



Lime Down

Solar Park

9.32 Hydraulic Modelling Report

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Hydraulic Modelling Technical Note

Prepared by: [REDACTED]

For: Lime Down Solar Park

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Reference of Terms

Annual Exceedance Probability (AEP)

The AEP is the chance or probability of a natural hazard event (usually a rainfall or flooding event) occurring annually and is usually expressed as a percentage.

Aquifers

- Principal Aquifers are layers of rock or drift deposits that have high intergranular and/or fracture permeability - meaning they usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale.
- Secondary A Aquifers are 'permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers'.
- Secondary B Aquifers are 'predominantly lower permeability layers which may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering. These are generally the water-bearing parts of the former non-aquifers'.
- Secondary Undifferentiated Aquifers are assigned in 'cases where it has not been possible to attribute either category A or B to a rock type. In most cases, this means that the layer in question has previously been designated as both minor and non-aquifer in different locations due to the variable characteristics of the rock type'.
- Unproductive Strata are 'rock layers or drift deposits with low permeability that have negligible significance for water supply or river base flow'.

Canal Failure

Canal failure can occur due to high-intensity rainfall or structural failure and can be dangerous due to the rapid release of large volumes of water. It is typically limited to raised canal reaches and can result in a rapid peak in flow followed by a gradual reduction.

Climate Change

A change in global or regional climate patterns. For flood risk, climate change is assessed in terms of allowances which are predictions of anticipated change for peak river flow, peak rainfall intensity, sea level rise and offshore wind speed and extreme wave height. Climate change scenario data exists across different epochs (time periods) to determine the needs for climate resilience measures. Climate change data is requested as part of an EAPD request. If a separate Environmental, Social, and Governance (ESG) Flood Risk and Climate Change Assessment is needed, additional climate change data will be required.

Environment Agency (EA) and EA Product Data (EAPD)

The EA is the lead organisation for providing flood and coastal risk management and warnings of flooding from Main Rivers and on the coast. For sites within or in close elevational proximity to Flood Zone 2 or Flood Zone 3, EAPD is ordered to obtain more detailed flood risk data such as flood depths, breach and overtopping mapping and fluvial/tidal risks associated with climate change.

Fluvial Flooding

Fluvial flooding typically occurs when a river's capacity is exceeded, and the excess water overtops the riverbanks. It can also occur when the watercourse has a high level downstream, perhaps due to structures or blockage, thus limiting conveyance. This creates a backup of water which can overtop the banks. Typical

flooding issues occur when the natural floodplain has been urbanised and the river has been confined. EA mapping defines three zones of different flood risk, the third of which is subdivided into two categories:

- Zone 1 “Low probability of flooding” – This zone comprises land assessed as having a less than 1 in 1,000 annual probability of river or sea flooding (<0.1%);
- Zone 2 “Medium probability of flooding” – This zone comprises land assessed as having between a 1 in 100 and 1 in 1,000 annual probability of river flooding (1% – 0.1%), or between a 1 in 200 and 1 in 1,000 annual probability of sea flooding (0.5% – 0.1%) in any year;
- Zone 3a “High probability of flooding” – This zone comprises land assessed as having a 1 in 100 or greater annual probability of river flooding (>1%), or a 1 in 200 or greater annual probability of flooding from the sea (>0.5%) in any year; and
- Zone 3b “Functional floodplain” – A sub-part of Zone 3, this zone comprises land where water has to flow or be stored in times of flood. This zone is not normally included within the national Flood Map for Planning and is calculated where necessary using detailed hydraulic modelling.

Groundwater Flooding

Groundwater flooding is caused by the emergence of water from beneath the ground at either point or diffuse locations when the natural level of the water table rises above ground level. This can result in deep and long-lasting flooding of low-lying or below-ground infrastructure such as underpasses and basements. Groundwater flooding can cause significant damage to property, especially in urban areas, and can pose further risks to the environment and ground stability.

Sewer Flooding

Flooding from sewers primarily occurs when flow entering a system exceeds available capacity or if the network capacity has been reduced through blockage or collapse. In the case of surface water sewers that discharge to watercourses, the same effect can be caused as a result of high-water levels in the receiving watercourse. As a result, water can begin to surcharge the sewer network, emerging at ground level through gullies and manholes and potentially causing flooding to highways and properties. If this occurs flooding can represent a significant hazard to human health due to the potential for contaminants in flood water.

Source Protection Zones

Source Protection Zones (SPZs) are areas of land through which water infiltrates into a groundwater borehole, well or spring that is used for public drinking water supply. These zones show the risk of contamination from potential pollution. SPZ's have been created as public facing boundaries where discrete groundwater bodies within SPZ's have been dissolved on zone number where common boundaries and overlaps have been removed. SPZs are defined around large and public potable groundwater abstraction sites. The purpose of SPZs is to provide additional protection to safeguard drinking water quality through constraining the proximity of an activity that may impact upon a drinking water abstraction.

- Zone 1 (Inner Protection Zone) is defined by a travel time of 50-days or less from any point within the zone at, or below, the water table. Additionally, the zone has as a minimum a 50-metre radius.
- Zone 2: (Outer Protection Zone) - This zone is defined by the 400-day travel time from a point below the water table. Additionally, this zone has a minimum radius of 250 or 500 metres, depending on the size of the abstraction.
- Zone 3: (Total catchment) - This zone is defined as the total area needed to support the abstraction or discharge from the protected groundwater source. A further Zone 4, or ‘Zone of Special Interest’ was previously defined for some groundwater sources.

Surface Water Runoff

Surface water runoff is defined as water flowing over the ground that has not yet entered a drainage channel or similar. It usually occurs because of an intense period of rainfall which exceeds the infiltration capacity of the ground. Typically, runoff occurs on sloping land or where the ground surface is relatively impermeable. The ground can be impermeable either naturally due to the soil type or geology, or due to development which places impervious material over the ground surface (e.g. paving and roads).

Tidal Flooding

Tidal flooding is caused by high tides coinciding with a low-pressure storm system which raises sea and tidal water levels, overwhelming coastal and river defences. This may be made worse by gale-force winds blowing the raised body of water up tidal river basins some distance from the coast, due to floodwater being forced up the tidal reaches of rivers and estuaries. Such flooding may become more frequent in future years due to rising sea levels.

Reservoirs Failure

Reservoir failure can be a particularly dangerous form of flooding as it results in the sudden release of large volumes of water that can travel at high velocity, causing deep and widespread flooding. The likelihood of this occurring is low as large reservoirs are managed in accordance with the Reservoirs Act 1975. The EA's online reservoir inundation map illustrates the maximum flood extents that could occur in the event of a reservoir.

1. Introduction

1.1 Acknowledgement

1.1.1 This report has been prepared for the sole and exclusive use of Lime Down Solar Park in accordance with the scope of work presented via email by Arthian, dated 14/10/2024. This report is based on information and data collected by Arthian. Should any of the information be incorrect, incomplete, or subject to change, Arthian may wish to revise the report accordingly.

1.1.2 Arthian has been instructed to provide hydraulic modelling support to inform the Flood Risk Assessment and Drainage Strategy for **ES Volume 3, Appendix 11-6: Flood Risk Assessment and Drainage Strategy - Lime Down D [EN010168/APP/6.3 (Rev 3)]**. This modelling forms part of the wider suite of Flood Risk Assessment and Drainage Strategy documents submitted in support of the Lime Down Solar Park DCO application.

1.2 Project Understanding

1.2.1 The development comprises solar PV sites, battery energy storage systems (BESS), and the associated cable route corridor. It is divided into five areas (Lime Down A–E) plus the cable route corridor, with the BESS located within Lime Down D.

1.2.2 For Lime Down A, B, C and E, the developable areas have been positioned using relevant strategic Environment Agency (EA) datasets, including the Flood Map for Planning (FMfP) and NaFRA2¹. All development lies outside the current and future fluvial flood extents indicated by these datasets, and strategic mapping is considered sufficient to assess fluvial flood risk. Detailed hydraulic modelling is therefore not required for these parts of the site.

1.2.3 In contrast, the developable area within Lime Down D, which includes the proposed BESS, intersects Flood Zones 2 and 3 in both the current and future Flood Map for Planning. The fluvial flood risk to the site is associated with Gauze Brook, an EA main river flowing through the site.

1.2.4 No EA hydraulic model is available for the Gauze Brook, therefore a new site-specific hydraulic model has been built to refine the fluvial flood risk classification for this area and is detailed within this report.

1.2.5 This report takes into account the following guidance documents:

- <https://www.gov.uk/guidance/using-modelling-for-flood-risk-assessments> - Using modelling for flood risk assessments (2023);
- TUFLOW manual (2025)².

1.3 Project Limitations

¹ EA National Flood Risk Assessment 2 – a significant update on national flood risk that delivers enhanced flood modelling, high-resolution mapping, and improved climate change projections.

² <https://docs.tuflow.com/classic-hpc/manual/2025.1/>

1.3.1 The wider Arthian limitations are contained within Appendix A.

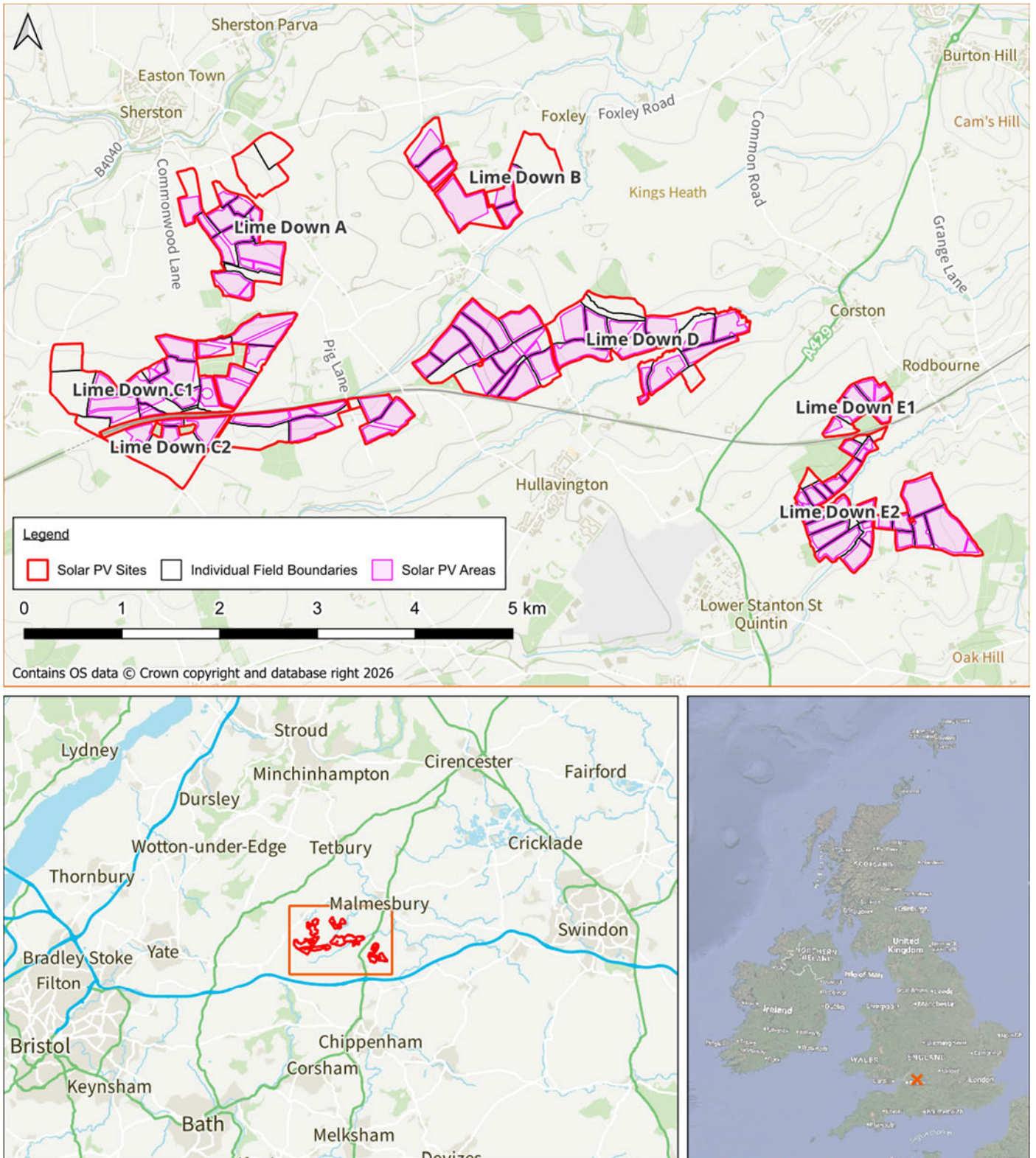


Figure 1: Site location

2. Model Build and Testing

2.1 Model Requirements

2.1.1 A site-specific hydraulic model was developed to quantify fluvial flood behaviour along Gauze Brook within the study area and to generate outputs suitable for Flood Risk Assessment purposes.

2.1.2 The key requirements of the model were to:

- Simulate water levels and flow conveyance along the watercourse for a range of design events;
- Produce flood extents and depths across the model domain;
- Represent in-channel and overbank flow mechanisms influencing floodplain behaviour;
- Assess sensitivity to climate change allowances in accordance with current guidance; and
- Generate mapping and data outputs suitable for informing development layout and flood risk management measures.

2.1.3 The model domain, resolution and parameterisation were selected to provide a stable and hydraulically representative simulation of the watercourse and adjacent floodplain, while remaining proportionate to the scale and purpose of the assessment.

2.1.4 The following section describes the model build, including topographic representation, hydrological inputs, boundary conditions and simulation setup.

2.2 Conceptual Model

2.2.1 The conceptual understanding of flood behaviour at Lime Down D is that fluvial flooding is driven by exceedance of in-channel capacity within Gauze Brook during higher magnitude rainfall events. Overtopping of the channel banks results in shallow floodplain inundation, with flow conveyed along existing topographic depressions and natural overbank storage areas. A potential hydraulic control within the study reach is the culvert beneath the South Wales Main Line, which may influence upstream water levels during larger magnitude events. No formal flood defences are present. Receptors comprise the proposed BESS and associated infrastructure within Lime Down D. The model has therefore been configured to represent in-channel conveyance, culvert control, overbank spill mechanisms and floodplain storage processes in sufficient detail to inform assessment of risk to the developable area.

2.3 Data Sources

Table 1: Data sources used during model development

Data Source	Provider	Date/Age	Comments
Topographic survey	Client	Q1 2025	Good coverage of Lime Down D up to banks of Gauze Brook
Channel survey	Arthian	Q1 2025	Good coverage of the watercourses through the site Structure details such as culvert inverts and diameters included
EA Composite LiDAR DTM	EA	November 2020	Full coverage of study/model area at 1m resolution Good agreement with the topographic survey coverage noted

2.4 Model Setup

Table 2: Model details, methodology, and parameters

Arthian Model Reference and Version:	317212_ENG/09_v9
Simulation Type:	Fluvial
Model Type:	1D-2D
Software Builds:	Flood Modeller 7.3 TUFLOW Classic 2025.2.2 <i>(latest builds available at the time of simulation)</i>
Number of Domains and Extent:	Single domain – the model extent is shown in Figure 2.
DTM Data Sources:	LiDAR flown for the EA in March 2020 was used as the base DTM for this model – full model coverage at 1m resolution. This remains the latest data available at the time issue. Topographic survey levels showed good correlation with underlying LiDAR DTM data and has been stamped on top where available.
Cell Size:	2m – suitable to represent key flow paths without significantly impacting model run times
Building Representation:	Very few buildings are present within the model domain, however, OS MasterMap data was used to define land use, including building footprints. High roughness applied to all buildings to represent internal walls and contents – $0.5s/m^{1/3}$.
Existing Flood Defences:	No known formal flood defences were present within the study area.

Roughness Approach and Values:	<p>Manning’s n based on Chow (1959)³, survey, photographs, and aerial imagery. Land use based on OS MasterMap data.</p> <table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: left; border-bottom: 1px solid black;">Land Use Type</th> <th style="text-align: right; border-bottom: 1px solid black;">Roughness (s/m^{1/3})</th> </tr> </thead> <tbody> <tr> <td>General surface</td> <td style="text-align: right;">0.030</td> </tr> <tr> <td>Industrial land.....</td> <td style="text-align: right;">0.030</td> </tr> <tr> <td>Land/gardens</td> <td style="text-align: right;">0.060</td> </tr> <tr> <td>Rough ground/scrub</td> <td style="text-align: right;">0.080</td> </tr> <tr> <td>Roads, tracks, and paths.....</td> <td style="text-align: right;">0.020</td> </tr> <tr> <td>Buildings</td> <td style="text-align: right;">0.500</td> </tr> <tr> <td>Inland waters.....</td> <td style="text-align: right;">0.030</td> </tr> </tbody> </table>	Land Use Type	Roughness (s/m ^{1/3})	General surface	0.030	Industrial land.....	0.030	Land/gardens	0.060	Rough ground/scrub	0.080	Roads, tracks, and paths.....	0.020	Buildings	0.500	Inland waters.....	0.030
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Boundary Conditions:	<p>Design inflows were derived from a site-specific hydrological assessment for Gauze Brook and a northern tributary using ReFH2 rainfall-runoff and Flood Estimation Handbook (FEH) Statistical methods in line with current EA guidance, with FEH Statistical peaks being higher and therefore taken forward as a more conservative estimate of flood risk at the site. The FEH depth duration frequency (DDF) 22 rainfall dataset has been used in the assessment. Peak flows and hydrographs were calculated at the downstream extent of the delineated catchments and distributed to upstream inflow locations using proportional catchment area weighting.</p> <p>Inflow boundaries were applied at key upstream nodes along Gauze Brook and the northern tributary. An additional southern tributary was represented as a 2D inflow to the model domain to account for its hydrological contribution without explicit in-channel representation.</p> <p>Climate change uplifts for the Avon Bristol and North Somerset Streams Management Catchment are presented below, with the 2080s higher value of +39% being used to inform the design event for this scheme:</p> <table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: left; border-bottom: 1px solid black;">Scenario</th> <th style="text-align: right; border-bottom: 1px solid black;">2020s</th> <th style="text-align: right; border-bottom: 1px solid black;">2050s</th> <th style="text-align: right; border-bottom: 1px solid black;">2080s</th> </tr> </thead> <tbody> <tr> <td>Central</td> <td style="text-align: right;">+10%.....</td> <td style="text-align: right;">+12%</td> <td style="text-align: right;">+26%</td> </tr> <tr> <td>Higher</td> <td style="text-align: right;">+15%.....</td> <td style="text-align: right;">+19%</td> <td style="text-align: right;">+39%</td> </tr> <tr> <td>Upper</td> <td style="text-align: right;">+27%.....</td> <td style="text-align: right;">+38%</td> <td style="text-align: right;">+71%</td> </tr> </tbody> </table> <p>Flows are presented in Table 3.</p> <p>Downstream conditions were defined using a normal depth boundary based on channel bed gradient.</p> <p>A separate Flood Estimation Calculation (FEC) Record is available upon request and provides full details of the hydrological assessment, including catchment descriptors, donor station selection, QMED estimation, pooling group composition and ReFH2 design hydrograph derivation.</p>	Scenario	2020s	2050s	2080s	Central	+10%.....	+12%	+26%	Higher	+15%.....	+19%	+39%	Upper	+27%.....	+38%	+71%
Scenario	2020s	2050s	2080s														
Central	+10%.....	+12%	+26%														
Higher	+15%.....	+19%	+39%														
Upper	+27%.....	+38%	+71%														

³ Chow, V.T. (1959) Open Channel Hydraulics. McGraw-Hill, New York.

<p>Structures:</p>	<p>All structures identified during the channel survey were reviewed as part of the model build. Features considered likely to influence conveyance and water levels were represented within the model using surveyed or estimated dimensions as appropriate.</p> <p>A number of minor structures, including informal plank footbridges, were not explicitly included. Initial testing indicated that their representation introduced additional instability and unnecessary complexity to the model without materially affecting water levels, flow routes or flood extents. These features were therefore omitted on the basis that they are not hydrodynamically significant at the scale of the assessment and their exclusion does not influence the modelled flood risk outcomes.</p> <p>A culvert conveying Gauze Brook beneath the South West Wales Mainline railway was not accessible during the channel survey and therefore could not be measured directly. Its dimensions and levels were estimated from site observations, topographic data and engineering judgement and incorporated within the model accordingly. Sensitivity testing was undertaken to understand the influence of reasonable variations in culvert size on upstream water levels and flood extents.</p> <p>Orifice “GAU_3290ou” within the model has been included to represent hydraulic connectivity between the main river channel and an adjacent topographic depression identified from the LiDAR and underlying mapping. The feature is evident as a secondary flow path running broadly parallel to the main river and has the potential to convey flow during higher magnitude events.</p> <p>The downstream sill level currently reported for GAU_3290ou contains a typographical error and should be 87.00 mAOD rather than 7.00 mAOD. This discrepancy has been identified through the EA review process. The model is currently being revisited as part of ongoing Natural Flood Management (NFM) investigations, and this minor amendment will be incorporated as part of that update. Given the localised nature of the structure and its function within the model, no material change to the model results or conclusions is anticipated.</p>
<p>Post-Development Layout:</p>	<p>Discussed in section 2.5.</p>
<p>Other DTM Adjustments:</p>	<p>Bank elevations have been defined primarily using the available topographic survey data, which focused on the channel corridor and immediate floodplain rather than the entirety of the model domain. Localised differences between the adopted bank elevations and LiDAR data are expected due to differences in survey coverage, data capture methodologies, vegetation effects and the interpretation required during model construction. The surveyed levels have been used in preference where available as they provide the most reliable representation of key hydraulic features. Initial model testing demonstrated good agreement with existing flood mapping, providing confidence that the adopted bank elevations appropriately represent floodplain connectivity and flow routing within the model.</p>
<p>Timestep:</p>	<p>1D – 0.25s 2D – 1s</p>

<p>Initial Conditions:</p>	<p>Consistent initial conditions for all simulations were generated using a single preceding run with constant inflow applied at all upstream boundaries. This allowed water levels and channel storage to establish across the model domain prior to the design event simulations, improving numerical stability and reducing model warm-up effects. Outputs from this constant flow run were then used to initialise each subsequent event simulation.</p>
<p>Non-Default Parameters:</p>	<p>Numerical solution parameters were reviewed during model development to ensure stable and reliable convergence of the 1D solver. The Preissmann weighting factor (theta) was increased from the default value of 0.7 to 0.8 to introduce additional numerical damping and reduce local oscillatory behaviour observed within the channel network. The iteration weighting parameter (alpha) was reduced to 0.6 and applied alongside an increase in the minimum iteration setting to smooth transitions between successive iterations while allowing sufficient solver refinement at each timestep. These adjustments were implemented to support numerical stability and mass balance performance in a complex fluvial system and were verified through sensitivity testing to have no material influence on predicted water levels, flows or flood extents.</p>
<p>Further Comments:</p>	<p>Topographic survey data has been used in preference to LiDAR where available, with LiDAR utilised only in areas not covered by survey. The vicinity of model links “GAU_400FPlu” and “GAU_400FPru” is characterised by dense vegetation, which can adversely affect the accuracy of LiDAR-derived elevations. Consequently, some differences between LiDAR-derived topography and model spill elevations are to be expected. In addition, the implementation of SX connections requires localised modification of the underlying 2D cell elevations to facilitate stable hydraulic connectivity between model domains. These adjustments are highly localised and are not considered to materially affect flood routing or model predictions. The adopted spill elevations are considered appropriate based on the available survey information and provide a realistic representation of floodplain flow routing within the model. As part of the ongoing NFM study, the model is being further developed and refined, and the representation of this area may be reviewed as part of that wider update.</p>

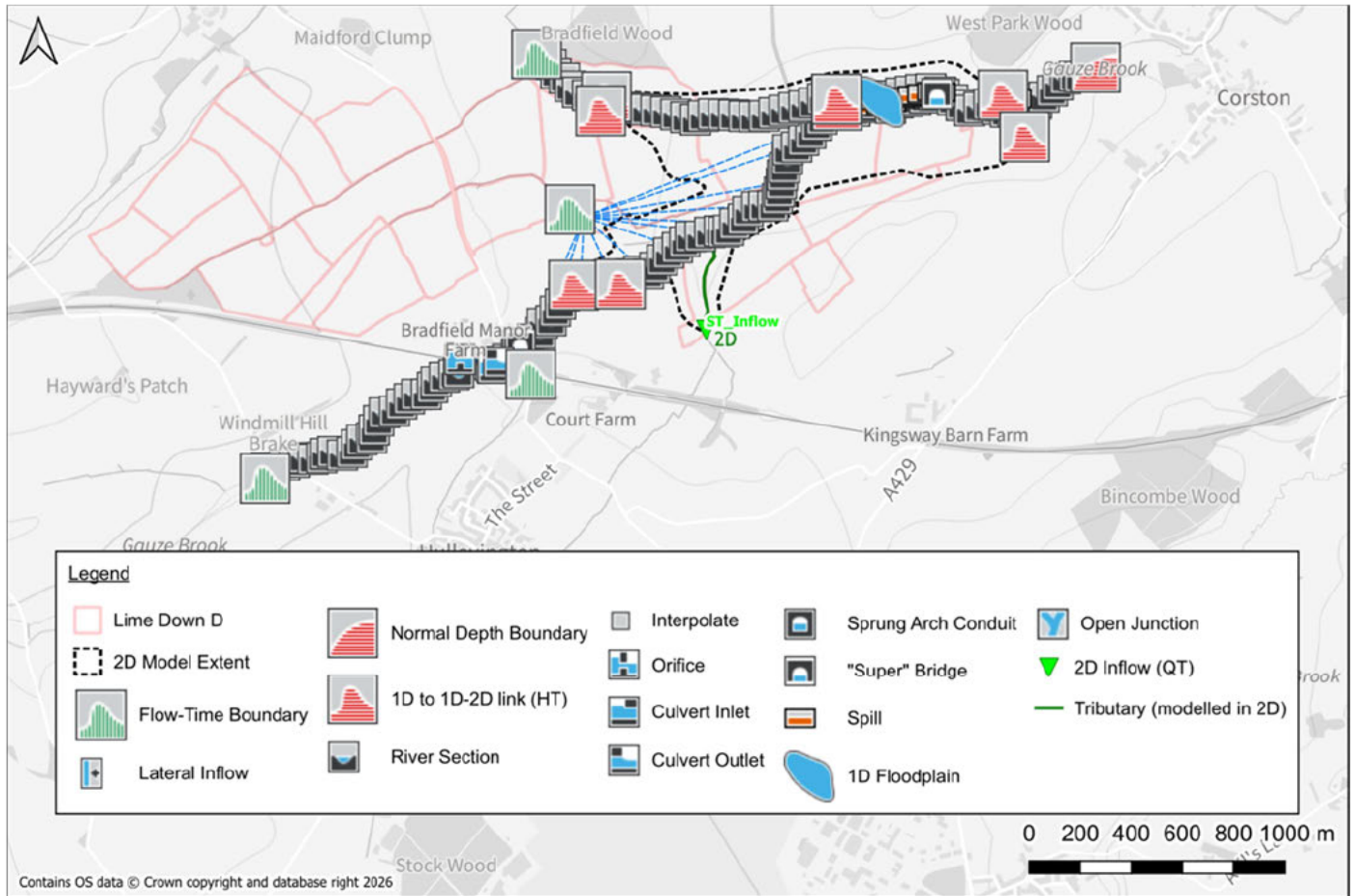


Figure 2: Model extent

Table 3: Modelled inflows (FEH Statistical)

Fluvial Event (AEP)	Gauze Brook (m ³ /s)	Northern Tributary (m ³ /s)	Total (m ³ /s)
3.3%	8.18	1.96	10.1
1%	10.8	2.65	13.5
0.1%	17.6	4.62	22.2
1% +39%CC (higher)	15.0	3.68	18.7
1% +71%CC (upper)	18.5	4.53	23.0
0.1% +39%CC (higher)	24.5	6.42	30.9
0.1% +71%CC (upper)	30.1	7.90	38.0

2.5 Simulated Flood Events and Scenarios

The model was used to simulate three present-day fluvial events: 3.3%, 1%, and 0.1% Annual Exceedance Probability (AEP) as well as the 1% AEP +39% climate change and 1% AEP +71% climate change events.

2.5.1 Only the baseline (pre-development) scenario was modelled, as the proposed solar development and BESS does not involve significant changes to topography, land use, or drainage characteristics that would affect the modelled flood response. As such, the development is not expected to materially alter flood risk within the model domain.

Hydraulic Model Resolution – Purpose and Application

2.5.2 Hydraulic models are typically developed at a scale appropriate to the study objectives, balancing representation of flood behaviour across catchments and floodplains with computational stability and simulation time. As such, models commonly utilise grid resolutions in the order of 2m to 15m (or greater in some applications), depending on the level of detail required and available data.

2.5.3 This scale of modelling is appropriate for:

- Defining flood extents, levels and depths across large areas;
- Supporting planning-level Flood Risk Assessments (FRAs); and
- Identifying broad flow routes and floodplain behaviour.

2.5.4 However, by definition, hydraulic models do not resolve very small-scale features. Elements with dimensions significantly smaller than the model cell size, such as individual solar panel support posts and associated infrastructure, fall below the effective resolution of the model and are not explicitly represented, even where relatively fine grids (e.g. 2m) are applied.

2.5.5 This is an inherent and accepted limitation of all hydraulic modelling. Model resolution is selected to balance accuracy, stability and computational practicality, and is not intended to capture sub-grid scale features.

2.5.6 Accordingly, hydraulic models remain entirely suitable for site-specific flood risk assessment where the objective is to define flood levels and inform development design, provided their limitations are appropriately understood and accounted for.

Use of Baseline Model Outputs

2.5.7 The baseline (pre-development) hydraulic model setup provided for this assessment has been used to extract flood levels and depths across the site for the relevant design events.

2.5.8 Baseline outputs from this modelling have been used to:

- Inform the layout of the solar development, both panels and BESS;
- Position infrastructure outside of higher-risk areas where practicable;
- Set finished levels and panel elevations, typically with an appropriate freeboard above the design

flood level; and

- Confirm that the panels themselves remain above the modelled flood surface and do not interact with flood flows under design conditions.

2.5.9 This approach is consistent with standard practice and ensures that the primary development elements do not introduce obstruction to floodplain storage or conveyance.

Limitations of Post-Development Modelling

2.5.10 Explicitly modelling the post-development scenario within the hydraulic model is not considered appropriate or proportionate for the following reasons:

Scale Mismatch

2.5.11 The characteristic dimensions of solar panel support posts (typically on the order of 0.1m) are an order of magnitude smaller than the model grid resolution (2m). As such:

- The supports cannot be resolved explicitly within the model grid; and
- Any attempt to represent them directly would be numerically meaningless.

Use of Proxy Methods

2.5.12 Alternative approaches sometimes used include:

- Storage reduction factors;
- Artificial flow constrictions; and
- Increased roughness coefficients.

2.5.13 Whilst each of these methods appears simple initially, they often bring significant assumptions and uncertainty.

- They operate at the scale of the model cell and can therefore vastly over-represent the physical obstruction;
- They may introduce disproportionate and non-physical changes to flow behaviour;
- They can be highly sensitive to subjective parameter selection such as roughness increases and therefore lack robustness; and
- They are likely to significantly overestimate impacts rather than provide a realistic representation as a result.

2.5.14 Given the extremely small scale of the supports relative to the floodplain and model resolution, these methods would reduce model reliability rather than improve it.

Quantitative Assessment of Displacement

2.5.15 In lieu of inappropriate model manipulation, a direct volumetric assessment of displacement has been undertaken where necessary.

2.5.16 The methodology used in this assessment is as follows:

1) Identification of Locations

Proposed panel support locations are overlaid onto the baseline model outputs.

2) Extraction of Flood Depths

Flood depths at each support location are obtained from the baseline results.

3) Calculation of Displaced Volume

The flood depth at each location is multiplied by the cross-sectional area of the support to determine the displaced volume.

4) Summation and Conservatism

The total displaced volume is summed across all supports and conservatively rounded up.

5) Redistribution of Volume

The total volume is distributed across an appropriate flooded area, selected based on local hydraulic conditions (e.g. areas of comparable flood level or the wider flood extent within the development boundary).

6) Resulting Level Change

The predicted change in flood level is calculated as:

$$Level\ increase = Volume / Area$$

2.5.17 This approach provides a transparent, physically representative and conservative estimate of potential impact.

2.6 Model Assumptions and Limitations

2.6.1 The hydraulic model has been developed using industry-standard methods in accordance with current EA guidance. Nevertheless, all models are simplifications of real-world systems, and several assumptions and limitations apply.

Topography and survey data: The model topography is based on topographic survey data where available, supplemented by EA LiDAR (1m resolution) elsewhere. This is assumed to be representative of current ground levels. Small-scale features such as embankments, field boundaries, or minor channels

outside the topographic survey coverage and below the resolution of the LiDAR may not be fully captured. However, a desktop review of the catchment and comparison with existing flood mapping datasets indicate that the model is performing appropriately.

Hydrological inputs: Hydrological inflows were derived using ReFH2 rainfall-runoff modelling and FEH Statistical analysis in line with current EA guidance, with ReFH2 used to define hydrograph shape and FEH methods used to inform peak flow estimation. Catchment losses were accounted for within the hydrological assessment and not represented explicitly within the hydraulic model. Design flows were applied at model inflow locations and distributed using proportional catchment area weighting, which is considered appropriate given the relatively small, predominantly rural catchment and the proportionate scope of the assessment.

Downstream boundary condition: Downstream water levels are controlled using a normal depth boundary condition derived from the local channel slope at the downstream extent of the model. This approach was adopted due to limited survey coverage beyond the model domain and the absence of known hydraulic controls further downstream. Sensitivity testing was undertaken to assess the influence of reasonable variations in the assumed slope on modelled water levels and flood extents; results indicated no material change within the study area, and the adopted boundary condition is therefore considered appropriate and proportionate for the purposes of this assessment.

Railway culvert: The culvert conveying Gauze Brook beneath the South Wales Main Line was not accessible during survey and therefore its dimensions, levels and condition could not be confirmed directly. The structure was assumed to comprise a brick-built sprung arch culvert based on the age of the railway and typical construction practice, with dimensions estimated from visual interpretation of the channel cross-section (approximately 2.5m base width, 1.5m springing height above bed level and 1.0m arch rise). Sensitivity testing was undertaken to assess the influence of reasonable variations in culvert size on modelled water levels and flood extents; results indicated no material change within the study area, and the adopted representation is therefore considered appropriate and proportionate for the purposes of this assessment.

2.7 Model Health and Stability

- 2.7.1 A review of the log files confirms that there are no comments, warnings or errors warranting attention.
- 2.7.2 Mass balance error statistics show the 1D model achieves between $\pm 1\%$ mass balance error for all primary simulations.
- 2.7.3 The 2D mass balance error peaks at over -5% during the initial wetting phase of each primary simulation, when a relatively small number of cells first become active and total water volumes within the domain are low. At this stage, small absolute differences between inflow, outflow and storage can translate into a larger percentage value. As flooding becomes established and the overall water volume within the model increases, the mass balance percentage reduces and remains close to zero for the main duration of the event. This indicates that the higher percentage is associated with the early activation of isolated floodplain cells rather than widespread hydraulic behaviour, and that mass conservation during the primary flooding phase is good. Mass balance error during the simulation peak is within $\pm 1\%$.

2.7.4 There are no negative depths reported in any primary simulations.

Results Summary

2.7.5 Shallow depth flooding (<300mm) is present across Lime Down D during the 3.3% AEP event, showing parts of Lime Down D to lie within the functional floodplain.

2.7.6 During the 1% AEP +39% climate change event (the design event – higher climate change scenario), floodplain inundation across Lime Down D is generally shallow, with depths typically less than 300mm over much of the site. Areas of greater depth are largely confined to the main watercourse corridor and immediate overbank margins. Predicted flow velocities across the wider floodplain are generally low (typically <0.5 m/s), with only localised increases within the channel and defined conveyance routes where velocities marginally exceed 1.0 m/s. The overall hydraulic response across the developable area is therefore characterised by shallow, low-energy overbank flow rather than deep or fast-flowing conditions.

2.7.7 Flood depths remain shallow (< 300mm) across Lime Down D during the 1% AEP +71%CC event.

Maximum flood depths the 3.3% AEP, 1% AEP +39%CC, and 1% AEP +71%CC events are presented in Figure 3, Figure 4, and Figure 5 respectively.

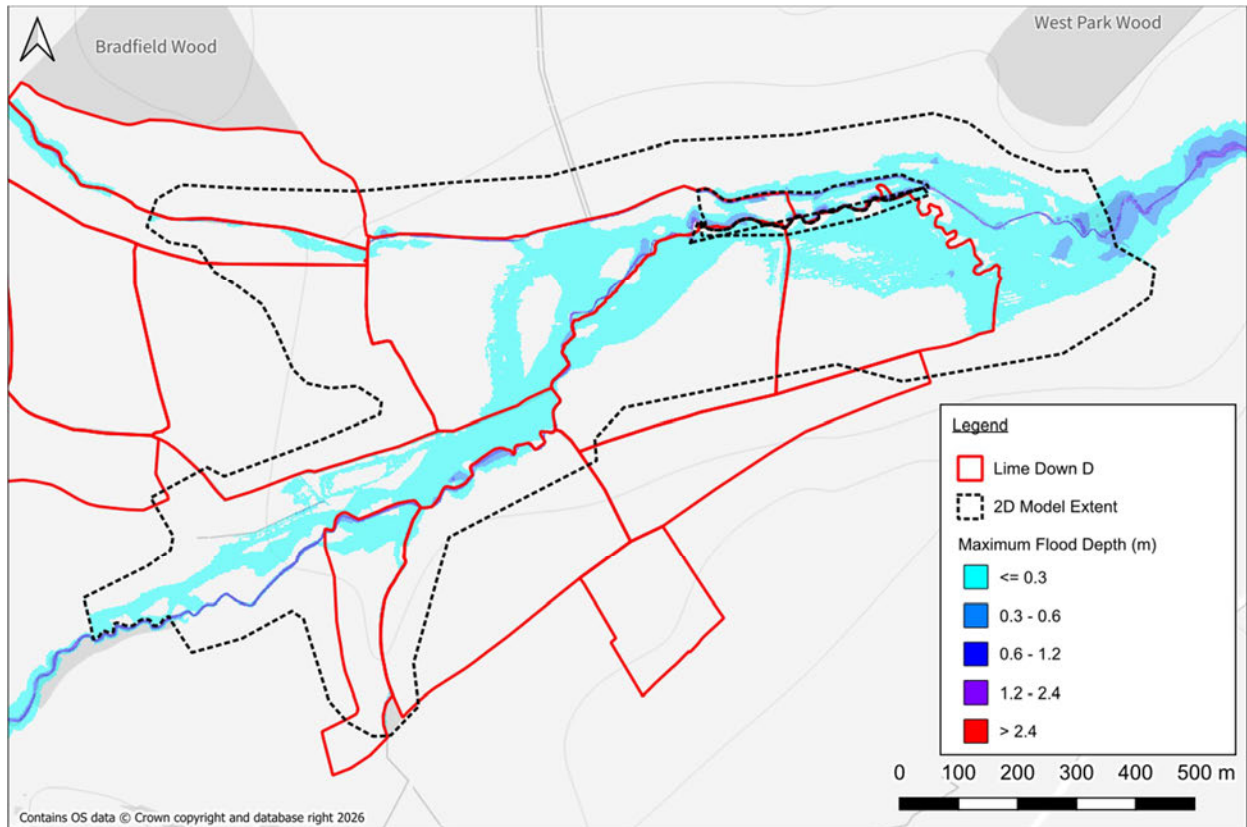


Figure 3: Maximum flood depths at Lime Down D, 3.3% AEP fluvial event, baseline site layout

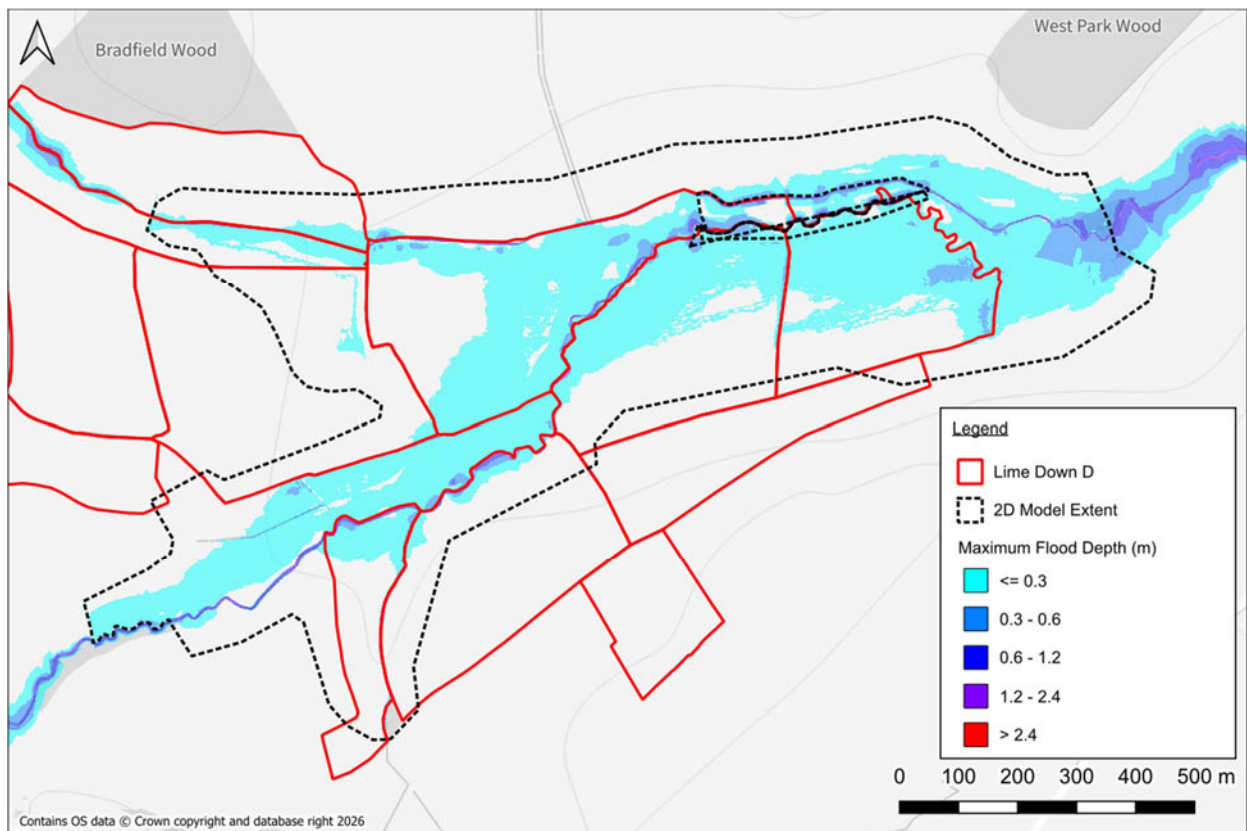


Figure 4: Maximum flood depths at Lime Down D, 1% AEP +39% climate change fluvial event, baseline site layout

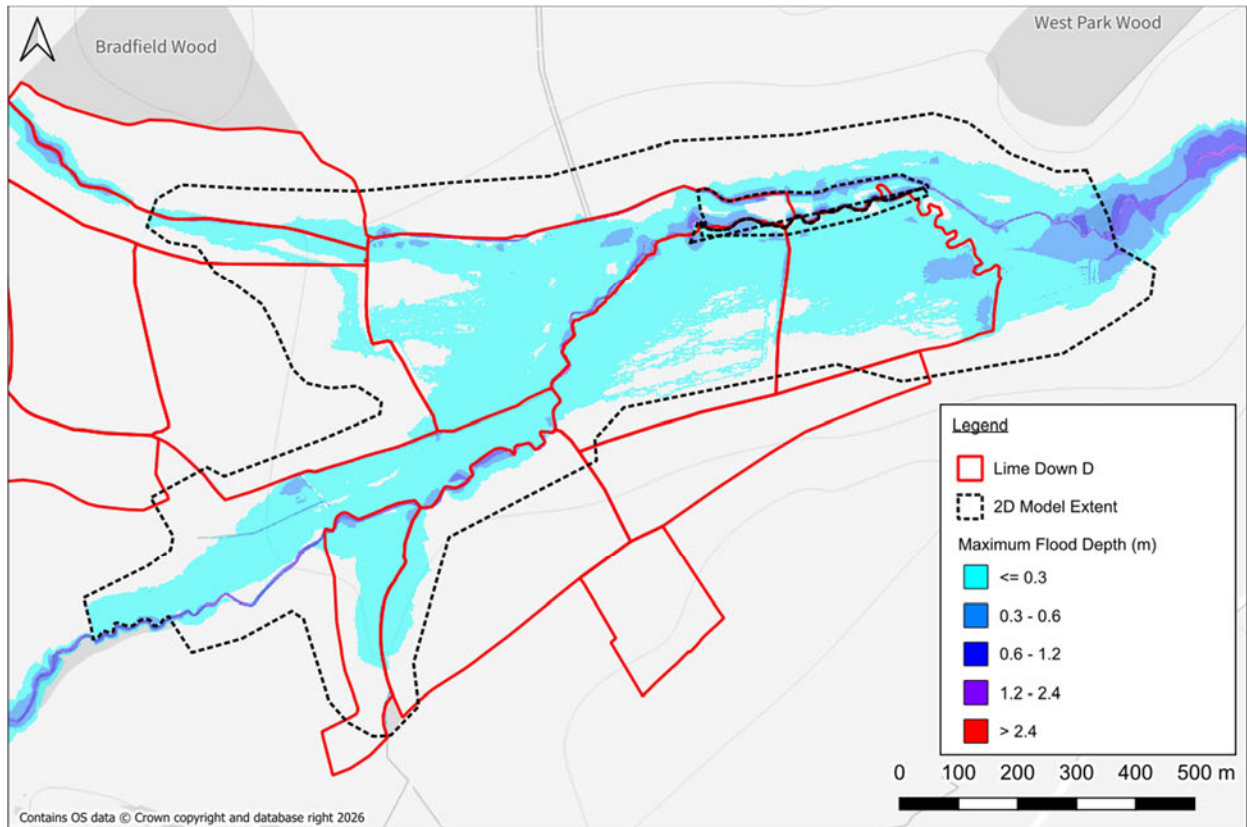


Figure 5: Maximum flood depths at Lime Down D, 1% AEP +71% climate change fluvial event, baseline site layout

2.8 Model Verification and Sensitivity Testing

2.8.1 A comparison has been undertaken between the 1% AEP +39% climate change modelled flood extent and the EA FMfP + climate change extent. The results demonstrate a good overall level of agreement in terms of the spatial distribution of flooding and the general extent of inundation along the main watercourse corridor. Minor localised differences are present, which are expected given differences in model resolution, topographic representation and underlying hydraulic assumptions. However, there is no material divergence in the predicted floodplain behaviour across Lime Down D, and the site-specific modelling is considered to provide a robust and proportionate refinement of the strategic Flood Map for Planning dataset.

2.8.2 Sensitivity testing was undertaken on key model parameters to assess the robustness of results. The following variations were applied to the 1% AEP +39% climate change simulation:

- ST1 and ST2 – roughness: $\pm 20\%$
- ST3 and ST4 – inflows: $\pm 20\%$
- ST5 and ST6 – downstream boundary condition slope: $\pm 30\%$
- ST7 and ST8 – South Wales Main Line culvert – width: $\pm 20\%$ ($\pm 0.5\text{m}$)

2.8.3 The adopted sensitivity ranges ($\pm 20\%$ for roughness and inflows, $\pm 30\%$ for downstream boundary slope, and $\pm 20\%$ for culvert dimensions) are considered proportionate and representative of reasonable uncertainty in hydrological estimation, roughness parameterisation and assumed structure geometry for a rural catchment of this scale. A larger variation was applied to the downstream boundary slope to reflect the greater uncertainty associated with extrapolating channel gradient beyond the surveyed model extent. As slope influences the stage–discharge relationship through the square root term within Manning’s equation, a modest increase in slope can produce a proportionally smaller change in conveyance; the $\pm 30\%$ range was therefore selected to provide a meaningful test of boundary condition sensitivity while remaining within realistic hydraulic bounds.

2.8.4 The model outputs were not found to be particularly sensitive to any of the tested parameters, with relatively minor variations observed in peak flow and flood extent for all tests across much of the model. This suggests that the model is reasonably robust to typical uncertainties in input data and configuration.

2.8.5 Key statistics from the sensitivity tests are presented in Table 4.

Table 4: Sensitivity test outcomes vs baseline

Sensitivity Test	Differences in Water Level Whole Model (mm)		Differences in Water Level Adjacent to Site (mm)	
	Maximum	10 th -90 th %ile range	Maximum	10 th -90 th %ile range
ST1	+249	0 to +73	+249	+4 to +75
ST2	-139	-87 to 0	-139	-92 to -14
ST3	+255	0 to +80	+110	+16 to +44
ST4	-301	-101 to 0	-115	-77 to -19
ST5	-51	0	-1	0
ST6	+77	0 to +1	-1	0
ST7	-218	-1 to 0	-1	-1 to 0
ST8	+304	0	-1	0

- 2.8.6 The sensitivity testing shows that model results respond to changes in key parameters, with roughness and flow uplifts having the greatest influence on flood depths across the model. However, the magnitude and spatial extent of these changes are generally limited, particularly within and adjacent to Lime Down D, where variations in predicted depths are typically small and localised. The largest differences associated with the railway culvert sensitivity tests (ST7/ST8) occur upstream of the structure. Changes within the site itself are negligible, with differences typically close to zero. The downstream boundary condition was also shown to have negligible influence on flood levels across the site.
- 2.8.7 Flood mapping comparing the sensitivity tests flood extents against baseline is presented in Appendix B.
- 2.8.8 Overall, the sensitivity testing demonstrates that the model responds in a hydraulically realistic manner to changes in key parameters, while the principal conclusions regarding flood behaviour and depth across Lime Down D remain consistent. The model is therefore considered robust and appropriate for informing **ES Volume 3, Appendix 11-6: Flood Risk Assessment and Drainage Strategy - Lime Down D [EN010168/APP/6.3 (Rev 3)]**.

3. Conclusions and Recommendations

3.1 Conclusions

- 3.1.1 A new site-specific 1D–2D hydraulic model has been developed to assess fluvial flood risk to Lime Down D, where the proposed solar infrastructure and BESS intersect Flood Zones 2 and 3 associated with Gauze Brook. The model has been constructed using detailed topographic and channel survey data, supported by EA LiDAR, and represents the hydraulic behaviour of the main watercourse and adjacent floodplain at a resolution proportionate to the scale of the catchment and development.
- 3.1.2 Hydrological inputs were derived using ReFH2 rainfall-runoff modelling and FEH Statistical methods in accordance with current EA guidance, with conservative FEH Statistical peak flows adopted. Inflows were applied using a catchment-based approach and the model configuration incorporates appropriate boundary conditions, structures and parameterisation to simulate both in-channel and overbank processes. Model health checks, mass balance performance and numerical stability testing indicate that the model performs reliably and is suitable for assessment purposes.
- 3.1.3 Predicted flooding across Lime Down D during the 1% AEP +39% climate change design event is generally shallow, with depths typically less than 300mm across much of the site and low velocities (typically <0.5m/s) across the floodplain. Areas of deeper or faster flow are largely confined to the existing watercourse corridor and localised low-lying areas. The overall hydraulic response across the developable area is therefore characterised by shallow, low-energy overbank flooding rather than deep or fast-flowing conditions.
- 3.1.4 Comparison of the modelled flood extent with the EA FMfP + climate change extents shows good overall agreement, indicating that the model provides an appropriate refinement of the strategic mapping for this location. Sensitivity testing demonstrates that the model responds realistically to variations in key parameters, while the principal conclusions regarding flood behaviour and depth across Lime Down D remain consistent.
- 3.1.5 On this basis, the hydraulic modelling provides a robust and proportionate technical evidence base for assessing fluvial flood risk to the proposed development and informing the Flood Risk Assessment.

3.2 Recommendations

- 3.2.1 The site-specific hydraulic model and associated outputs should be used to inform **ES Volume 3, Appendix 11-6: Flood Risk Assessment and Drainage Strategy - Lime Down D [EN010168/APP/6.3 (Rev 3)]**, including refinement of Gauze Brook flood extents, depth mapping and consideration of the proposed BESS location within Lime Down D.
- 3.2.2 The modelling results indicate that flood risk across the developable area is dominated by shallow floodplain interaction. It is recommended that the development layout continues to consider these findings, including appropriate siting, finished levels and management of residual flood risk in accordance with national planning policy and EA guidance.

Appendices

Appendix A – Limitations

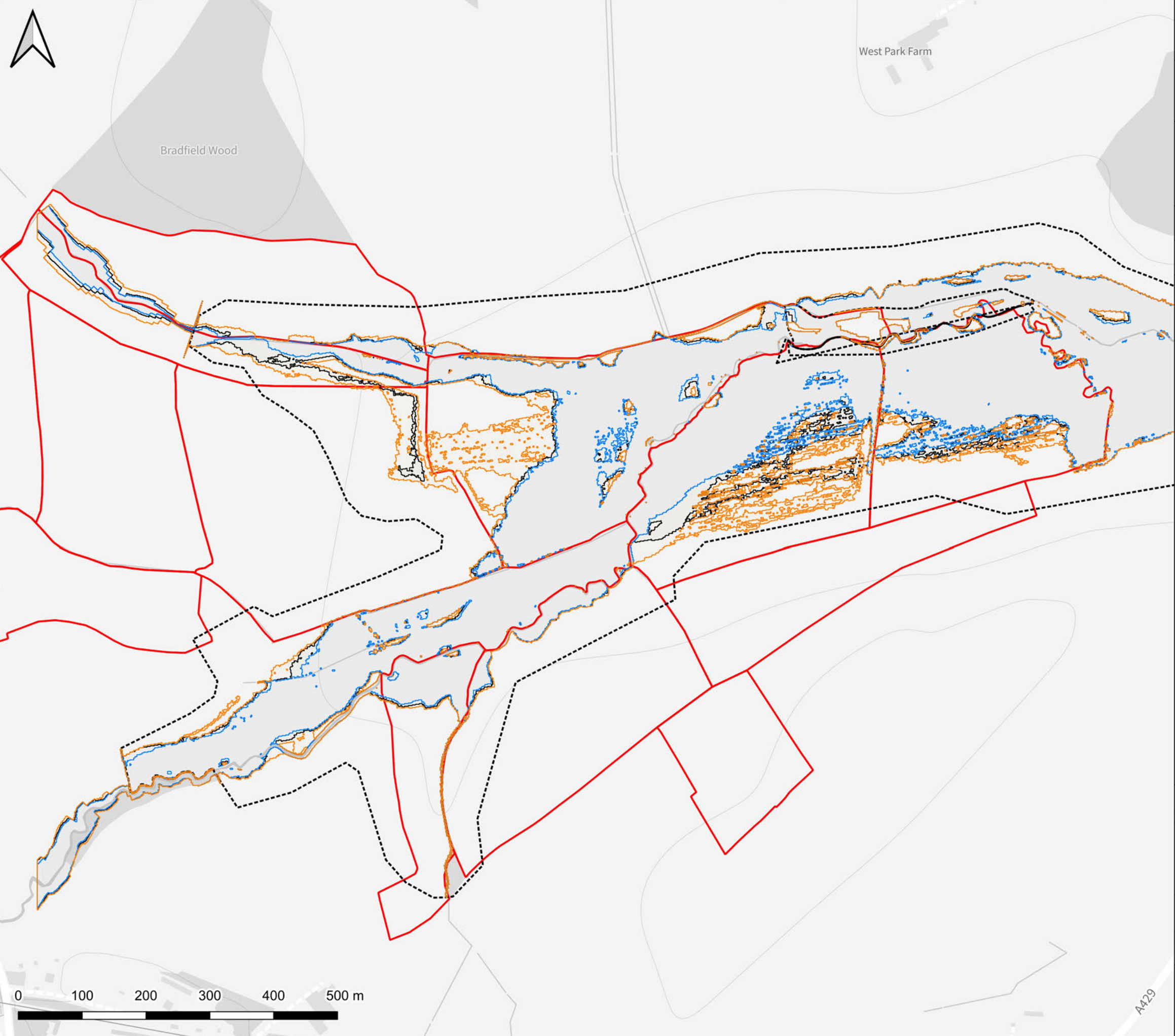
Limitations

This report contains recommendations from Arthian, which are based on the information listed in the report and reflect the professional opinions of an experienced Environmental Consultant. Arthian obtained, reviewed, and evaluated information from the Client and others to prepare this report. The conclusions, opinions, and recommendations presented in this report are based on this information. However, Arthian does not guarantee the accuracy of the information provided and will not be held responsible for any opinions or conclusions reached based on information that is later proven to be inaccurate.



This report was prepared exclusively for the Client and for the specific purpose for which Arthian was instructed. It is not intended for use by anyone other than the Client without Arthian's written consent. Any unauthorized use of this report is at the sole risk of the user. Anyone using or relying on this report, other than the Client, agrees to indemnify and hold harmless Arthian from any claims, losses, or damages arising from the performance of the work by the Consult

Appendix B – Sensitivity Test Mapping

390000 390500 391000 391500



Project Reference:
317212 Lime Down Solar Farm

Client:



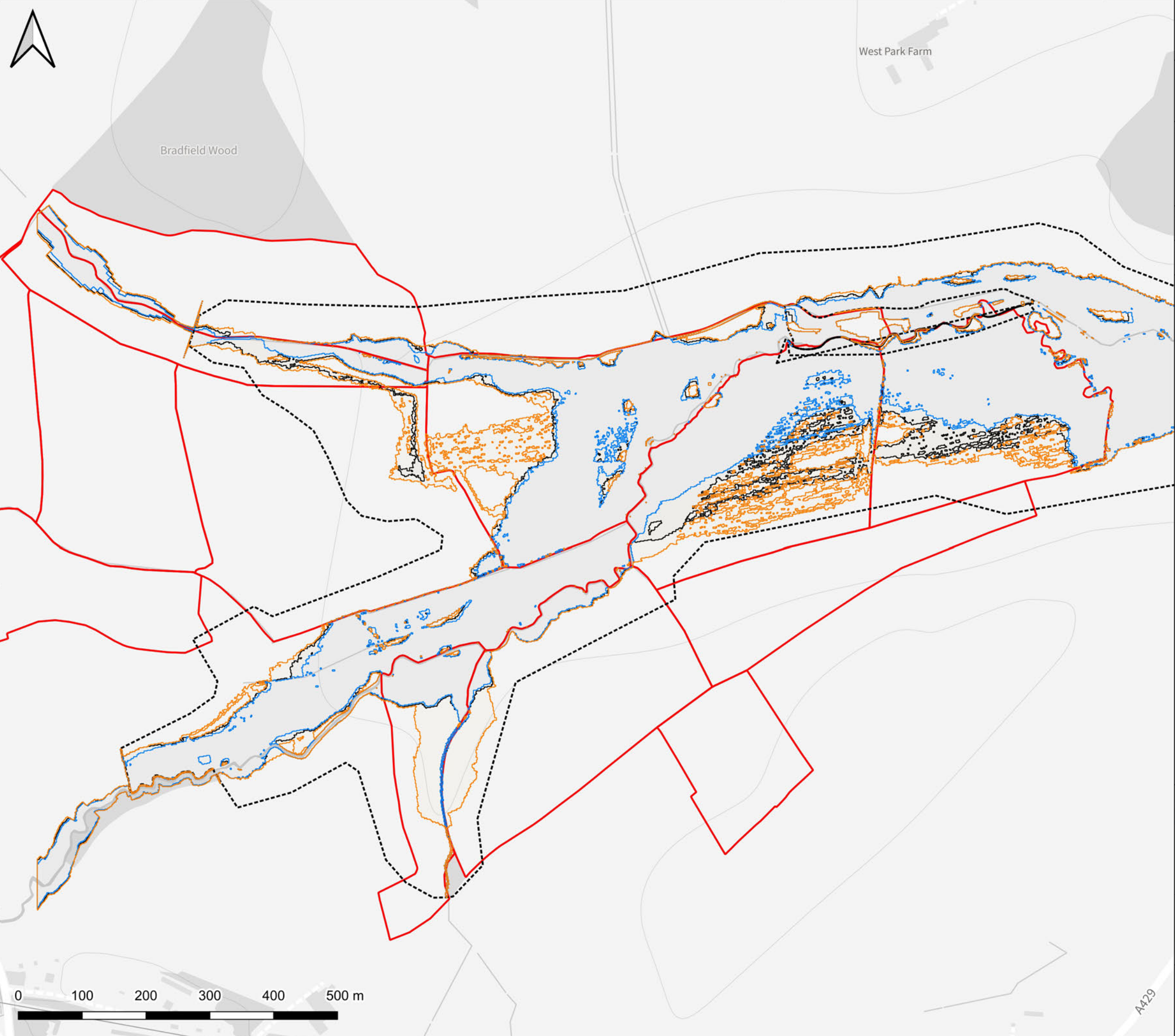
Drawing Title:
Maximum Flood Extent Comparison
 Baseline: 1% AEP +39%CC fluvial event
 ST1: Manning's 'n' +20%
 ST2: Manning's 'n' -20%



Drawing Name: 317212-ENG-MOD-01	Revision: -	Date: 27 Feb 2026		
Drawing Scale (A3): 1:6000	Drawing Status: Final	Drawn: DH	Checked: JR	Approved: JR

- Legend**
- Lime Down D
 - 2D Model Extent
 - Baseline Flood Extent (1% AEP +39%CC)
 - ST1 Flood Extent (Manning's n +20%)
 - ST2 Flood Extent (Manning's n -20%)



390000 390500 391000 391500

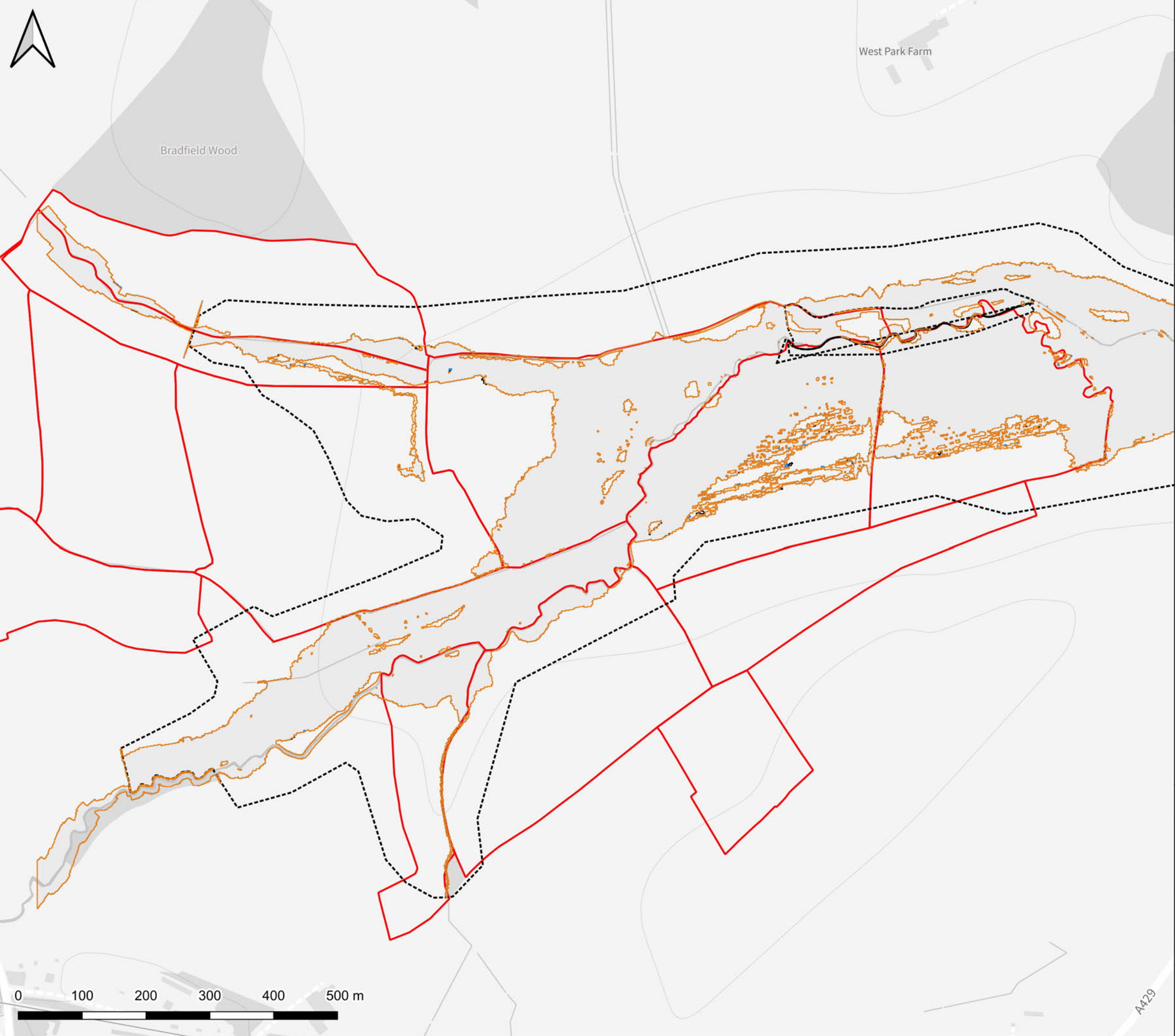




Project Reference: 317212 Lime Down Solar Farm				
Client:  				
Drawing Title: Maximum Flood Extent Comparison Baseline: 1% AEP +39%CC fluvial event ST3: Inflows +20% ST4: Inflows -20%				
Drawing Name: 317212-ENG-MOD-02			Revision: -	Date: 27 Feb 2026
Drawing Scale (A3): 1:6000	Drawing Status: Final	Drawn: DH	Checked: JR	Approved: JR

- Legend**
- Lime Down D
 - 2D Model Extent
 - Baseline Flood Extent (1% AEP +39%CC)
 - ST3 Flood Extent (Inflows +20%)
 - ST4 Flood Extent (Inflows -20%)



390000 390500 391000 391500

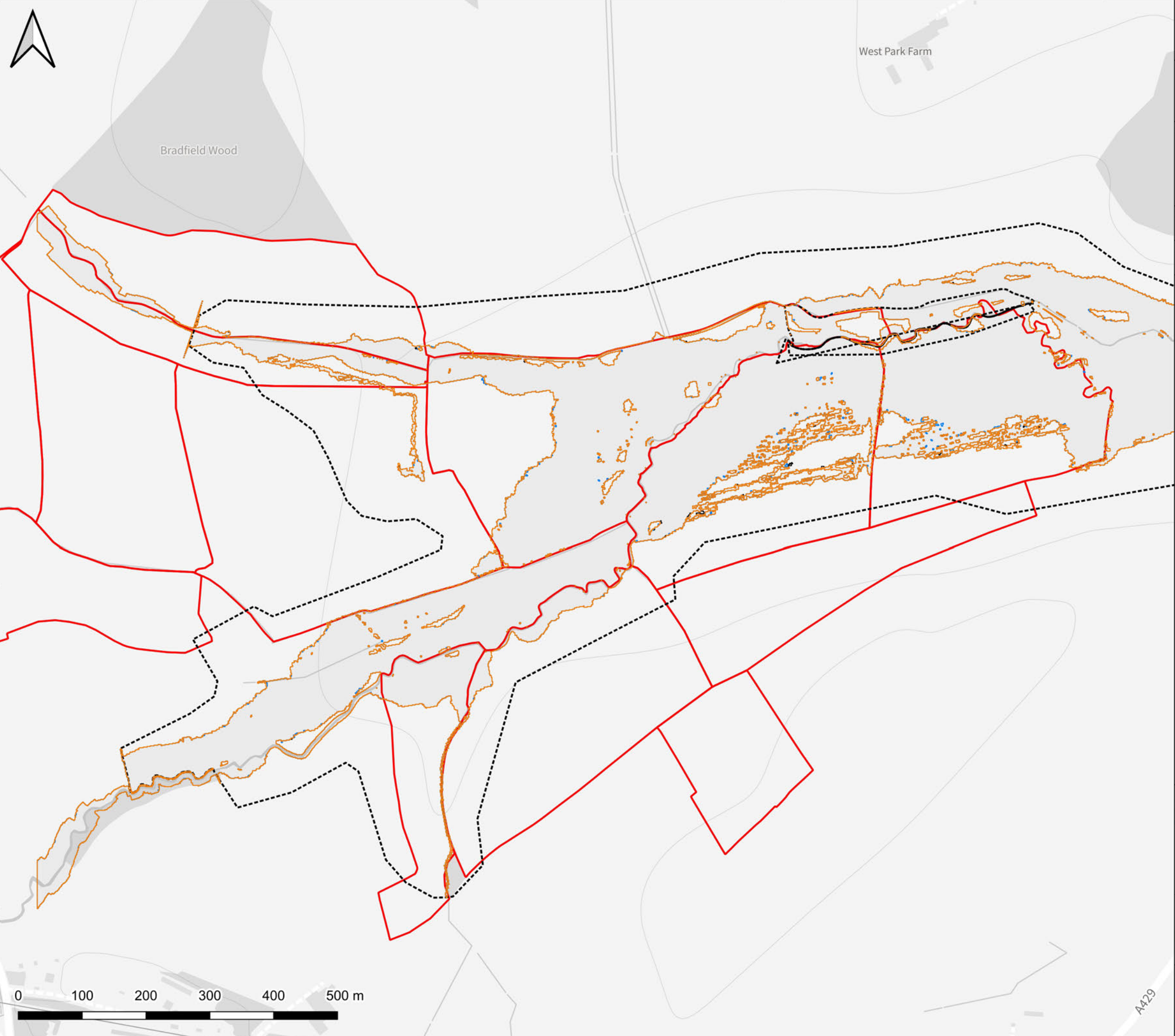


Project Reference: 317212 Lime Down Solar Farm				
Client:  				
Drawing Title: Maximum Flood Extent Comparison Baseline: 1% AEP +39%CC fluvial event ST5: DSBC Slope +30% ST6: DSBC Slope -30%				
Drawing Name: 317212-ENG-MOD-03			Revision: -	Date: 27 Feb 2026
Drawing Scale (A3): 1:6000	Drawing Status: Final	Drawn: DH	Checked: JR	Approved: JR



- Legend**
- Lime Down D
 - 2D Model Extent
 - Baseline Flood Extent (1% AEP +39%CC)
 - ST5 Flood Extent (DSBC Slope +30%)
 - ST6 Flood Extent (DSBC Slope -30%)



390000 390500 391000 391500



Project Reference:
317212 Lime Down Solar Farm

Client:



Drawing Title:
Maximum Flood Extent Comparison
 Baseline: 1% AEP +39%CC fluvial event
 ST7 Flood Extent (Railway Culvert Width +20%)
 ST8 Flood Extent (Railway Culvert Width -20%)

Drawing Name: 317212-ENG-MOD-04	Revision: -	Date: 27 Feb 2026		
Drawing Scale (A3): 1:6000	Drawing Status: Final	Drawn: DH	Checked: JR	Approved: JR

- Legend**
- Lime Down D
 - 2D Model Extent
 - Baseline Flood Extent (1% AEP +39%CC)
 - ST7 Flood Extent (Railway Culvert Width +20%)
 - ST8 Flood Extent (Railway Culvert Width -20%)

