 - 0.30
	0.30 - 0.50
	0.50 - 0.75
	0.75 - 1.00
	1.00 - 1.50
	> 1.50

Model boundary
 1D Model Domain
 Site Boundary
 Results Point
 Results Line
 OS Mapping

Notes:
The velocities represent the maximum velocity achieved. The flood prediction does not represent a moment in time as maximum velocities can be achieved at different times.

Model run date: 22/04/2017
Corresponding data:
35989-C1345_Base_Fluvial_F100.xlsx

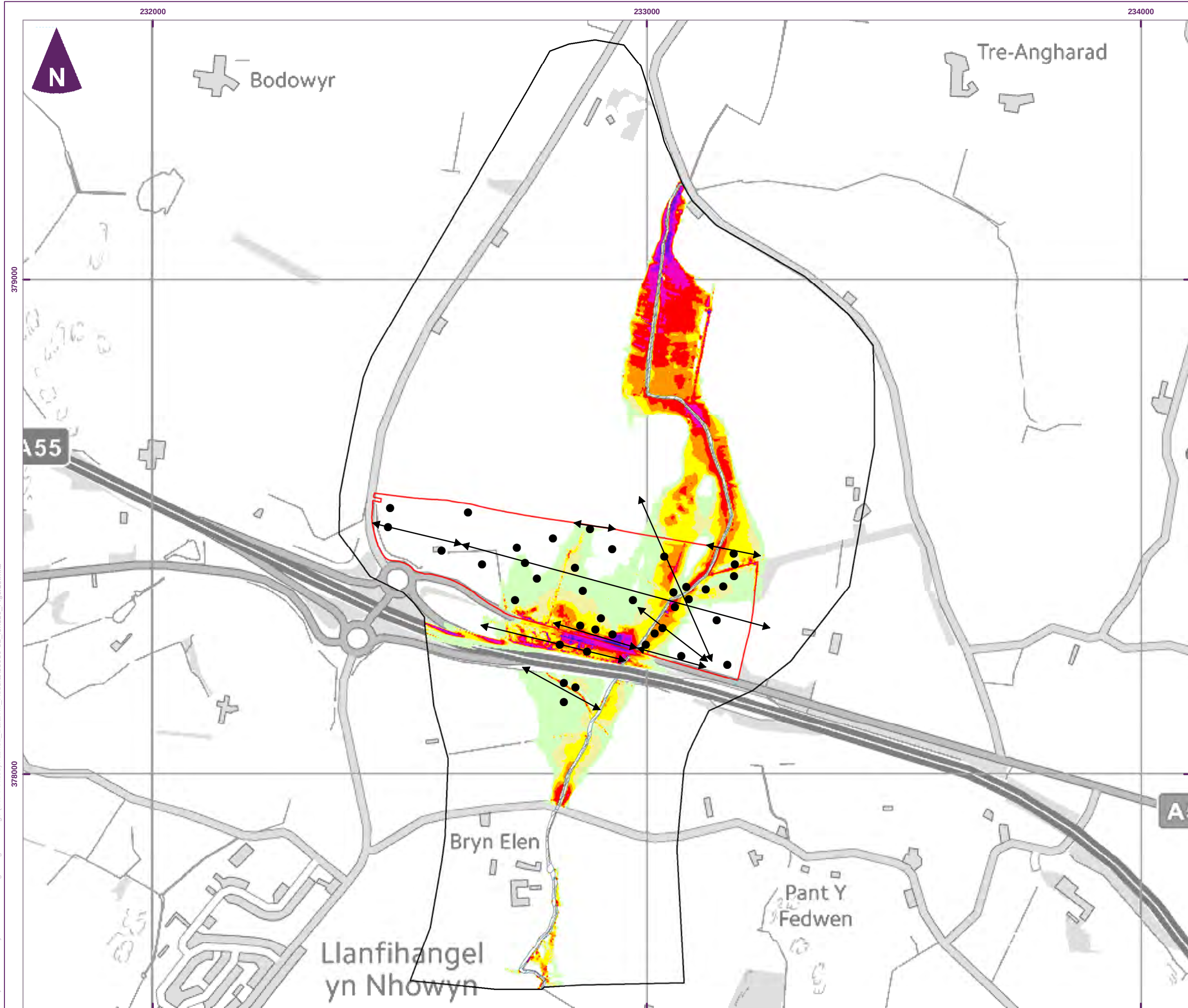
0 100 200 300 400 m
Scale at A3

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Associated
Developments
Hydraulic Modelling

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Figure 6.18
Dalar Hir baseline peak fluvial flood
velocity 1:100 year AEP present day

May 2017 35989_Lon515 jamek



Key

Peak flood velocity (m/s)
Baseline
1:1000 year AEP fluvial
Present day

	< 0.05
	0.05 - 0.10
	0.10 - 0.20
	0.20 - 0.30
	0.30 - 0.50
	0.50 - 0.75
	0.75 - 1.00
	1.00 - 1.50
	> 1.50

Model boundary

1D Model Domain

Site Boundary

Results Point

Results Line

OS Mapping

Notes:
The velocities represent the maximum velocity achieved. The flood prediction does not represent a moment in time as maximum velocities can be achieved at different times.

Model run date: 22/04/2017
Corresponding data:
35989-C1346_Base_Fluvial_F1000.xlsx

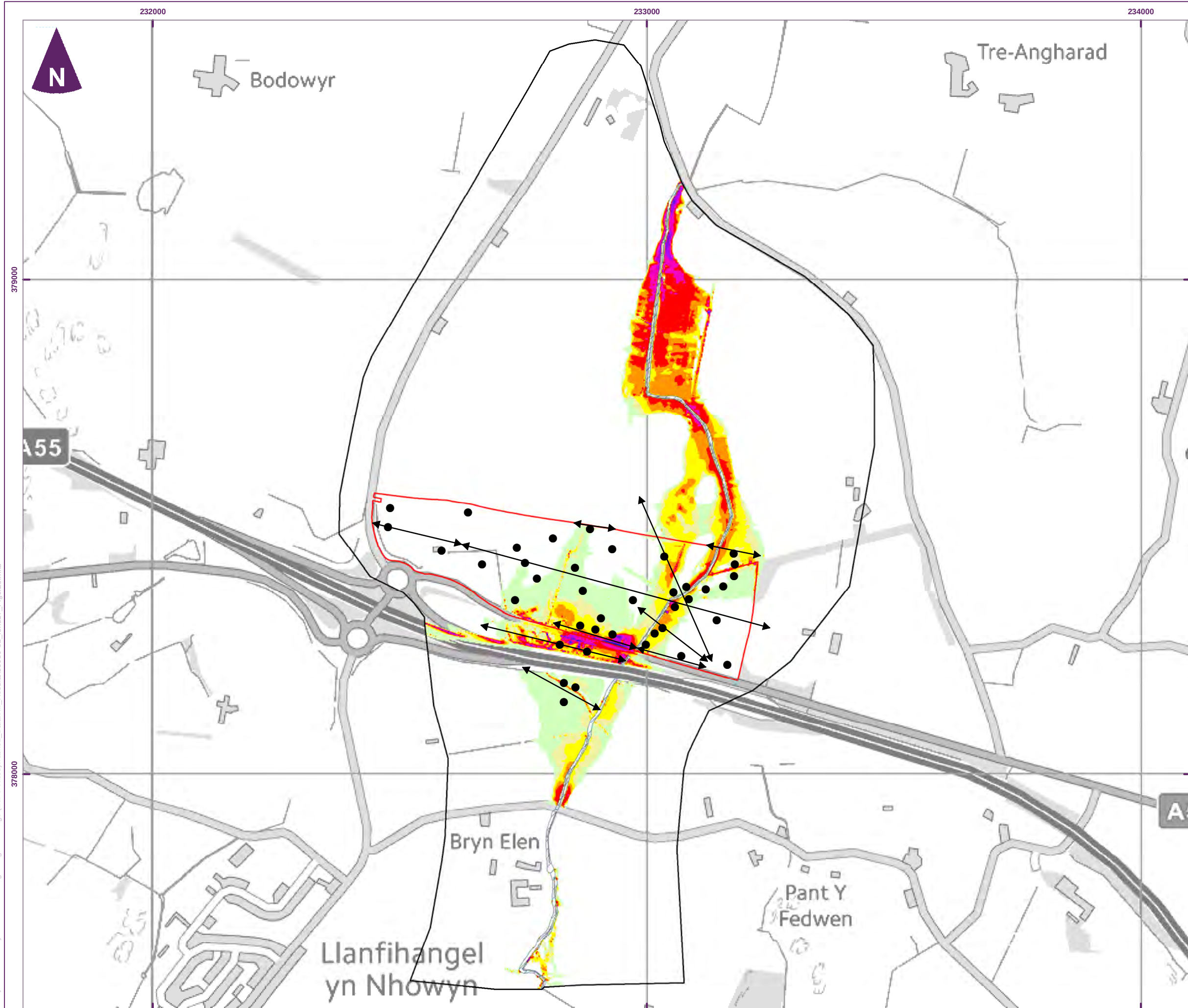
0 100 200 300 400 m
Scale at A3

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Figure 6.19
Dalar Hir baseline peak fluvial flood
velocity 1:1000 year AEP present day

May 2017

35989_Lon516 jamek



Key

Peak flood velocity (m/s)
Baseline
1:100 year AEP fluvial
Climate change (30%)

	< 0.05
	0.05 - 0.10
	0.10 - 0.20
	0.20 - 0.30
	0.30 - 0.50
	0.50 - 0.75
	0.75 - 1.00
	1.00 - 1.50
	> 1.50

Model boundary

1D Model Domain

Site Boundary

Results Point

Results Line

OS Mapping

Notes:
The velocities represent the maximum velocity achieved. The flood prediction does not represent a moment in time as maximum velocities can be achieved at different times.

Model run date: 22/04/2017
Corresponding data:
35989-C1347_Base_Fluvial_F100cc.xlsx

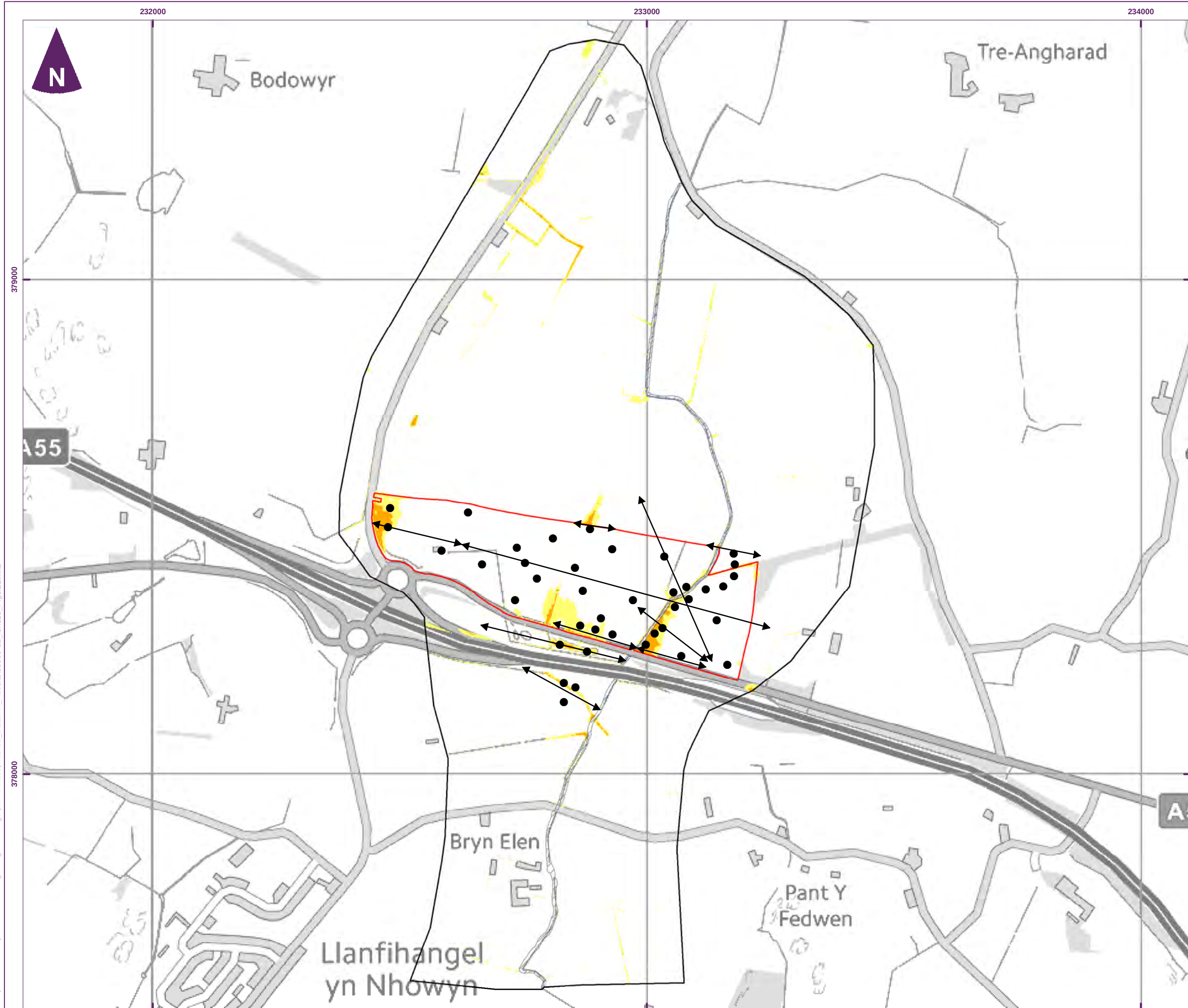
0 100 200 300 400 m
Scale at A3

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Developments
Hydraulic Modelling

Figure 6.20
Dalar Hir baseline peak fluvial flood
velocity 1:100 year AEP plus climate
change (30%)

May 2017

35989_Lon517 jamek



Key

Peak flood hazard (HR)
Baseline
1:30 year AEP pluvial
Present day

	< 0.75 Very low hazard - Caution
	0.75 - 1.25 Danger for some - includes children, the elderly and the infirm
	1.25 - 2 danger for most - includes the general public
	> 2 Danger for all - includes the emergency services
	Model boundary
	1D Model Domain
	Site Boundary
	Results Point
	Results Line
	OS Mapping

Notes:
The flood hazard rating is based on the formula and classification documented in the DEFRA Flood Risks to People guidance (FD2321).

Model run date: 22/04/2017

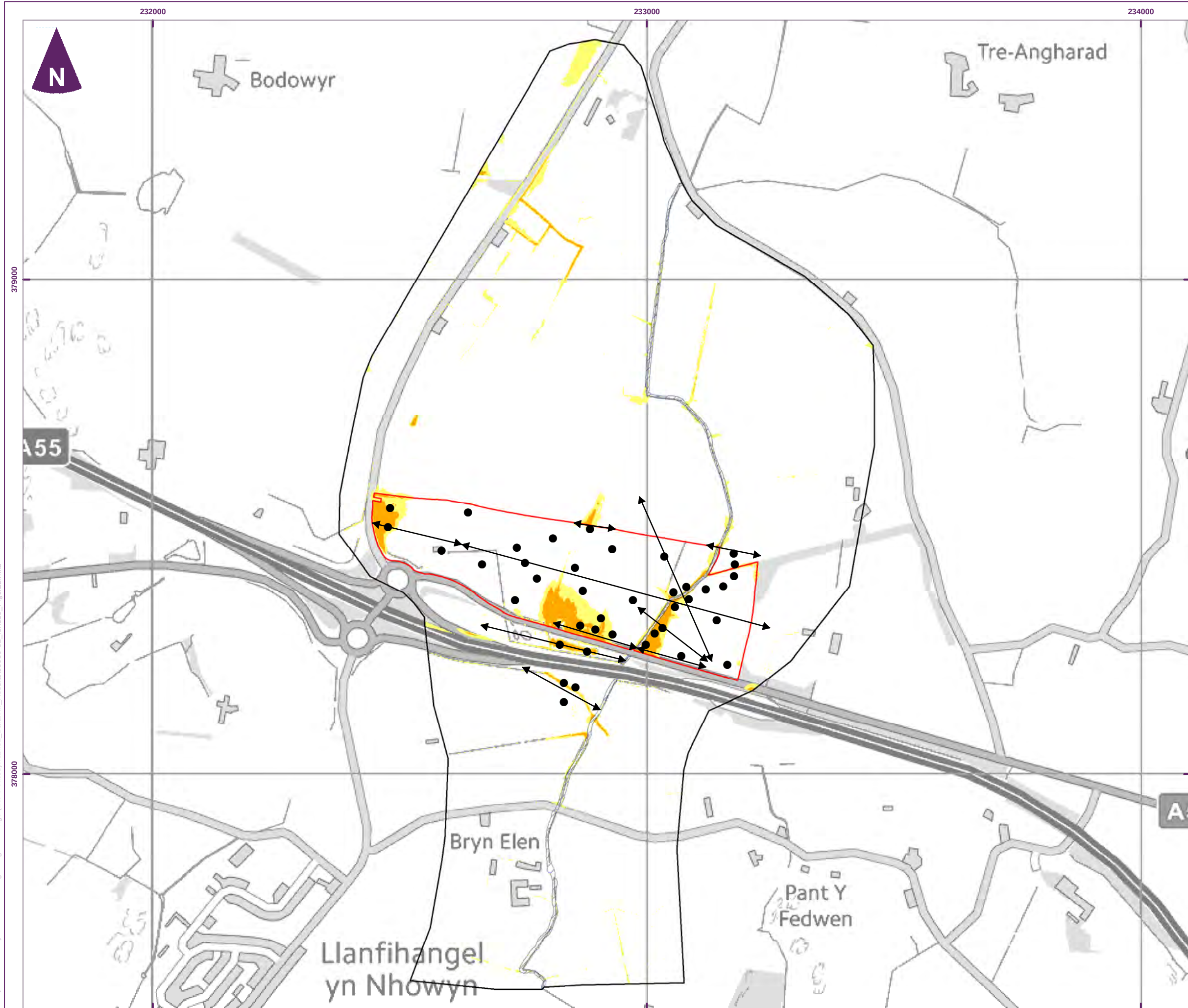
0 100 200 300 400 m
Scale at A3

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Associated
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Hydraulic Modelling

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Figure 6.21
Dalar Hir baseline peak pluvial flood hazard 1:30 year AEP present day (6 hour storm event)

May 2017 35989_Lon518 jamek



Key

Peak flood hazard (HR)
Baseline
1:100 year AEP pluvial
Present day

	< 0.75 Very low hazard - Caution
	0.75 - 1.25 Danger for some - includes children, the elderly and the infirm
	1.25 - 2 danger for most - includes the general public
	> 2 Danger for all - includes the emergency services
	Model boundary
	1D Model Domain
	Site Boundary
	Results Point
	Results Line
	OS Mapping

Notes:
The flood hazard rating is based on the formula and classification documented in the DEFRA Flood Risks to People guidance (FD2321).

Model run date: 22/04/2017

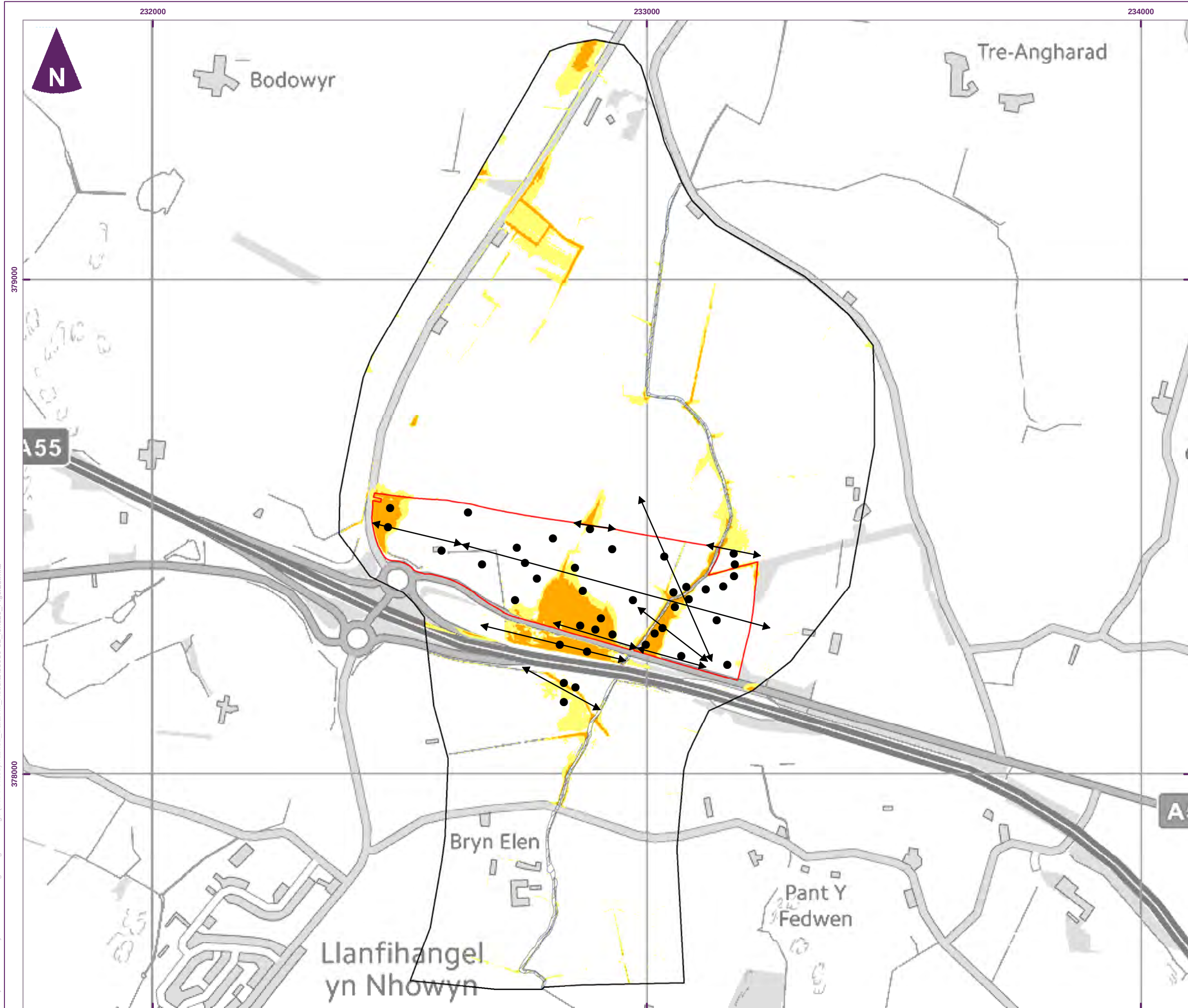
0 100 200 300 400 m
Scale at A3

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Associated
Developments
Hydraulic Modelling

amec
foster
wheeler

Figure 6.22
Dalar Hir baseline peak pluvial flood
hazard 1:100 year AEP present day
(6 hour storm event)

May 2017 35989_Lon519 jamek



Key

Peak flood hazard (HR)
Baseline
1:1000 year AEP pluvial
Present day

	< 0.75 Very low hazard - Caution
	0.75 - 1.25 Danger for some - includes children, the elderly and the infirm
	1.25 - 2 danger for most - includes the general public
	> 2 Danger for all - includes the emergency services

Model boundary

1D Model Domain

Site Boundary

Results Point

Results Line

OS Mapping

Notes:
The flood hazard rating is based on the formula and classification documented in the DEFRA Flood Risks to People guidance (FD2321).

Model run date: 22/04/2017

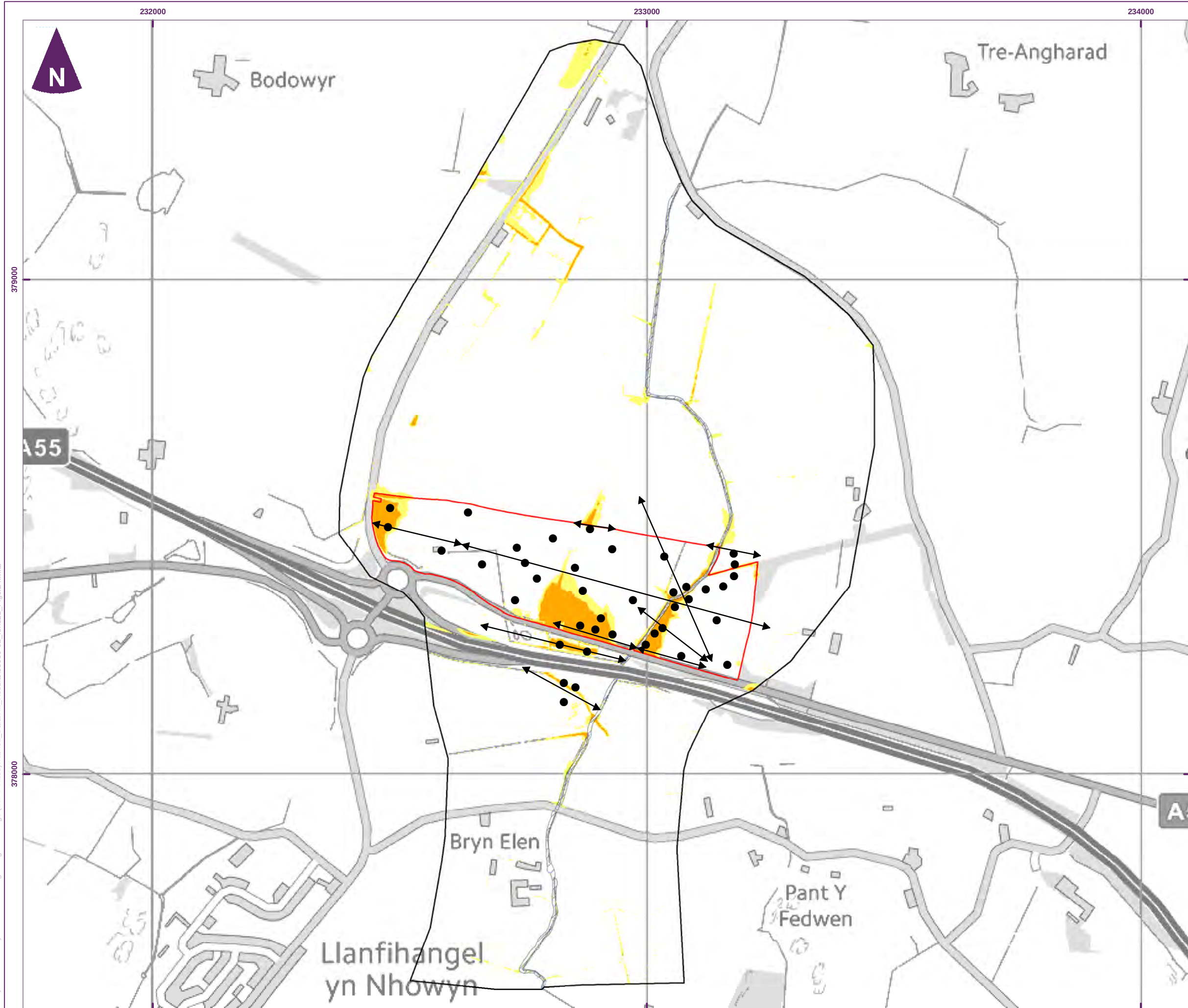
0 100 200 300 400 m
Scale at A3

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Figure 6.23
Dalar Hir baseline peak pluvial flood hazard 1:1000 year AEP present day (6 hour storm event)

May 2017

35989_Lon520 jamek



Key

Peak flood hazard (HR)
Baseline
1:100 year AEP pluvial
Climate change (20%)

	< 0.75 Very low hazard - Caution
	0.75 - 1.25 Danger for some - includes children, the elderly and the infirm
	1.25 - 2 danger for most - includes the general public
	> 2 Danger for all - includes the emergency services
	Model boundary
	1D Model Domain
	Site Boundary
	Results Point
	Results Line
	OS Mapping

Notes:
The flood hazard rating is based on the formula and classification documented in the DEFRA Flood Risks to People guidance (FD2321).

Model run date: 22/04/2017

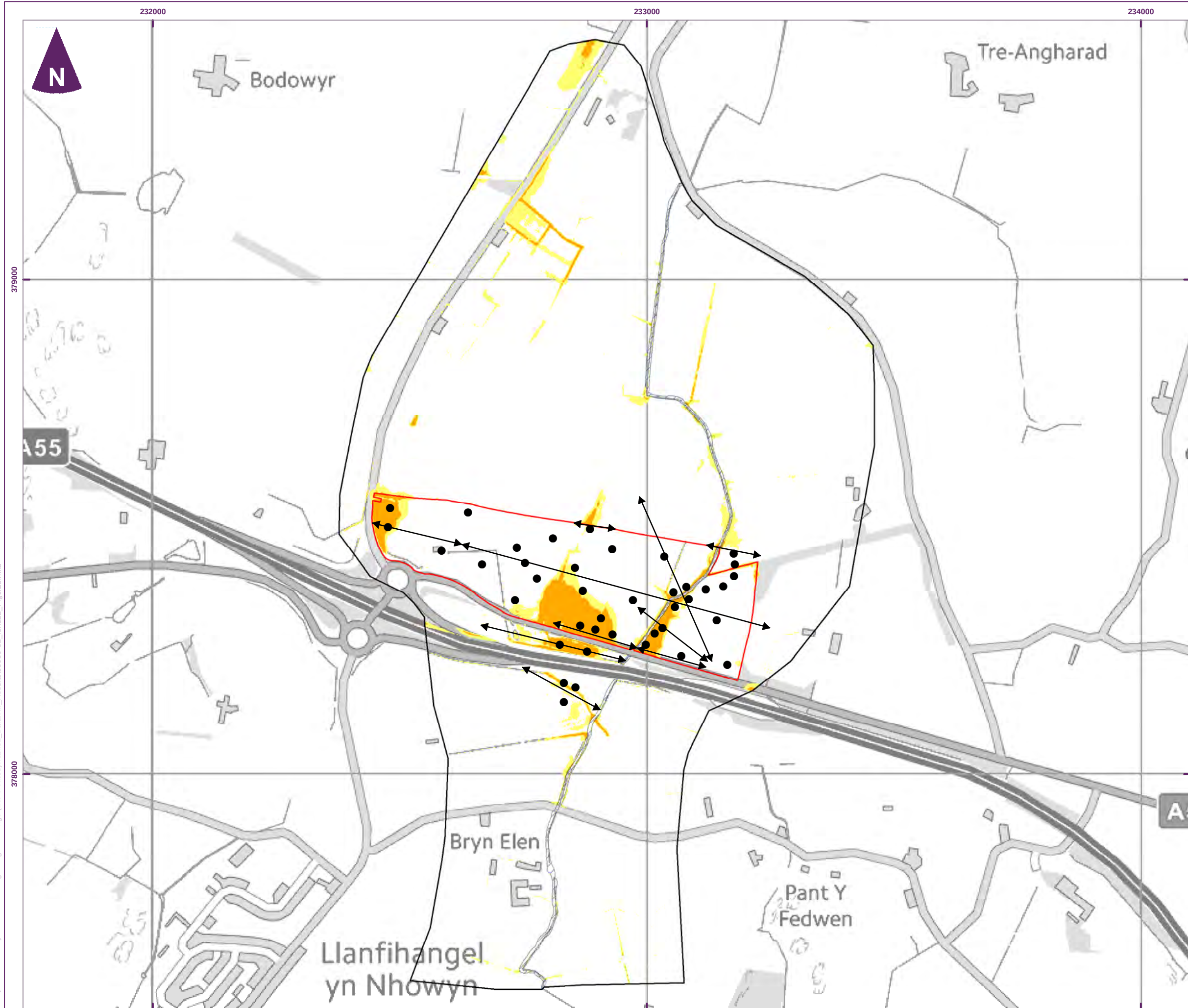
0 100 200 300 400 m
Scale at A3

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Associated
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Hydraulic Modelling

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Figure 6.24
Dalar Hir baseline peak pluvial flood hazard 1:100 year AEP (6 hour storm event) plus climate change (20%)

May 2017 35989_Lon521 jamek



Key

Peak flood hazard (HR)
Baseline
1:100 year AEP pluvial
Climate change (40%)

	< 0.75 Very low hazard - Caution
	0.75 - 1.25 Danger for some - includes children, the elderly and the infirm
	1.25 - 2 danger for most - includes the general public
	> 2 Danger for all - includes the emergency services
	Model boundary
	1D Model Domain
	Site Boundary
	Results Point
	Results Line
	OS Mapping

Notes:
The flood hazard rating is based on the formula and classification documented in the DEFRA Flood Risks to People guidance (FD2321).

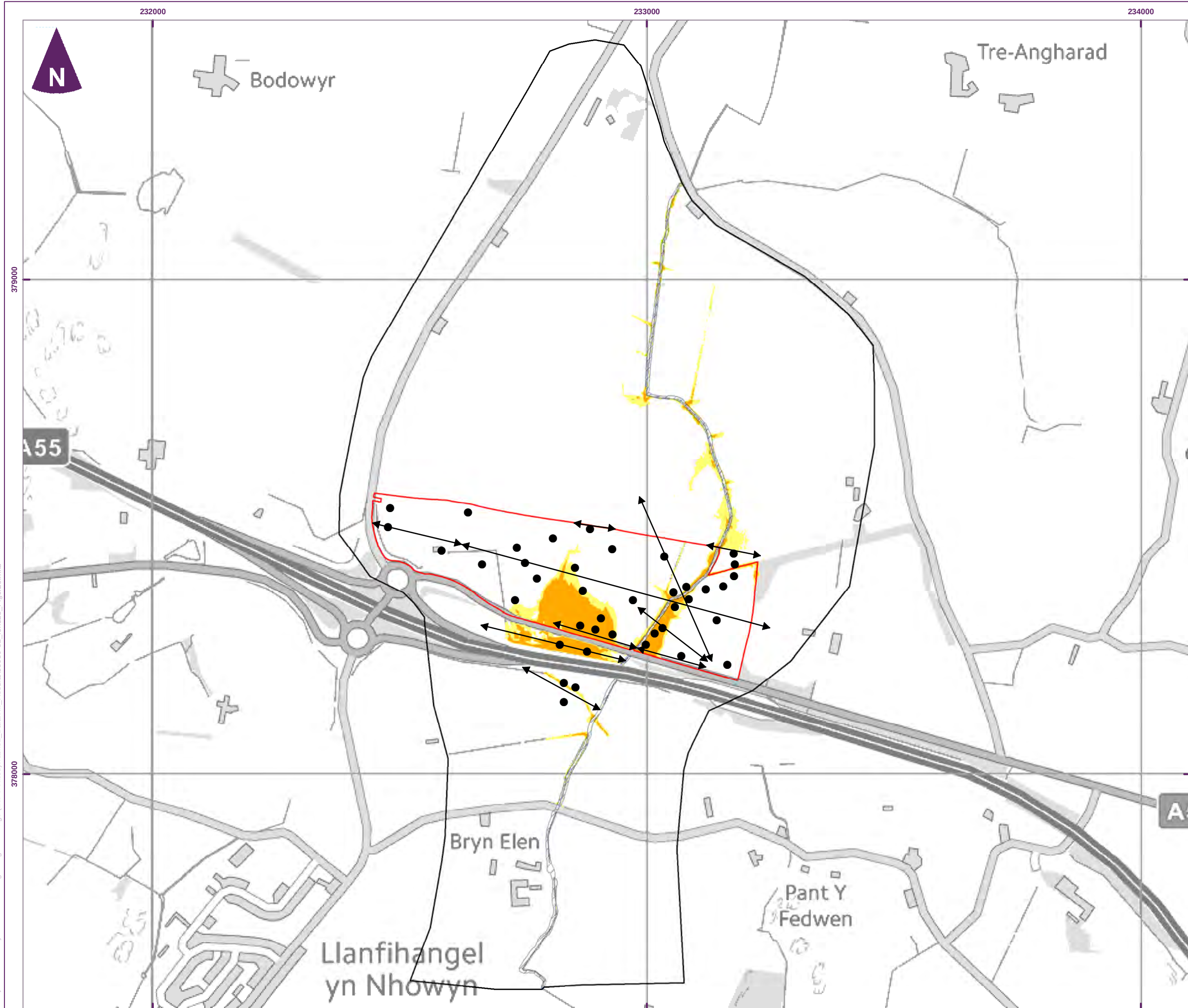
Model run date: 22/04/2017

0 100 200 300 400 m
Scale at A3

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Developments
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Figure 6.25
Dalar Hir baseline peak pluvial flood hazard 1:100 year AEP (6 hour storm event) plus climate change (40%)

May 2017 35989_Lon522 jamek



Key

Peak flood hazard (HR)
Baseline
1:20 year AEP fluvial
Present day

	< 0.75 Very low hazard - Caution
	0.75 - 1.25 Danger for some - includes children, the elderly and the infirm
	1.25 - 2 danger for most - includes the general public
	> 2 Danger for all - includes the emergency services
	Model boundary
	1D Model Domain
	Site Boundary
	Results Point
	Results Line
	OS Mapping

Notes:
The flood hazard rating is based on the formula and classification documented in the DEFRA Flood Risks to People guidance (FD2321).

Model run date: 22/04/2017

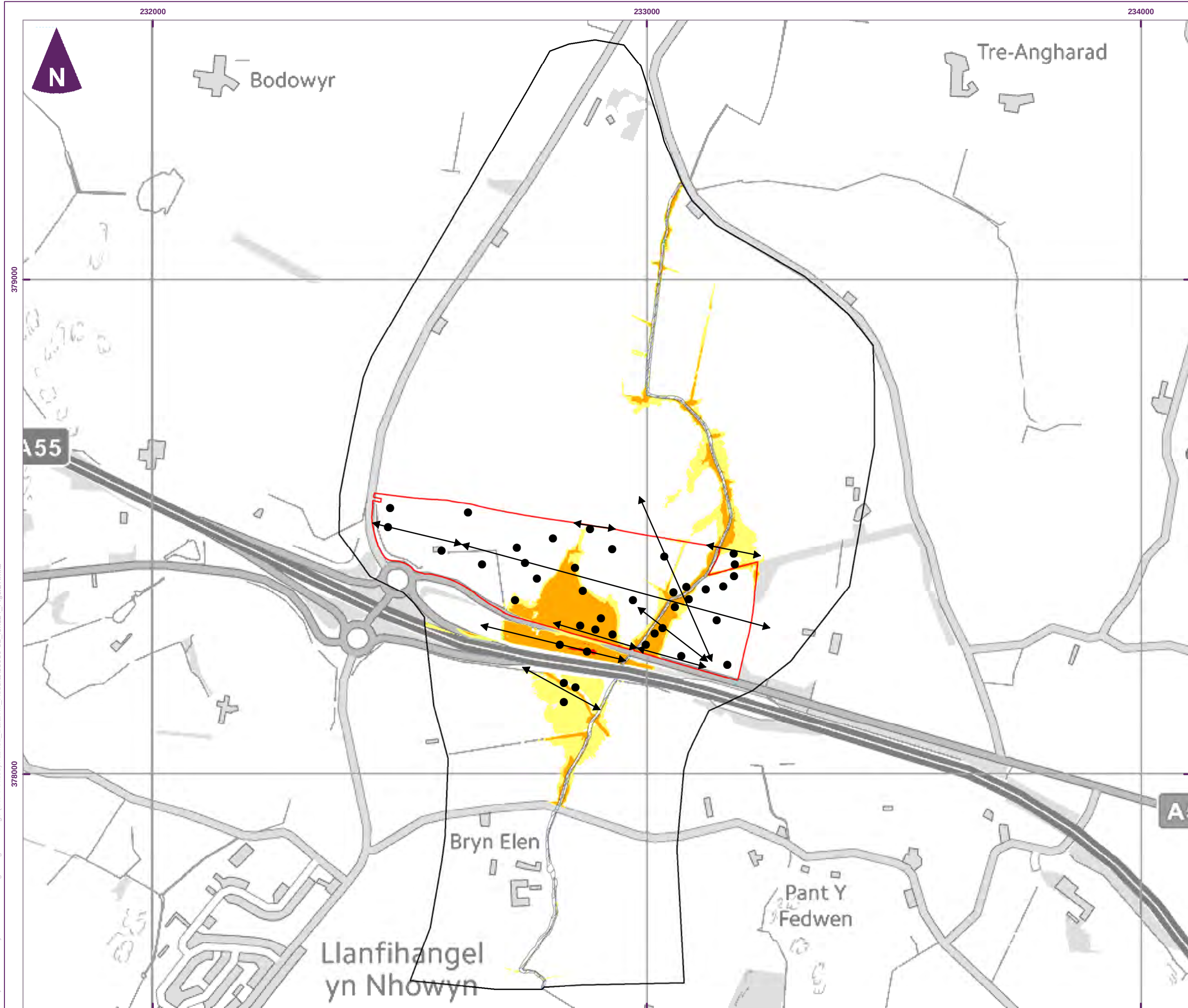
0 100 200 300 400 m
Scale at A3

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Associated
Developments
Hydraulic Modelling

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foster
wheeler

Figure 6.26
Dalar Hir baseline peak fluvial flood
hazard 1:20 year AEP present day

May 2017 35989_Lon523 jamek



Key

Peak flood hazard (HR)
Baseline
1:100 year AEP fluvial
Present day

	< 0.75 Very low hazard - Caution
	0.75 - 1.25 Danger for some - includes children, the elderly and the infirm
	1.25 - 2 danger for most - includes the general public
	> 2 Danger for all - includes the emergency services
	Model boundary
	1D Model Domain
	Site Boundary
	Results Point
	Results Line
	OS Mapping

Notes:
The flood hazard rating is based on the formula and classification documented in the DEFRA Flood Risks to People guidance (FD2321).

Model run date: 22/04/2017

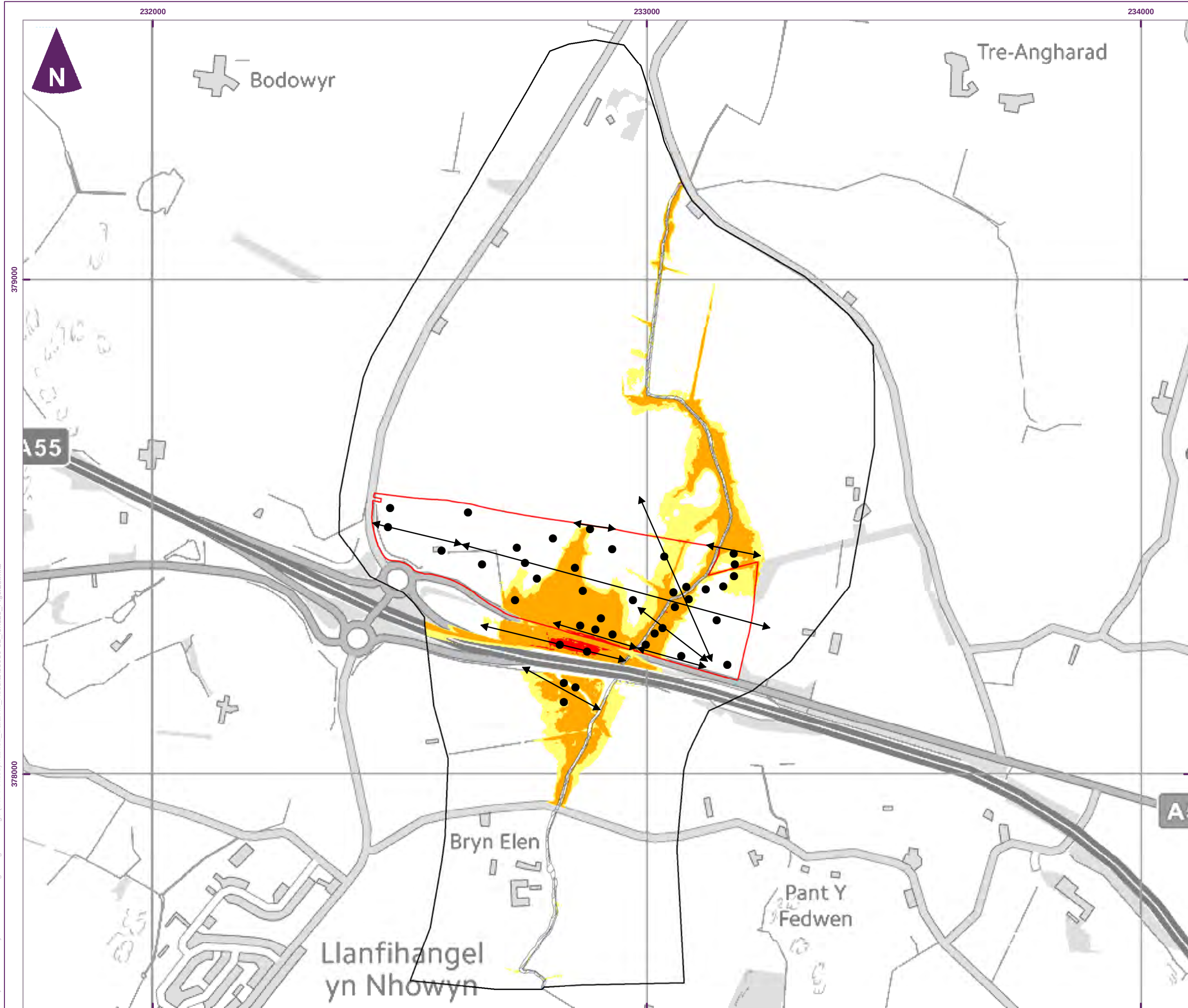
0 100 200 300 400 m
Scale at A3

Wylfa Newydd
Associated
Developments
Hydraulic Modelling

amec
foster
wheeler

Figure 6.27
Dalar Hir baseline peak fluvial flood
hazard 1:100 year AEP present day

May 2017 35989_Lon524 jamek



Key

Peak flood hazard (HR)
Baseline
1:1000 year AEP fluvial
Present day

	< 0.75 Very low hazard - Caution
	0.75 - 1.25 Danger for some - includes children, the elderly and the infirm
	1.25 - 2 danger for most - includes the general public
	> 2 Danger for all - includes the emergency services
	Model boundary
	1D Model Domain
	Site Boundary
	Results Point
	Results Line
	OS Mapping

Notes:
The flood hazard rating is based on the formula and classification documented in the DEFRA Flood Risks to People guidance (FD2321).

Model run date: 22/04/2017

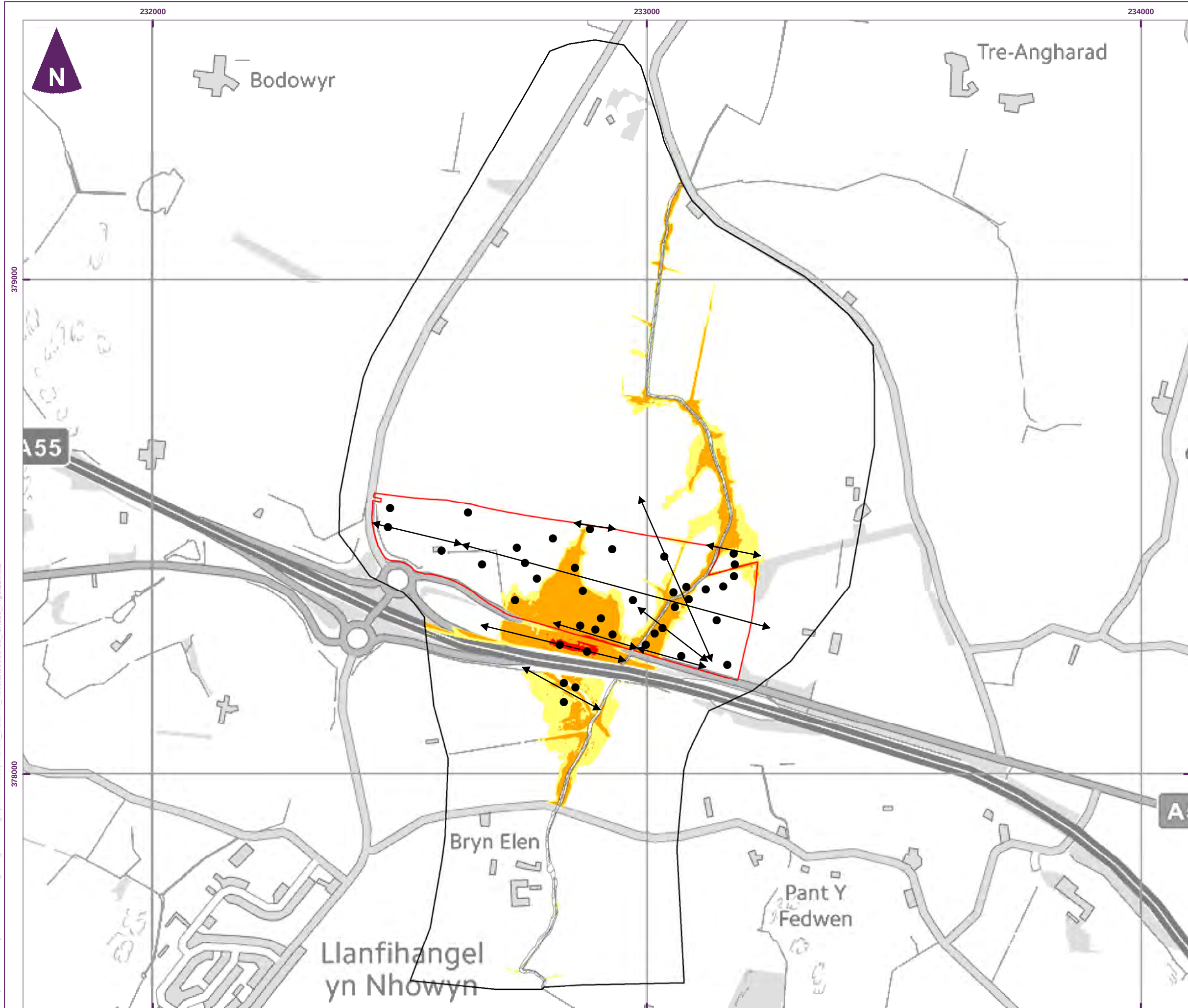
0 100 200 300 400 m
Scale at A3

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Associated
Developments
Hydraulic Modelling

amec
foster
wheeler

Figure 6.28
Dalar Hir baseline peak fluvial flood
hazard 1:1000 year AEP present day

May 2017 35989_Lon525 jamek



Key

Peak flood hazard (HR)
Baseline
1:100 year AEP fluvial
Climate change (30%)

	< 0.75 Very low hazard - Caution
	0.75 - 1.25 Danger for some - includes children, the elderly and the infirm
	1.25 - 2 danger for most - includes the general public
	> 2 Danger for all - includes the emergency services
	Model boundary
	1D Model Domain
	Site Boundary
	Results Point
	Results Line
	OS Mapping

Notes:
The flood hazard rating is based on the formula and classification documented in the DEFRA Flood Risks to People guidance (FD2321).

Model run date: 22/04/2017

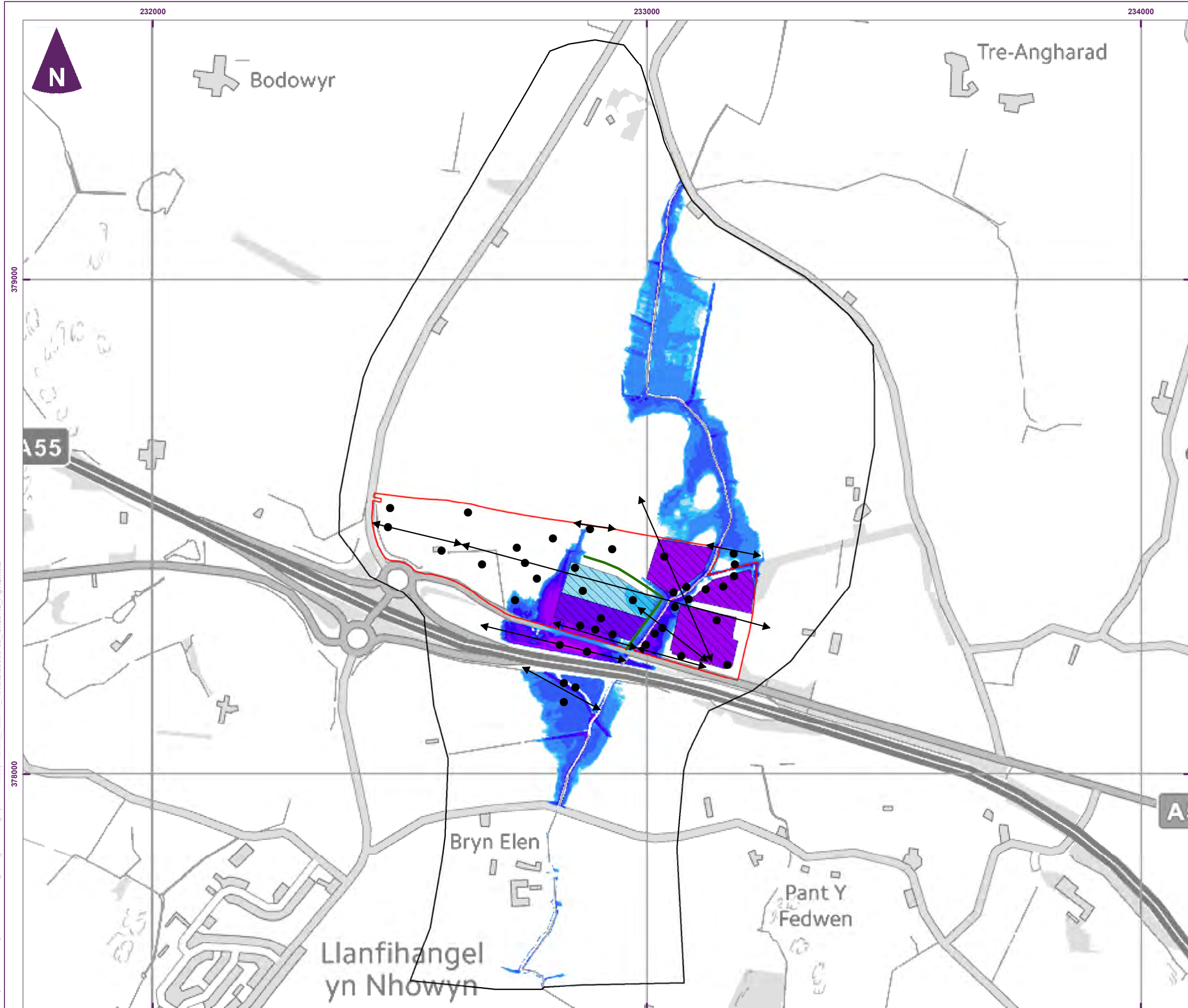
0 100 200 300 400 m
Scale at A3

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Associated
Developments
Hydraulic Modelling

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foster
wheeler

Figure 6.29
Dalar Hir baseline peak fluvial flood
hazard 1:100 year AEP plus climate
change (30%)

May 2017 35989_Lon526 jamek



Key

Peak flood depth (m)
'With development'
1:100 year AEP event fluvial
climate change (30%)

0.01 - 0.05
0.05 - 0.10
0.10 - 0.25
0.25 - 0.50
0.50 - 0.75
0.75 - 1.00
1.00 - 1.50
1.50 - 2.00
> 2.00

Model boundary

1D Model Domain

Site Boundary

Results Point

Results Line

OS Mapping

Area of proposed ground level change

Proposed flood defence wall

Notes:
The depths represent the maximum depth achieved. The flood prediction does not represent a moment in time as maximum depths can be achieved at different times.
Model run date: 23/06/2017
Corresponding data:
35989-C1431_Mit_Fluvial_F100cc.xlsx

0 100 200 300 400 m
Scale at A3

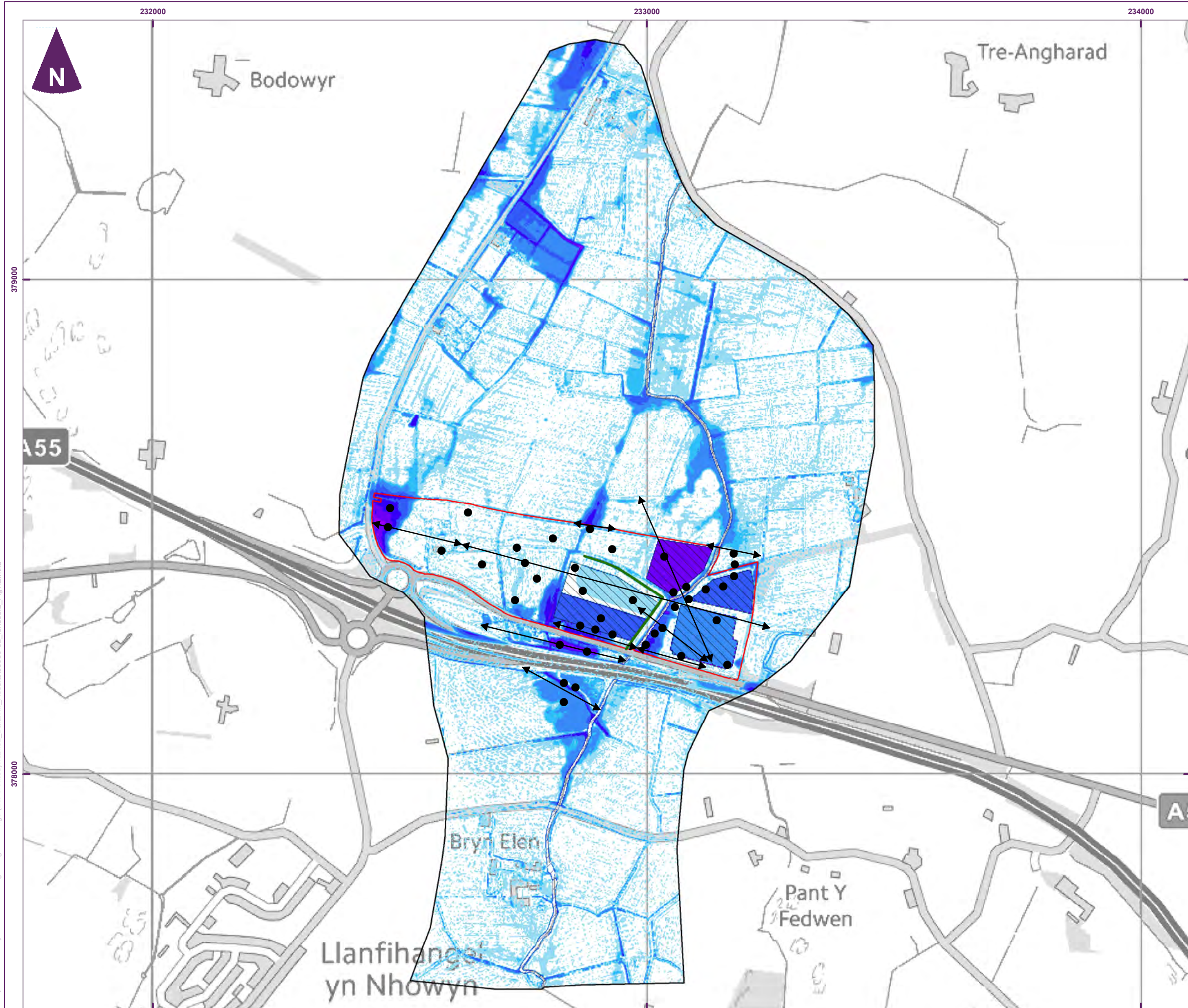
Wylfa Newydd
Associated
Developments
Hydraulic Modelling

amec
foster
wheeler

Figure 7.1
Dalar Hir 'with development' peak
fluvial flood depth 1:100 year AEP
plus climate change (30%)

July 2017

35989_Lon567i1 brams



Key

Peak flood depth (m)
'With development'
1:100 year AEP event pluvial
climate change (40%)

	0.01 - 0.05
	0.05 - 0.10
	0.10 - 0.25
	0.25 - 0.50
	0.50 - 0.75
	0.75 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	> 2.00

Model boundary

1D Model Domain

Site Boundary

Results Point

Results Line

OS Mapping

Area of proposed ground level change

Proposed flood defence wall

Notes:
The depths represent the maximum depth achieved. The flood prediction does not represent a moment in time as maximum depths can be achieved at different times.
Model run date: 24/06/2017
Corresponding data:
35989-C1432_Mit_Pluvial_R100cc40_360m.xlsx

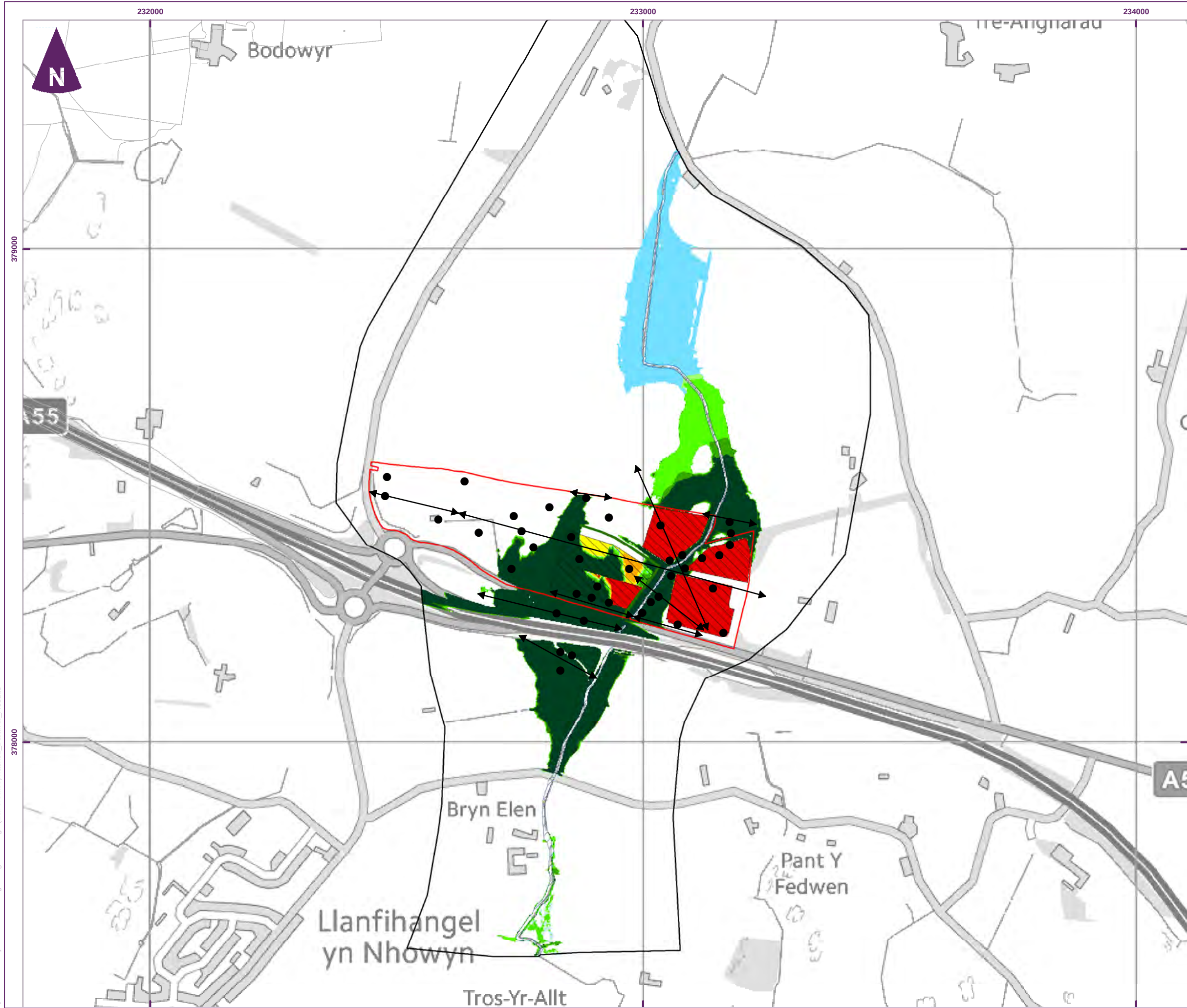
0 100 200 300 400 m
Scale at A3

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Hydraulic Modelling

Figure 7.2
Dalar Hir 'with development' peak
pluvial flood depth 1:100 year AEP
plus climate change (40%)

July 2017

35989_Lon568i1 brams



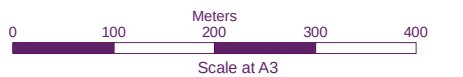
Key

Peak flood depth difference (m)
1:100 year AEP fluvial
Climate change (30%)

- > 0.1
- 0.05 to 0.1
- 0.01 to 0.05
- 0.005 to 0.01
- No Change
- 0.005 to -0.01
- 0.01 to -0.05
- 0.05 to -0.1
- < -0.1
- Model boundary
- 1D Model Domain
- Results Point
- OS Mapping
- Area of proposed ground level change
- Proposed flood defence wall

Notes:
The depths compared use the maximum depth achieved. The flood prediction does not represent a moment in time as maximum depths can be achieved at different times.

Where positive values represent an increase in peak flood depth, and negative values represent a decrease in peak flood depth, as a consequence of the proposed development.



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Associated
Developments
Hydraulic Modelling

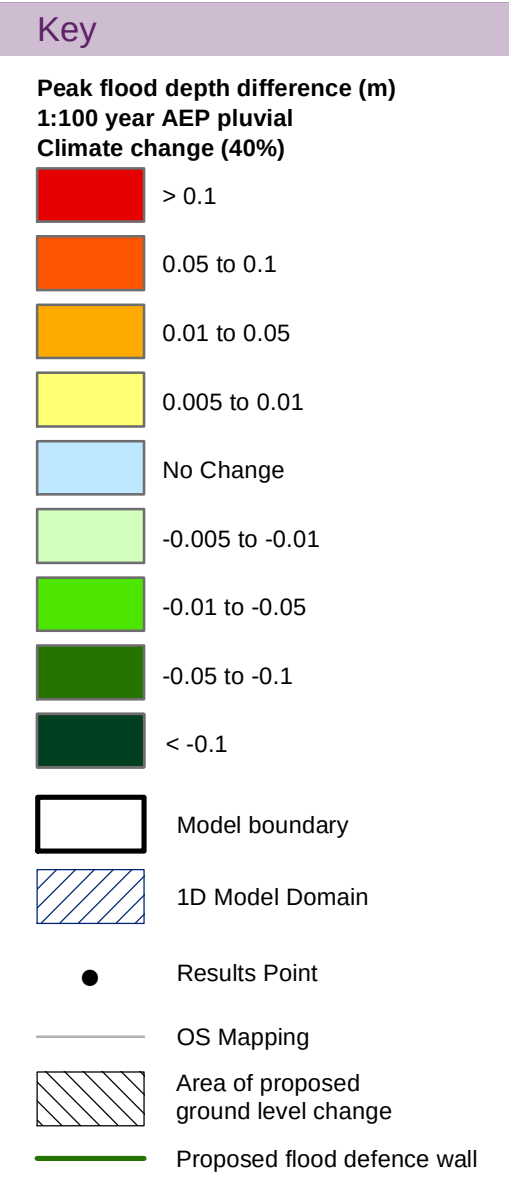
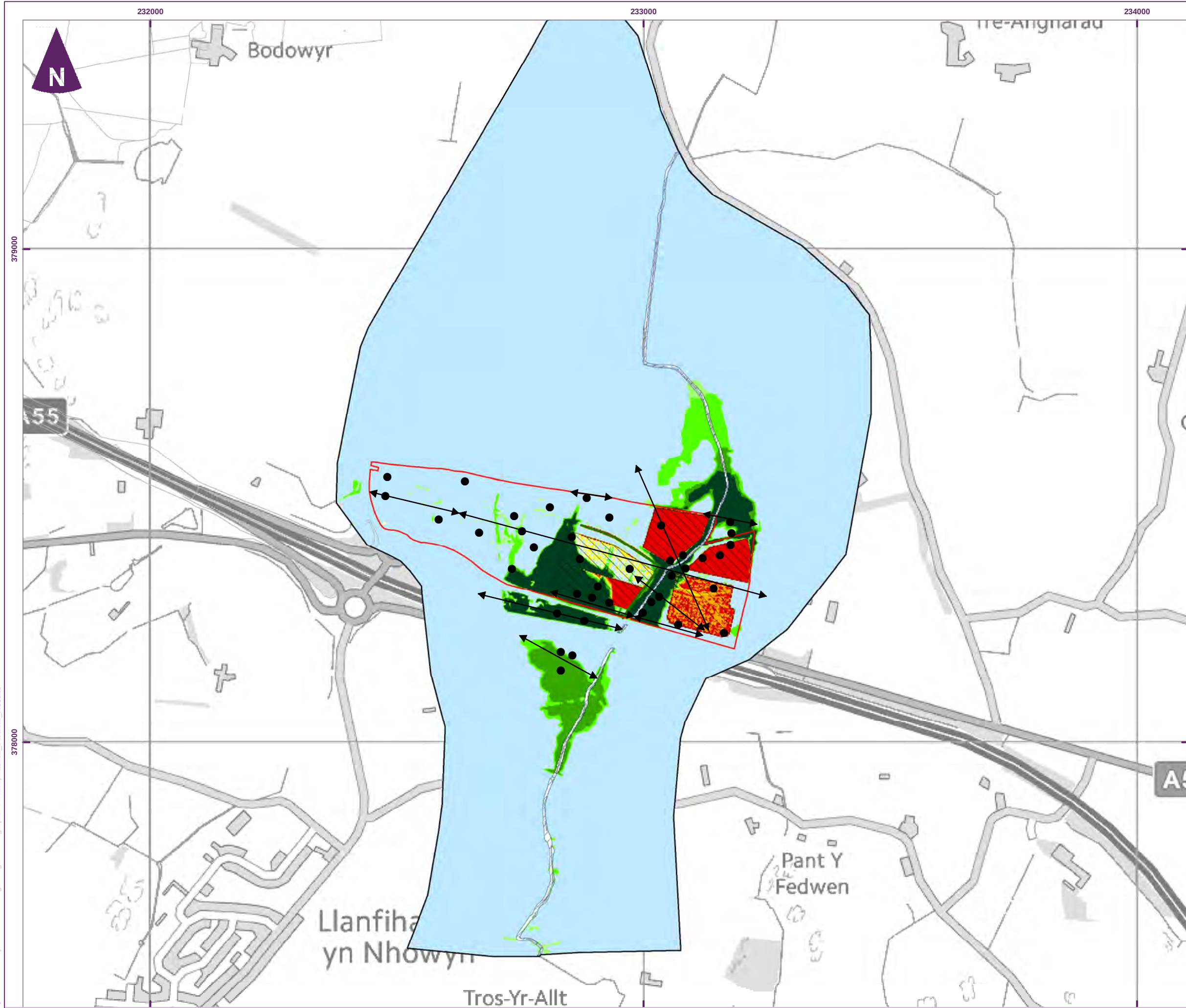


Figure 7.3
Dalar Hir peak depth difference
fluvial 1:100 year AEP plus climate
change (30%)



July 2017

35989-Lon569i1 brams



Notes:
The depths compared use the maximum depth achieved. The flood prediction does not represent a moment in time as maximum depths can be achieved at different times.

Where positive values represent an increase in peak flood depth, and negative values represent a decrease in peak flood depth, as a consequence of the proposed development.

0 100 200 300 400
Meters
Scale at A3

NOT PROTECTIVELY MARKED

Appendix B

Channel roughness representation

Reach	Manning's n roughness value	Evidence/photograph
DALA01_1710 to DALA01_313	In-channel: Clean, winding, but some weeds and stones - 0.045 Banks: Pasture, light brush and trees, in summer – 0.06	 Source DALA01_1710  Source DALA01_1478  Source DALA01_817

NOT PROTECTIVELY MARKED

NOT PROTECTIVELY MARKED

Reach	Manning's n roughness value	Evidence/photograph
DALA01_1710 to DALA01_313	In-channel: Clean, winding, but some weeds and stones - 0.045 Banks: Pasture, light brush and trees, in summer – 0.06	 Source DALA01_720  Source DALA01_528  Source DALA01_313
DALA01_294	Clean, straight, full stage, no rifts or deep pools - 0.035 Banks: Pasture, light brush and trees, in summer – 0.06	 Source DALA01_294

NOT PROTECTIVELY MARKED

NOT PROTECTIVELY MARKED

Reach	Manning's n roughness value	Evidence/photograph
DALA01_269 to DALA01_099	In-channel: Clean, winding, but some weeds and stones - 0.045 Banks: Pasture, light brush and trees, in summer – 0.06	 Source DALA01_269  Source DALA01_099
DALA01_269 to DALA01_099	In-channel: Clean, winding, but some weeds and stones - 0.045 Banks: Pasture, light brush and trees, in summer – 0.06	 Source DALA01_000

NOT PROTECTIVELY MARKED



NOT PROTECTIVELY MARKED

Appendix C

Structure representation

NOT PROTECTIVELY MARKED

NOT PROTECTIVELY MARKED

Structure 1			
Name of Structure	Access Bridge		
OS Grid Ref	SH330783		
Survey reference	DALA01_0916		
Included in Model?	Yes	Model Label / reason for exclusion	DALA01_0916
Model representation	Culvert represented by Spill, Orifice (DALA01_916O1 added. Upstream sill level 14.580, throat invert level 14.750, downstream sill level 14.580 Throat soffit level 15.680. The XS from upstream at DALA01_0916 and reduced by the calculated invert level change downstream. The invert level was calculated as being 0.09 less than upstream and thus the whole DALA01_0916 was reduced by 0.09 for DALA01_0916D. Length 3.6m.		
Coefficients used	Concrete pipe less than grid cell length (2m) so orifice used. Discharge coefficients set at 1.0		
Assumptions	Small orifice/ culvert under track between agricultural fields. Bore area 0.93 cm concrete pipe.		
Photograph			

NOT PROTECTIVELY MARKED

NOT PROTECTIVELY MARKED

Structure 2			
Name of Structure	A5 Culvert		
OS Grid Ref	SH329782		
Survey reference	DALA01_0791		
Included in Model?	Yes	Model Label / reason for exclusion	DALA01_0791
Model representation	Culvert represented by Spill, Conduit 1 (c1 - u/s), Conduit 2 (c2 - d/s) added. Spill units have been used instead of culvert inlet and outlet units for stability and the account for the fact the invert of the pipes is higher than the bed level of the channel. Invert level upstream at 14.66. Soffit level upstream at 15.26. Soffit level downstream at 15.16. The XS from upstream at DALA01_0791 and reduced by the calculated invert level change downstream. The invert level was calculated as being 0.1 less than upstream and thus the whole DALA01_0791 was reduced by 0.1 for DALA01_791D. There is a risk of blockage for this culvert and that 30% blockage would increase flood depths at the site by a maximum of 0.080m and that this should be considered in the FCA. Length 22.4m.		
Coefficients used	Manning's n roughness: 0.012 (Concrete: Conduit, straight and free of debris) Diameter set to 0.6 m.		
Assumptions	22.4 m long culvert under A5 road bridge.		
Photograph			

NOT PROTECTIVELY MARKED

NOT PROTECTIVELY MARKED

Structure 3			
Name of Structure	A55 Culvert		
OS Grid Ref	SH329782		
Survey reference	DALA01_0755		
Included in Model?	Yes	Model Label / reason for exclusion	DALA01_0755
Model representation	Culvert represented by Spill, Culvert Inlet, Culvert 1 (c1 - u/s), Culvert 2 (c2 - d/s), Culvert Outlet added Invert level upstream at 13.96, Soffit level upstream at 14.87. Soffit level downstream at 14.77. The XS from upstream at DALA01_0755 and reduced by the calculated invert level change downstream. The invert level was calculated as being 0.1 less than upstream and thus the whole DALA01_0755 was reduced by 0.1 for DALA01_0755D. Length 36.0m.		
Coefficients used	Manning's n roughness: 0.011 (Concrete: Culvert, straight and free of debris) Culvert Inlet type A. Parameters in 1D - K:078, M: 2, C:0.0292, Y: 0.74, Ki: 0.3 Diameter set to 0.91 m.		
Assumptions	36 m long culvert under A55 road bridge		
Photograph			

NOT PROTECTIVELY MARKED

NOT PROTECTIVELY MARKED

Structure 4			
Name of Structure	Road Bridge (Alltwen Goch)		
OS Grid Ref	SH328779		
Survey reference	DALA01_0434		
Included in Model?	Yes	Model Label / reason for exclusion	DALA01_434
Model representation	Culvert represented by Spill, Culvert Inlet, Culvert 1 (c1 - u/s), Culvert 2 (c2 - d/s), Culvert Outlet added Invert level upstream at 13.80, Soffit level upstream at 14.81. Soffit level downstream at 14.80. The XS from upstream at DALA01_0434 and reduced by the calculated invert level change downstream. The invert level was calculated as being 0.01 less than upstream and thus the whole DALA01_0434 was reduced by 0.01 for DALA01_0434D. Length 9.4m		
Coefficients used	Culvert Inlet type B. Parameters in 1D - K:0.515, M: 0.667, C:0.0375, Y: 0.79, Ki: 0.5 Rectangular Conduit. Manning's n roughness: 0.025 (Concrete: Culvert, straight and free of debris).		
Assumptions	Brick/ Stone lined rectangular culvert through agricultural land.		
Photograph			

NOT PROTECTIVELY MARKED



NOT PROTECTIVELY MARKED

Appendix F8-1-4 Assessment methodology

Assessment methodology

9-1.1.1 In order to allow for the wider assessment of flood risk, a generalised assessment methodology has been developed in line with the risk-based approach detailed by the Welsh Government and recommended elsewhere in industry guidance [RD20]. The key to the classification is that the designation of risk is based upon the consideration of:

- the sensitivity of the receptor – takes into account the nature of the proposals or receptor and its likely response to increased risk;
- the severity of flooding (i.e. the potential magnitude of the hazard) – takes into account the potential nature of the flooding; and
- the likelihood of occurrence (i.e. probability) – takes into account both the presence of the hazard and receptor, and the integrity of the pathway.

Classification of sensitivity of the receptor

9-1.1.2 When considering new developments, the classification of sensitivity is based (where possible) directly on the technical guidance set out within TAN 15 [RD4]. When considering off-site impacts, there is a general assumption that all developments are highly sensitive. This assumption can, however, typically be relaxed when considering a water-compatible development or undeveloped land. Given this, the sensitivity of the receptor is ranked as shown in table F8-1-4.

Table F8-1-4 Classification of sensitivity of receptor

Sensitivity of receptor	New development	Off-site
Very high	Emergency services* developments	All built developments unless mitigating circumstances exist Key access routes
High	Highly vulnerable* developments	Other access routes
Medium	Less-vulnerable* developments	Undeveloped land
Low	Water-compatible ¹ developments	-
Very low	Flood attenuation features	-

* For definitions of terms, please see figure 2 in TAN 15

¹ Category not outlined within TAN 15, but would include any types of development that clearly by their nature often need to be in a floodplain, such as buildings associated with water-sports or pumping stations for low-lying areas.

Classification of the magnitude of hazard

- 9-1.1.3 To classify the severity of the potential flooding, it is necessary to look at the nature and scale of the individual impacts. These include, but are not confined to, the extent, depth and duration of flooding, and the velocity of flood waters. For new developments, the assessment is based on the likely post-development situation; for off-site receptors, it is based solely on the likely deterioration.
- 9-1.1.4 Given this, the severity of the potential flooding (hazard) is then ranked in terms of its magnitude as shown below in table F8-15.

Table F8-1-5 Classification of magnitude of hazard

Magnitude of hazard	New development	Off-site
High	Any one of the following criteria achieved: • flood depths greater than 1m; • flood flow velocities greater than 0.45m/s; or • likely flood duration in excess of 24 hours.	Any marked (>10%) increase in flood depth, flood flow velocity or flood duration Any change in flood extent that impacts additional properties, including access to those properties
Medium	Any one of the following criteria achieved: • flood depths between 0.3m and 1m; • flood flow velocity greater than 0.15m/s; • likely flood duration in excess of one hour; or • any restrictions to access and egress.	Any other measurable increase of flood depths, durations, flow velocities or extent
Low	All of the following criteria achieved: • flood depths below 0.3m; • likely flood duration below one hour; and • flood-proofing measures planned.	Likely but unquantifiable small increases of flood depths, durations, flow velocities or extent
Very low	Planned or permitted flooding that does not adversely impact the built development	-
Negligible	No potential for flooding, or no identifiable impact of flooding	No likely increase in flood severity at any off-site location

Significance of potential effect

- 9-1.1.5 The magnitude of the hazard and the sensitivity of the receptor are combined using a matrix (shown below in table F8-1-6) to determine the significance of the potential effect, if realised.

Table F8-1-6 Matrix for determining the significance of the potential effect

		SENSITIVITY OF RECEPTOR				
		VERY LOW	LOW	MEDIUM	HIGH	VERY HIGH
MAGNITUDE OF POTENTIAL HAZARD	HIGH	Low	Moderate	Moderate	High	High
	MEDIUM	Very low	Low	Moderate	Moderate	High
	LOW	Very low	Very low	Low	Moderate	Moderate
	VERY LOW	Negligible	Very low	Very low	Low	Low
	NEGLIGIBLE	Negligible	Negligible	Negligible	Negligible	Negligible

Classification of likelihood of occurrence

- 9-1.1.6 To classify the likelihood or probability of occurrence for a potential effect, it is necessary to understand how regularly a given event or outcome will occur. This can be assessed in a number of ways, including assessments based on historical data, quantitative analysis or experience from other similar sites. Often, this assessment will be based on standard guidance. The classifications used for defining the likelihood of a potential effect occurring are as shown below in table F8-1-7.

Table F8-1-7 Classification of likelihood of occurrence

Likelihood of occurrence	Potential effect
High	Any consequence would likely appear in the medium term and inevitably in the long term (i.e. the lifetime of the proposed development).
	Equivalent to an annual probability of flooding of greater than 1% (0.5% for tidal).
Medium	Circumstances are such that an event is possible in the medium term and likely over the long term, although not necessarily inevitable.
	Equivalent to an annual probability between 0.1% and 1% (0.1% and 0.5% for tidal).
Low	It is unlikely that any consequence would arise within the lifetime of the proposed development.
	Equivalent to an annual probability of less than 0.1%.
Very low	It is unlikely that any consequence would ever arise.

- 9-1.1.7 It should be noted that in circumstances where sites have flood defences, determining an accurate assessment of probability of flood occurrence is complex, and assumptions that defences will not fail are unlikely to be acceptable. In such cases, assessments cannot be prescriptive and site-

specific assessments would be undertaken. Factors that would be considered include construction, age, condition, maintenance, exposure and other external pressures.

Risk assessment

- 9-1.1.8 Once the significance of the potential effect and likelihood of occurrence have been assessed, these are then combined using a risk matrix (table F8-1-8) to assess the flood risk of each potential effect.

Table F8-1-8 Risk matrix

		LIKELIHOOD OF OCCURRENCE			
		VERY LOW	LOW	MEDIUM	HIGH
SIGNIFICANCE OF POTENTIAL EFFECT	HIGH	Low	Moderate	High	High
	MODERATE	Low	Low	Moderate	High
	LOW	Very low	Low	Low	Moderate
	VERY LOW	Negligible	Very low	Low	Low
	NEGLIGIBLE	Negligible	Negligible	Negligible	Negligible

- 9-1.1.9 Typically, flood risks assessed as Low or less are considered acceptable. If the assessment results in moderate or high risk, this is considered significant (i.e. equivalent to a significant effect under the Environmental Impact Assessment regulations as set out in section 8.4 of Chapter B8 (surface water and groundwater) (Application Reference Number: 6.2.8)), and additional mitigation measures would be required to facilitate development.
- 9-1.1.10 In some situations, the risk assessment procedure will result in an artificially low assessment of risk. This is particularly the case in situations where consequences of very rare flooding (i.e. breach scenarios) are so extreme that any residual risk, however low, would not be allowed. In such instances, the assessed risk would be elevated. Such decisions must always be accompanied by detailed justification.