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Flood Risk Assessment

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Notice

EXECUTIVE SUMMARY

This Flood Risk Assessment (FRA) has been prepared in accordance with the requirements set out in the National Planning Policy Framework (NPPF) and the associated Planning Practice Guidance. It has been produced on behalf of Bloor Homes Limited in respect of an outline planning application involving a proposed mixed use urban extension of land at Lower Bullingham (known as the 'Southern Urban Expansion' in the adopted Herefordshire Local Plan - Core Strategy) to provide up to 1300 dwellings (including specialist housing), B1, B2 and B8 employment uses, a Neighbourhood Community Hub, a new primary school, a Park and Choose, a country park, public open space, access, drainage and other associated works and demolition of existing industrial buildings. All matters are reserved for future consideration save for 'access'.

This report demonstrates that the proposed development is not at significant flood risk, subject to the recommended flood mitigation strategies being implemented.

For the purpose of this report the site has been divided into three development parcels, and the Watery Lane vehicle bypass facility.

A park and choose scheme is proposed on the 'western' parcel. While this area is in close proximity to the Norton Brook, a detailed hydraulic modelling exercise has shown that the development can be located within the site on land solely within Flood Zone 1 – land at a low risk of fluvial flooding. Additionally, all other sources of flooding have been shown to pose a low risk to the proposed development area.

A country park is proposed within the 'central' parcel. The Norton Brook floodplain is present within this centre of this area. The proposals do not include any built development; therefore, it is considered to be water compatible and the existing flood risk conditions acceptable.

The majority of the development is located within the 'eastern' parcel, this is to comprise of a mix of residential, employment, education, and community uses. The Red Brook and two smaller watercourses flow through the area. Hydraulic modelling of the local fluvial system has been used to define the Red Brook floodplain through the centre of the site. The modelling has also shown that the Withy Brook floodplain enters the eastern parcel from the west, creating an additional floodplain in the north of the site. The hydraulic modelling includes for the influence of the River Wye on the smaller ordinary watercourses.

As part of the traffic management solutions for the development it is proposed to stop-up Watery Lane at the railway line. To preserve the existing residents' access to the high ground on the southern side of the railway line during a flood event, a gated layby arrangement is proposed. This is included within the application boundary as a means to preserve the existing egress routes during a flood event, as opposed to representing a new built development.

A review of the available British Geological Survey data and site specific ground investigations suggest the potential for shallow groundwater which could pose a flood risk to the development unless suitably mitigated.

Flood risk from other sources such as reservoir and canal are considered to be low.

The development has been arranged to avoid the floodplain in the eastern parcel where possible, but there are thought to be a few locations where the development could encroach into the design floodplain (the 1 in 100-year floodplain with a 35% allowance for climate change). These include a proposed bridge crossing of the Red Brook, and the edge of a proposed surface water attenuation pond/basin. To mitigate the impact that this loss of floodplain volume could have on the wider catchment, it is proposed to compensate for the loss in a level-for-level manner. It is also recommended that the potential impact of any bridge crossings are identified within the hydraulic model to ensure that impedance of flow routes do not result in detriment to third party land.

To ensure that the proposed development is resilient to the potential flood risk posed by the local watercourses, it is recommended that finished floor levels are set a minimum of 600mm above the relevant 1 in 100-year+35% peak flood level. The hydraulic modelling has shown that this freeboard is sufficient to raise finished levels above the 1 in 100-year+70% climate change event, the 1 in 1000-year event, and also above the flood levels generate by potential blockages of culverts and bridges around the site.

It is recommended that finished flood levels are also set a minimum of 150mm above surrounding finished ground levels, and that ground levels are profiled to encourage overland flows away from the built development and towards the nearest drainage point, to help mitigate the flood risk posed by pluvial events in excess of the drainage's design standard.

Safe dry access and egress will be fully achievable within all modelled flood events via the B4399 road to the south, and if necessary via Hoarwithy Road southwards to the north-west of the site.

The development will inevitably result in an increase in the total impermeable area. To account for this, it is proposed that the development discharge rates be limited to the equivalent QBAR greenfield rate thereby mitigating any potential negative impacts. Moreover, on site surface water attenuated storage in the form of Sustainable Drainage Systems (SuDS) will be provided within the development for storm events up to the 1 in 100-year with a 40% allowance for climate change.

In compliance with the requirements of National Planning Policy Framework, and subject to the mitigation measures proposed, the development could proceed without being subject to significant flood risk. Moreover, the development will not increase flood risk to the wider catchment area as a result of suitable management of surface water runoff discharging from the site.

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1. INTRODUCTION

1.1 This Flood Risk Assessment (FRA) has been prepared in accordance with the requirements set out in the National Planning Policy Framework (NPPF) and the associated Planning Practice Guidance. The FRA has been produced on behalf of Bloor Homes Limited in respect of an outline planning application involving a proposed mixed use urban extension of land at Lower Bullingham (known as the 'Southern Urban Expansion' in the adopted Herefordshire Local Plan - Core Strategy) to provide up to 1300 dwellings (including specialist housing), B1, B2 and B8 employment uses, a Neighbourhood Community Hub, a new primary school, a Park and Choose, a country park, public open space, access, drainage and other associated works and demolition of existing industrial buildings. All matters are reserved for future consideration save for 'access'.

1.2 This FRA is intended to support an outline planning application and as such the level of detail included is commensurate and subject to the nature of the proposals.

Table 1.1: Site Summary

Site Name	Lower Lane, Bullingham
Location	Hereford, HR2 7RZ
NGR (approx.)	351930, 237400
Application Site Area (ha)	75.64
Development Type	Residential / Commercial / Education
Flood Zone Classification	Flood Zone 1, 2 and 3
NPPF Vulnerability	More Vulnerable
Environment Agency Office	West Midlands
Lead Local Flood Authority	Herefordshire Council
Local Planning Authority	Herefordshire Council

Sources of Data

1.3 The report is based on the following information

i. Topographical Survey by BWB Consulting, reference BULL-BWB-00-01-DR-G-001 (available as Appendix 1)
ii. Site Layout Plan by Barton Willmore, reference 9300 (available as Appendix 2)
iii. Local Authority Surface Water Flood Risk Maps
iv. Herefordshire Strategic Flood Risk Assessment
v. Herefordshire Preliminary Flood Risk Assessment

vi. Herefordshire Local Flood Risk Management Strategy

vii. Hydraulic modelling of the Red Brook, Norton Brook and Withy Brook undertaken by BWB Consulting, reference BUL-BWB-EWE-XX-RP-EN-0002_HMR (available as Appendix 3)

viii. Welsh Water Sewer Records (available as Appendix 4)

ix. British Geological Survey Drift & Geology Maps

x. Intègral Gèotechnique, 2012, Lower Bullingham, Hereford, Site Investigation Report (11037/GNS/12/SI).

Existing Site

1.4 The site is located on the southern edge of Hereford, approximately 2.5km from the city centre. The entire site ownership covers an area of approximately 75 hectares and is predominately pasture and arable farmland which also includes some farm buildings. It is considered to be greenfield.

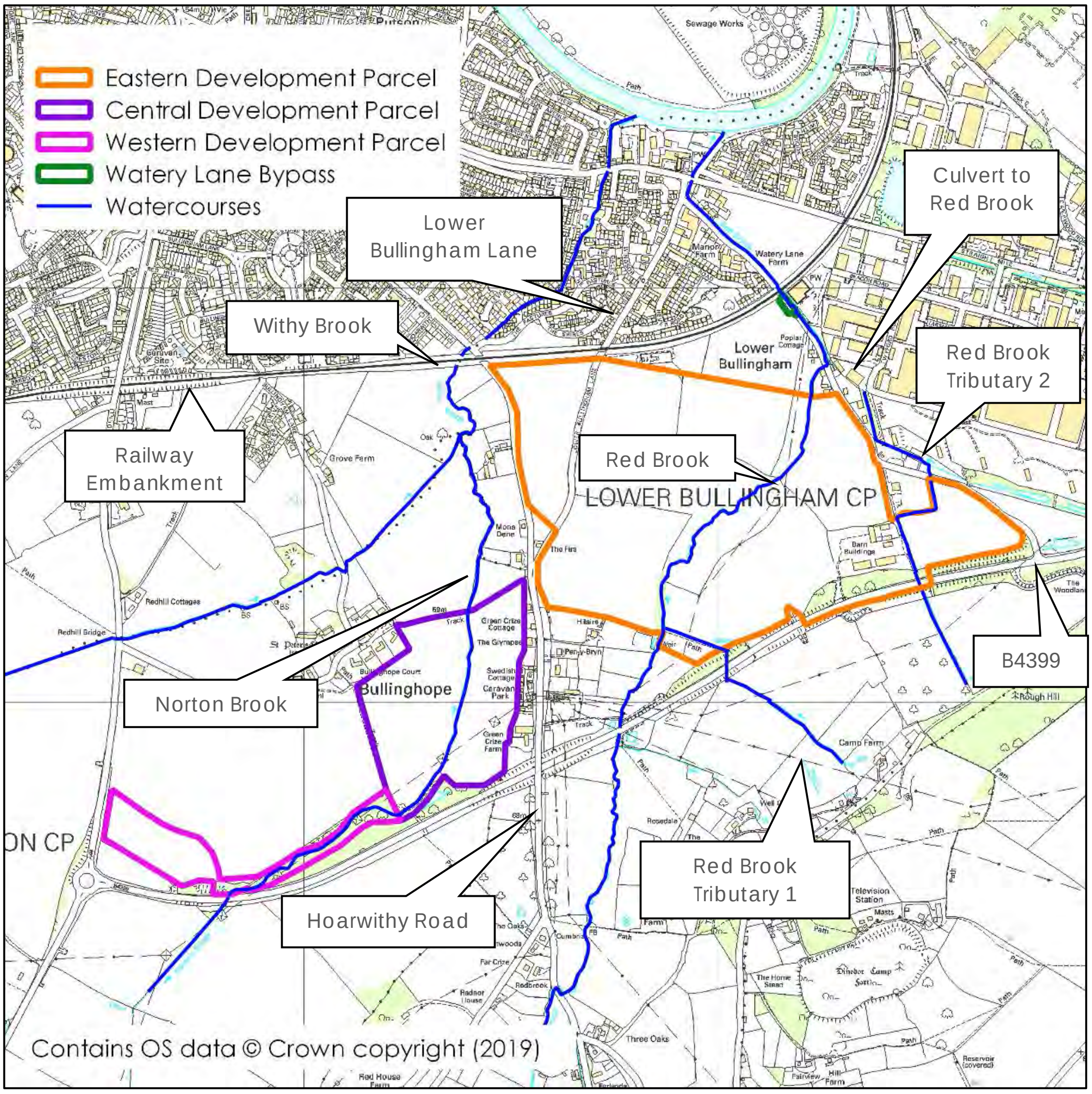


Figure 1.1: Site Location

1.5 The site falls within the River Wye valley between an embanked railway line to the north, the B4399 to the south, the A49 to the west and Watery Lane to the east.

1.6 The River Wye is located roughly 500m to the north of the site. The Norton and Withy Brook system, and the Red Brook flows through the site. All the minor watercourses flow in a northerly direction and ultimately outfall to the River Wye.

1.7 For the purpose of this report, the site has been divided into three parcels, which are illustrated within Figure 1.1.

<u>Western Parcel</u>

1.8 The Western Parcel is located adjacent to the A49 and the B4399.

1.9 The Norton Brook flows along the southern boundary of this parcel in a north-eastly direction, after first passing under the B4399.

1.10 Topographic elevations within the parcel range from 71.05mAOD on the western boundary to 61.24mAOD on the southern boundary, adjacent to the watercourse. The general fall of the area is towards the Norton Brook.

<u>Central Parcel</u>

1.11 The Central Parcel is located to the north of the B4399, between Hoarwithy Road and Bullinghope.

1.12 The Norton Brook flows through the centre of the site, in a northerly direction before its confluence with the Withy Brook approximately 430m to the north.

1.13 Topographic elevations within the parcel range from 74.34mAOD on the western boundary to 59.63mAOD in the south-western corner of the parcel. The topographical survey identifies a valley line in the centre of the site, in which the Norton Brook flows. Therefore, the majority of the site is likely to drain directly towards this watercourse.

<u>Eastern Parcel</u>

1.14 The Eastern Parcel is located to the north of the B4399, and to the south of the railway line, between Hoarwithy Road and Watery Lane. Lower Bullingham Lane runs through the western half of the site.

1.15 The Red Brook flows through the centre of the site, and a small tributary of the Red Brook flows under the B4399 and enters the parcel at its southern boundary. An unnamed drainage ditch is located within the eastern portion of this parcel.

1.16 Topographic elevations within the parcel range from 72.5mAOD on the southern boundary to 51.5mAOD on the northern boundary. The topographical survey identifies a valley line in the centre of the site in which the Red Brook flows. Therefore, the majority of the site is likely to drain directly to this watercourse.

Watery Lane Vehicle Bypass Facility

1.17 This minor development parcel is located on Watery Lane, just to the south of the railway line. The Red Brook runs in close proximity to this area before it passes beneath the railway line and flows to meet the River Wye.

Proposed Development

Western Parcel

1.18 It is proposed that the Western Development Parcel consist of a car park serving a 'Park and Choose' to encourage the use of public transportation within the city centre. The proposed developed is classifies as 'Less Vulnerable'.

Central Parcel

1.19 It is proposed that the Central Development Parcel consist of a country park, which is classified as 'Water Compatible'.

Eastern Parcel

1.20 It is understood that the proposals are for a mixed-use, residentially-led development which is to be delivered onto site in phases. The Eastern Development Parcel is classified as 'More Vulnerable'.

Watery Lane Vehicle Bypass Facility

1.21 As part of the traffic management solutions for the development it is proposed to stop-up Watery Lane at the railway line. To preserve the existing residents' access to the high ground on the southern side of the railway line during a flood event, a gated layby arrangement is proposed. This is included within the application boundary as a means to preserve the existing egress routes during a flood event, as opposed to representing a new arrangement.

2. FLOOD RISK PLANNING POLICY

National Planning Policy Framework

2.1 The NPPF[1] sets out the Government's national policies on different aspects of land use planning in England in relation to flood risk. Planning Practice Guidance is also available online[2].

2.2 The Planning Practice Guidance sets out the vulnerability to flooding of different land uses. It encourages development to be located in areas of lower flood risk where possible and stresses the importance of preventing increases in flood risk off site to the wider catchment area.

2.3 The Planning Practice Guidance also states that alternative sources of flooding, other than fluvial (river flooding), should also be considered when preparing a Flood Risk Assessment.

2.4 The Planning Practice Guidance includes a series of tables that define Flood Zones (Table 1), the flood risk vulnerability classification of development land uses (Table 2) and 'compatibility' of development within the defined Flood Zones (Table 3).

2.5 This Flood Risk Assessment is written in accordance with the NPPF and the Planning Practice Guidance.

Flood Map for Planning

2.6 With particular reference to planning and development, the Flood Map for Planning produced by the Environment Agency identifies Flood Zones in accordance with Table 1 of the Planning Practice Guidance.

2.7 Flood Zone 1 (Low Probability) is defined as land having less than a 1 in 1000 annual probability of river or sea flooding (<0.1% Annual Exceedance Probability).

2.8 Flood Zone 2 (Medium Probability) is defined as land having between a 1 in 100 and 1 in 1000 annual probability of river flooding (1% - 0.1% AEP); or between a 1 in 200 and 1 in 1000 annual probability of sea flooding (0.5% - 0.1% AEP).

2.9 Flood Zone 3a (High Probability) is defined as land having a 1 in 100 or greater annual probability of river flooding (>1% AEP); or land having a 1 in 200 or greater annual probability of flooding from the sea (>0.5% AEP). This is represented by "Flood Zone 3" on the Flood Map for Planning.

2.10 Flood Zone 3b (The Functional Floodplain) is defined as land where water has to flow or be stored in times of flood. This is not identified or separately distinguished from Zone 3a on the Flood Map for Planning.

[1] National Planning Policy Framework, CLG, February 2019
[2] Planning Practice Guidance: https://www.gov.uk/government/collections/planning-practice-guidance

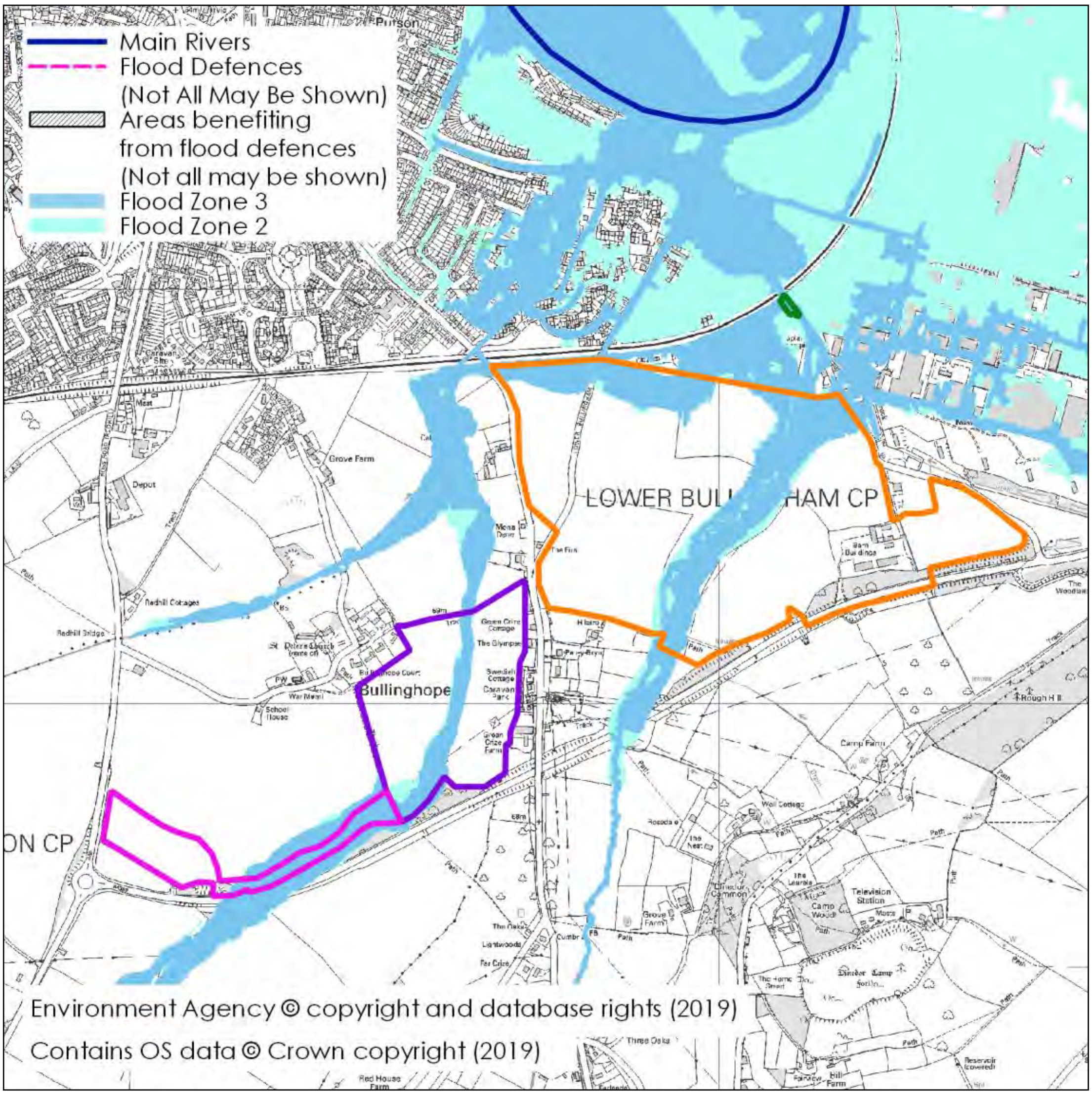


Figure 2.1: Flood Map for Planning

The Design Flood

2.11 The Planning Practice Guidance identifies that new developments should be designed to provide adequate flood risk management, mitigation, and resilience against the 'design flood' for their lifetime.

2.12 This is a flood event of a given annual flood probability, which is generally taken as fluvial (river) flooding likely to occur with a 1% annual probability (a 1 in 100 chance each year), or tidal flooding with a 0.5% annual probability (1 in 200 chance each year), against which the suitability of a proposed development is assessed and mitigation measures, if any, are designed.

Climate Change

2.13 In February 2016 the predicted future change in peak river flows were updated by the Environment Agency[3]. This replaced the previous national 20% allowance, with a range of projections applied to regionalised 'river basin districts'.

2.14 The Wye catchment falls within the Severn river basin district. Table 2.1 identifies the relevant peak river flow allowances from this river basin district.

Table 2.1: Peak River Flow Allowance for the Severn River Basin District

Allowance Category	Total potential change anticipated for the **'2020s' (2015 to 2039)**	Total potential change anticipated for the **'2050s' (2040 to 2069)**	Total potential change anticipated for the **'2080s' (2070 to 2115)**
Upper End	25%	40%	70%
Higher Central	15%	25%	35%
Central	10%	20%	25%

2.15 When determining the appropriate allowance for use in a Flood Risk Assessment the Flood Zone classification, flood risk vulnerability and the anticipated lifespan of the development should be considered.

2.16 Table 2.2 provides a matrix summarising the Environment Agency's guidance on determining the appropriate allowances.

2.17 The site as a whole is located partially within Flood Zone 3, and the highest vulnerability of the proposed is classified as 'More Vulnerable', with an anticipated lifespan of over 60 years. Therefore, the higher central and upper end allowances for the 2080 epoch should be considered.

2.18 Therefore, to ensure the development is designed adequately for its lifetime an allowance of 35% and 70% should applied to the design flood. The 35% allowance will be used to determine appropriate flood mitigation measures and assess the developments potential impact in the wider catchment, and the 70% and will be used to assess the resilience of the proposed flood mitigation strategy.

[3] Environment Agency. 2016. Flood risk assessments: climate change allowances: https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances#table-1. [last accessed 24 April 18].

Table 2.2: Application of the Appropriate Climate Change Allowance

Flood Zone	Essential Infrastructure	Highly Vulnerable	More Vulnerable	Less Vulnerable	Water Compatible
1	Use the central allowance				Use none of the allowances
2	Use the higher central and upper end to assess a range of allowances	Use the higher central and upper end to assess a range of allowances	Use the central and higher central to assess a range of allowances	Use the central allowance	Use none of the allowances
3a	Use the upper end allowance	Development should not be permitted	Use the higher central and upper end to assess a range of allowances	Use the central and higher central to assess a range of allowances	Use the central allowance
3b	Use the upper end allowance	Development should not be permitted	Development should not be permitted	Development should not be permitted	Use the central allowance
*If development is considered appropriate when not in accordance with Flood Zone vulnerability categories, then it would be appropriate to use the upper end allowance.					

Strategic Flood Risk Assessment

2.19 A Strategic Flood Risk Assessment (SFRA) is a study carried out by one or more local planning authorities to assess the risk to an area from flooding from all sources, now and in the future.

2.20 The Herefordshire Level 1 SFRA[4] has been reviewed in the production of this FRA. The SFRA provides information specific to the site location in the form of fluvial, surface water and groundwater flood risk mapping, as well as records of historical flooding. Information from the Level 1 SFRA will be referenced within Section 3 where applicable.

Preliminary Flood Risk Assessment

2.21 A Preliminary Flood Risk Assessment (PFRA) is an assessment of floods that have taken place in the past and floods that could take place in the future. It generally considers flooding from surface water runoff, groundwater and ordinary watercourses, and is prepared by the Lead Local Flood Authorities.

2.22 The Hereford PFRA[5] considers flooding from surface water runoff, groundwater, ordinary watercourses and canals. It also references any historical river flooding. However, no

[4] Level 1 Strategic Flood Risk Assessment (Herefordshire Council, April 2019)
[5] Preliminary Flood Risk Assessment (JBA Consulting, May 2011)

historic instances of flooding at the site are referenced. Information from the PFRA will be referenced within this report where applicable.

Local Flood Risk Management Strategy

2.23 A Local Flood Risk Management Strategy (LFRMS) is prepared by a Lead Local Flood Authority to help understand and manage flood risk at a local level. The LFRMS aims to ensure that the knowledge of local flood risk issues is communicated effectively so that they can be better managed. The LFRMS also aims to promote sustainable development and environmental protection.

2.24 The Herefordshire Council LFRMS[6] has been reviewed and will be referenced within this report where applicable.

Local Plan

2.25 A Local Plan is prepared by a Local Planning Authority to set out a vision and framework for the future development of the area - addressing needs and opportunities in relation to housing, the economy, community facilities and infrastructure – as well as a basis for safeguarding the environment, adapting to climate change and securing good design.

2.26 The site is included within the Herefordshire Local Plan[7] under Policy HD6 – Southern Urban Expansion (Lower Bullingham).

[6] Local Flood Risk Management Strategy (Herefordshire Council, October 2017)
[7] Herefordshire Local Plan 2011-2031 (Herefordshire Council, October 2015)

3. POTENTIAL SOURCES OF FLOOD RISK

3.1 Flooding can occur from a variety of sources, or combination of sources, which may be natural or artificial. Table 3.1 below identifies the potential sources of flood risk to the site in its current condition, and the impacts which the development could have in the wider catchment, prior to mitigation. These are discussed in greater detail in the forthcoming section. The mitigation measures proposed to address flood risk issues and ensure the development is appropriate for its location are discussed within Section 4.0.

Table 3.1: Pre-Mitigation Sources of Flood Risk

Flood Source	Potential Risk				Description
	High	Medium	Low	None	
Fluvial			X		The site is located outside the floodplain of the River Wye.
	X				The Eastern and Central Development Parcels are located in Flood Zone 3, attributed to ordinary watercourses.
Canals				X	There are no canals in the vicinity of the site.
Groundwater	X				Groundwater is relatively shallow under the site. There is a risk of emergence within the low-lying areas of the site.
Reservoirs and waterbodies			X		The site is shown to fall outside of the area at risk of reservoir failure.
Pluvial runoff	X				The is site is identified as being at risk of flooding from pluvial sources.
Sewers			X		The site is greenfield, with the majority of the local infrastructure located downstream of the site.
Effect of Development on Wider Catchment	X				The development could result in the impedance of surface water flow routes if not factored into the masterplan.
	X				The development will increase the area of impermeable surfaces leading to a potential increase in runoff.

Fluvial Flood Risk

3.2 Flooding from watercourses occurs when flows exceed the capacity of the channel, or where a restrictive structure is encountered, which leads to water overtopping the banks into the floodplain. This process can be exacerbated when debris is mobilised by high flows and accumulates at structures.

3.3 The site is located approximately 500m to the south of the River Wye, the nearest Environment Agency Main River. A series of ordinary watercourses flow through the site in a northerly direction and ultimately outfall to the River Wye, as follows:

- The Norton Brook flows past the western parcel and through the central parcel, before flowing into the Withy Brook.
- The Red Brook flows through the centre of the eastern parcel.
- A small tributary of the Red Brook flows under the B4399 and enters the eastern parcel at its southern boundary.

  A secondary tributary of the Red Brook is also located within the eastern parcel. This flows under the B4399, through the site, and beneath Watery Lane, before it is culverted to meet the Red Brook as it flows next to Watery Water upstream of the railway line.

3.4 As shown in Figure 2.1, the application site is identified as being partially located in Flood Zone 3, hence fluvial flooding is considered to pose a high risk to the site.

3.5 The Herefordshire SFRA outlines that fluvial flood risk in the area is significant, particularly within the Lower Bullingham residential site. Flooding events in the past few years have been particularly significant.

3.6 The SFRA states that any development on the south side of Bullingham will carry the potential to increase loadings on the Withy Brook and Red Brook. These watercourses already suffer from significant flooding at present. It is understood that this is largely due to high tailwater levels arising from the River Wye itself. Additional flows from new upstream development are anticipated to exacerbate this risk.

3.7 The SFRA points to the Preliminary Flood Risk Study undertaken in 2004. A HEC-RAS model was used to assess flood risk problems, particularly regarding Watery Lane, a flood prone area which borders the eastern site boundary. It is stated this road floods at the 1 in 50-year event.

3.8 The Herefordshire Preliminary Flood Risk Assessment (PFRA) was also undertaken in 2011. This document identifies the development to be located just south of a 'hotspot for flooding', as concluded from a number of reports of flooding within the local area, but particularly within the residential area to the north of the site.

3.9 The EA has provided mapping which demonstrates that the site has experienced flooding previously. The flood events detailed occurred in 1929-30, 1947 and 1960 and although it is likely that the nature of the landscape and hydrology has changed since this time, it gives an indication of the area naturally at risk from this source.

3.10 The Herefordshire 2019 Strategic Flood Risk Assessment identifies recent flood history of Lower Bullingham Lane and Watery Lane, in: 2007, 2008, 2012, 2014. The report notes that the 2007, 2012 and 2014 coincided with River Wye flood events.

3.11 A review of news articles also identified additional road closures on Bullingham Lane and Watery Lane due to flooding in 2015 and 2018.

3.12 Additionally, Herefordshire County Council have reported that the industrial estate adjacent to Watery Lane has flooded five times since 1990.

3.13 A hydraulic model of the Red Brook, Norton Brook, Withy Brook, and smaller tributary channels has been prepared by BWB Consulting to assess the fluvial flood risk to the site. This takes the form of a dynamically linked 1D-2D Flood Modeller-TUFLOW model.

3.14 The details of the model and detailed floodplain maps are available in the Hydraulic Model Report which is available in Appendix 3.

<u>Western Parcel</u>

3.15 The Norton Brook flows directly through the eastern portion of the Western Parcel, as such it is affected by all modelled flood events, from the 1 in 5-year event upwards.

3.16 However, the local topography confines the floodplain within a narrow corridor directly next to the watercourse, and the majority of the parcel is located outside of the 1 in 100-year + 35% and 1 in 1000-year floodplains. This is illustrated in Error! Reference source not found..

3.17 The culvert under the B4399 directly upstream of the site is shown to restrict flood flows leading to flooding over right bank, upstream of the B4399. This flooding follows the fall of the local topography and is directed away from the site.

3.18 A 75% blockage of the B4399 culvert on the Norton Brook is shown to increase upstream flood levels by up to 480mm during the 1 in 100-year event. This results in a slight increase in floodplain extents, but no negative impacts are predicted within the site. Floodplain mapping of this scenario is shown with Appendix 3.

3.19 A culvert under an informal access track is present on the Norton Brook at the downstream extent of the western parcel. A 75% blockage of this culvert on the Norton is shown to result in a localised increase in flood levels of up to 460mm during the 1 in 100-year event. This is accompanied by an increase in floodplain extents. While this scenario increases flood levels, the impact dissipates before reaching the proposed development area. Floodplain mapping of this scenario is shown with Appendix 3.

3.20 The modelling has shown that a decrease in channel and floodplain roughness (representative of winter seasonal conditions or following maintenance) results in a decrease in flood depths of between to 10-200mm during the 1 in 100-year event. This is a result of the ordinary watercourses becoming more efficient and capable of conveying more flow within bank. Floodplain mapping of this scenario is shown with Appendix 3.

3.21 An increase in channel and floodplain roughness (representative of summer seasonal conditions, and a period without maintenance) is shown to result in an increase in flood depths of up to 10-90mm during the 1 in 100-year event. This has a nominal effect on floodplain extents. Floodplain mapping of this scenario is shown with Appendix 3, Appendix 3.

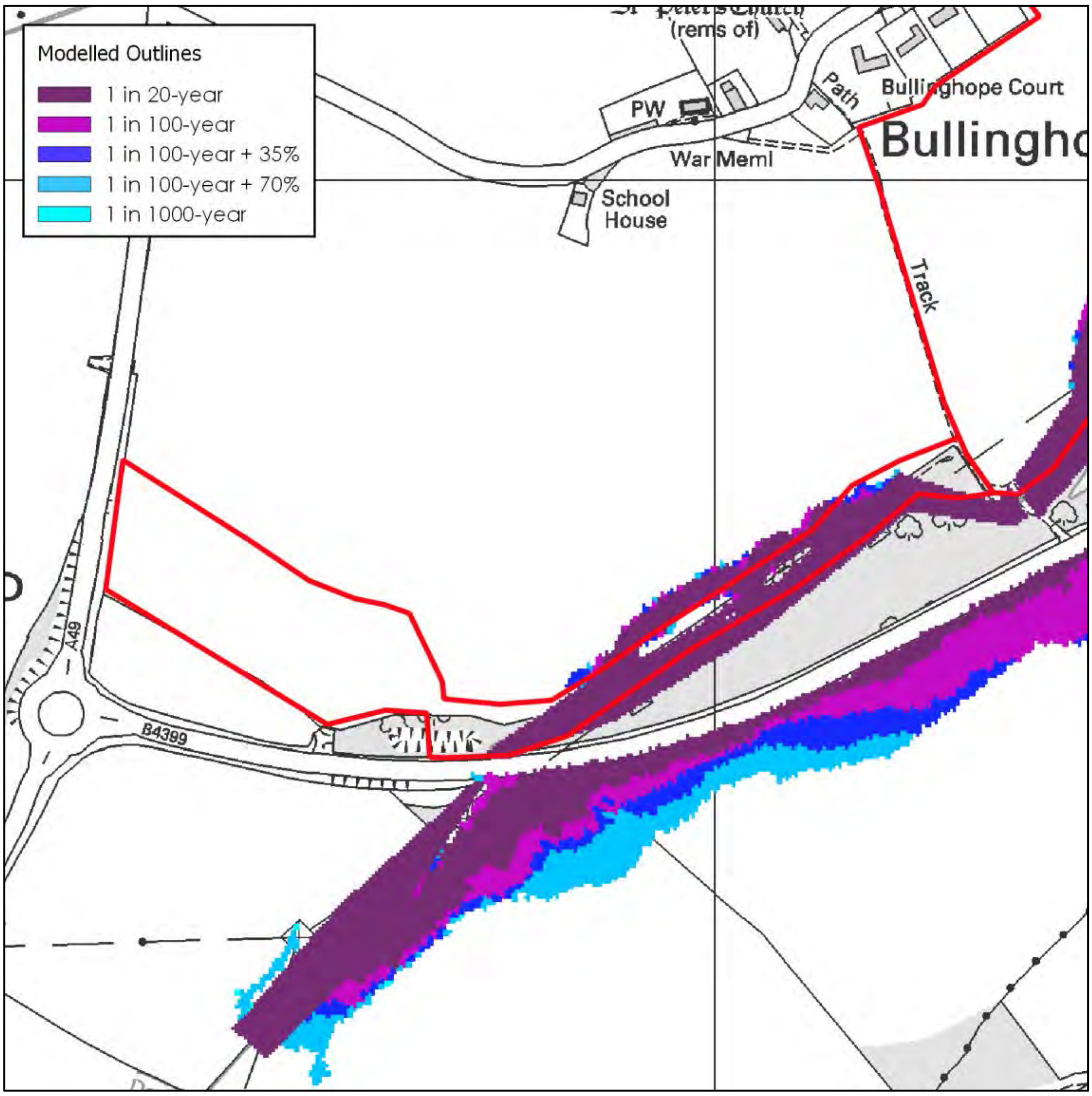


Figure 3.1 - Western Parcel Baseline Flood Extents

<u>Central Parcel</u>

3.22 The Norton Brook flows directly through the centre of the Central Parcel, as such it is affected by all modelled flood events, from the 1 in 5-year event upwards.

3.23 The local topography confines the floodplain within a relatively narrow corridor on either side of the watercourse. Therefore, there is little difference between modelled floodplain extents of the various events, from the 1 in 20-year to the 1 in 1000-year. This is illustrated within Figure 3.2.

3.24 A 75% blockage of the culvert under the informal access track in the western parcel, also affects flood levels in the central parcel. A localised increase in flood levels of up to 467mm is shown during the 1 in 100-year event. This is accompanied by an increase in floodplain extents. Floodplain mapping of this scenario is shown with Appendix 3.

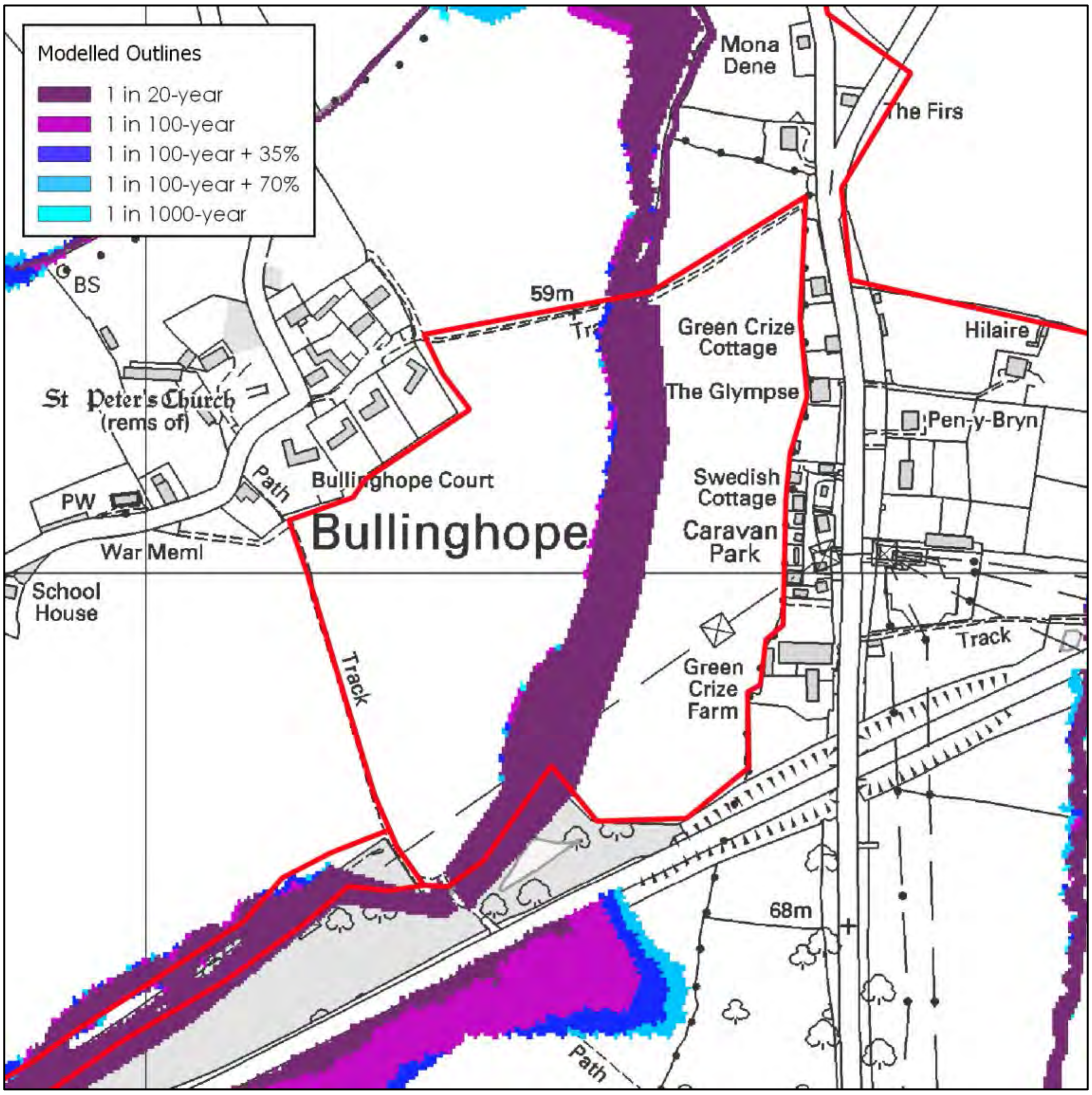


Figure 3.2 - Central Parcel Baseline Flood Extents

3.25 The modelling has shown that a decrease in channel and floodplain roughness in the central area results in a decrease in flood depths of between to 10-200mm during the 1 in 100-year event.

3.26 An increase in channel and floodplain roughness (is shown to result in an increase in flood depths of up to 10-90mm during the 1 in 100-year event. This has a nominal effect on floodplain extents.

Eastern Parcel

3.27 The floodplain extents within the Eastern Parcel are illustrated within Figure 3.3.

3.28 The Withy Brook is shown to be constrained by the culvert under the railway embankment. This leads to out of bank flows crossing Hoarwithy Road and entering the eastern parcel in the 1 in 20-year event and above.

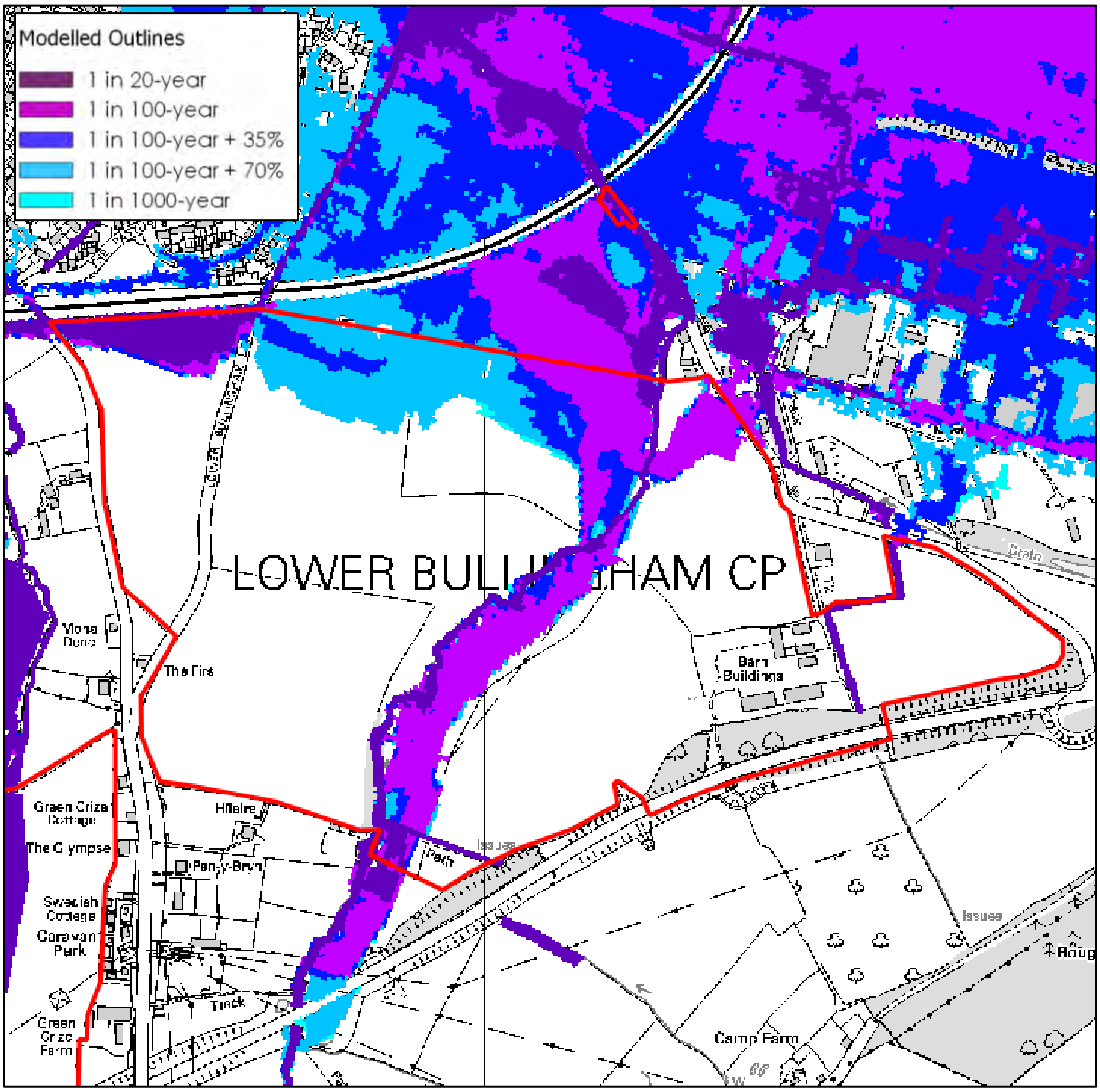


Figure 3.3 – Eastern Parcel Baseline Flood Extents

3.29 The flood route from the Withy Brook leaves the eastern development parcel and flows north under the railway embankment via Lower Bullingham Lane.

3.30 At events over the 1 in 100-year+25%, the Withy Brook floodplain overtops Lower Bullingham Lane and continues further into the eastern development parcel.

3.31 The Red Brook channel in the south of the eastern development parcel is located on the left extremity of the floodplain, therefore the majority of the out of bank flows occur in the right bank floodplain. Out of bank flooding is generally predicted to occur in events over the 1 in 20-year. Due to the constrained valley floor the extents of the 1 in 100, 1 in 100 + 35%, 1 in 100 + 70% and the 1 in 1000-year flood events are relatively similar.

3.32 As the topography flattens out in the northern half of the development parcel, a wide and relatively shallow flood route from the left bank of the Red Brook is generated at the 1 in 20-year event and above. This joins up with the flood route from Withy Brook before flowing onto Watery Lane.

3.33 A smaller flood route from the right bank of the Red Brook is also generated at and above the 1 in 20-year, this flows on to Watery Lane and into the industrial estate around Twyford Road.

3.34 The in-channel and left bank floodplain flows of the Red Brook leave the site via Watery Lane, but then pass under the railway embankment. Due to the flat nature of the floodplain downstream of the railway there is some interaction between the Red Brook and the River Wye.

3.35 Watery Lane and the adjacent industrial estate are shown to be at flood risk from the River Wye and Red Brook in all modelled scenarios, at events as low as the 1 in 5-year. It is believed that this agrees with the anecdotal reports.

During events in excess of the 1 in 100-year flood, the River Wye flood levels reverse the flow direction through the railway embankment, in these instances flood water is directed off Watery Lane and into the industrial around Twyford Road (i.e.: away from the site).

3.36 Flood flows in the tributary watercourse in the east of the parcel are predicted to remain in bank through the parcel but flooding of Watery Lane is predicted at and above the 1 in 20-year due to the restrictive culvert on Watery Lane.

3.37 A 75% blockage of the railway culvert on the Withy Brook shows that this would lead to a significant increase in the overland flows being directed towards the eastern parcel of site along the railway embankment. This leads to an increase of up to 150mm in peak flood levels within the north of the site, and an increase to the predicted floodplain extents. However, the additional floodplain falls in an area which is already at flood risk in the climate change scenarios. Floodplain mapping of this scenario is available within Appendix 3.

3.38 Blockages of the Watery Lane and B4399 culvert on the Red Brook, the B4399 culvert on the Red Brook tributary, and the B4399 culvert and a farm access track culvert on the unnamed ditch have also been assessed. Each of these have been shown to not pose a significant flood risk to the site. Floodplain mapping of these scenarios are available within Appendix 3.

3.39 The modelling has shown that a decrease in channel and floodplain roughness results in a decrease in flood depths of between to 10-100mm within the site, and a significant reduction in floodplain extents.

3.40 An increase in channel and floodplain roughness is shown to result in an increase in flood depths of up to 10-70mm within the site. The floodplain extents are also shown to generally increase within the site, although the main increases occur in the flatter northern proportion of eastern parcel, which is already at flood risk in the climate change scenarios.

3.41 Recommended mitigation measures to address the fluvial flood risk are summarised in Section 4.

Watery Lane Vehicle Bypass Facility

3.42 The Watery Lane vehicle bypass facility is at risk in all modelled scenarios. As stated previously there is no proposed development at this location, simply the preservation of existing egress routes.

Flood Risk from Canals

3.43 The Canal and River Trust (CRT) generally maintains canal levels using reservoirs, feeders and boreholes and manages water levels by transferring it within the canal system.

3.44 Water in a canal is typically maintained at predetermined levels by control weirs. When rainfall or other water enters the canal, the water level rises and flows out over the weir. If the level continues rising it will reach the level of the storm weirs. The control weirs and storm weirs are normally designed to take the water that legally enters the canal under normal conditions. However, it is possible for unexpected water to enter the canal or for the weirs to become obstructed. In such instances the increased water levels could result in water overtopping the towpath and flowing onto the surrounding land.

3.45 Flooding can also occur where a canal is impounded above surrounding ground levels and the retaining structure fails.

3.46 Ordnance Survey mapping shows there to be no canals within the vicinity of the site.

Groundwater Flood Risk

3.47 Groundwater flooding occurs when the water table rises above ground elevations. It is most likely to happen in low lying areas underlain by permeable geology. This may be regional scale chalk or sandstone aquifers, or localised deposits of sands and gravels underlain by less permeable strata such as that in a river valley.

3.48 The SFRA does not detail any groundwater flooding as having occurred within the local area.

3.49 All the parcels in the site are shown to be underlain by Raglan Mudstone Formation (Siltstone and Mudstone interbedded), which is designated by the Environment Agency as Secondary A aquifer. Secondary A aquifers are described as permeable layers capable of supporting water supplies at a local rather than strategic scale, and in sometimes forming an important baseflow to rivers.

3.50 The site also contains various superficial deposits as shown in Figure 3.4, which are also classified as Secondary A aquifers. The site investigation report that the depths of the superficial deposits vary across the site from 0.5m to 3.5m. Groundwater was generally recorded at depths of 2.0m to 3.5m below ground.

3.51 Site investigations have shown that soils of the site very between 0.2m to 0.5m depth and are comprised of silt, sandy clay, and clayey silts.

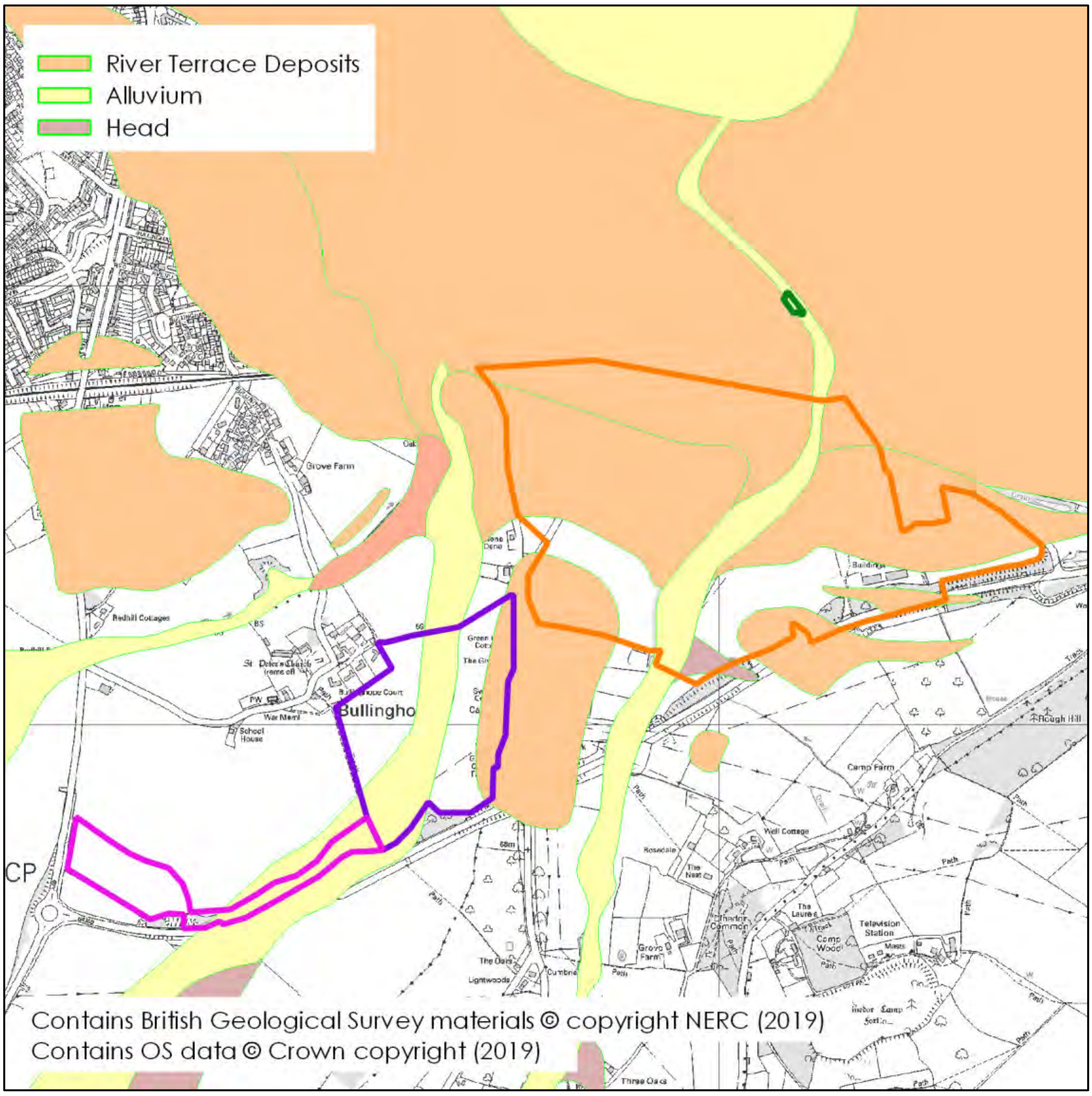


Figure 3.4 - Superficial Deposits at Site Location

Western Parcel

3.52 The Western Parcel is shown to be underlain by Alluvium superficial deposits (Clay, Silt, Sand and Gravel) associated with the Norton Brook floodplain. There is a risk of groundwater flooding from the alluvium, but this would likely be in continuity with the watercourse, and unlikely to exceed the extent of the fluvial floodplain.

3.53 The majority of the western parcel is elevated above the Norton Brook floodplain and so should be at low risk of groundwater flooding.

Central Parcel

3.54 The Central Parcel is shown to be underlain by Alluvium superficial deposits associated with the Norton Brook floodplain. There is also a region of River Terrace Deposits (Sand and Gravel) located on the eastern edge of the central parcel.

3.55 There is a risk of groundwater flooding from the alluvium, but this would likely be in continuity with the watercourse, and unlikely to exceed the extent of the fluvial floodplain.

3.56 The catchment of the River Terrace Deposit is understood to be limited, therefore the risk of groundwater emerging directly from the aquifer is considered to be low, unless excavations into the deposits are made.

3.57 However, it is underlain by less permeable mudstone, which may limit the ability for groundwater to drain away from the aquifer into the underlying strata. This may manifest itself at surface level as reduced infiltration and increased runoff during prolonged storm events.

Eastern Parcel

3.58 The Eastern Parcel is shown to be underlain by Alluvium superficial deposits associated with the Red Brook floodplain. There is are also isolated regions of River Terrace Deposits located on the southern boundary, and a large region in the north of the parcel.

3.59 There is a risk of groundwater flooding from the alluvium, but this would likely be in continuity with the watercourse event, and unlikely to exceed the extent of the fluvial floodplain.

3.60 The catchment of the isolated River Terrace Deposit on the southern boundary are understood to be limited, therefore the risk of groundwater emerging directly from these is considered to be low, unless excavations into the deposits are made.

3.61 However, they are underlain by less permeable mudstone, which may limit the ability for groundwater to drain away from the aquifer into the underlying strata. This may manifest itself at surface level as reduced infiltration and increased runoff during prolonged storm events.

3.62 The potential catchment of the River Terrace Deposit on the north of the site is potentially much greater and likely to be continuity with the River Wye, and there is a risk of that groundwater levels could rise in prolonged storm events. The clayey composition of the overlying soil may reduce the likelihood that groundwater could resurge at the surface, any potential emergence would occur in the low-lying areas to the north of the site or within the Red Brook floodplain via the alluvium, unless excavations into the deposits are made.

3.63 Recommended mitigation measures to address the groundwater flood risk are summarised in Section 4.

<u>Watery Lane Vehicle Bypass Facility</u>

3.64 The Watery Lane vehicle bypass facility is considered to be at risk from groundwater flooding. As stated previously there is no proposed development at this location, simply the preservation of existing egress routes.

Flood Risk from Reservoirs & Large Waterbodies

3.65 Flooding can occur from large waterbodies or reservoirs if they are impounded above the surrounding ground levels or are used to retain water in times of flood. Although unlikely, reservoirs and large waterbodies could overtop or breach leading to rapid inundation of the downstream floodplain.

3.66 To help identify this risk, reservoir failure flood risk mapping has been prepared, this shows the largest area that might be flooded if a reservoir were to fail and release the water it holds. The map displays a worst case scenario and is only intended as a guide. An extract from the mapping is included as Figure 3.5.

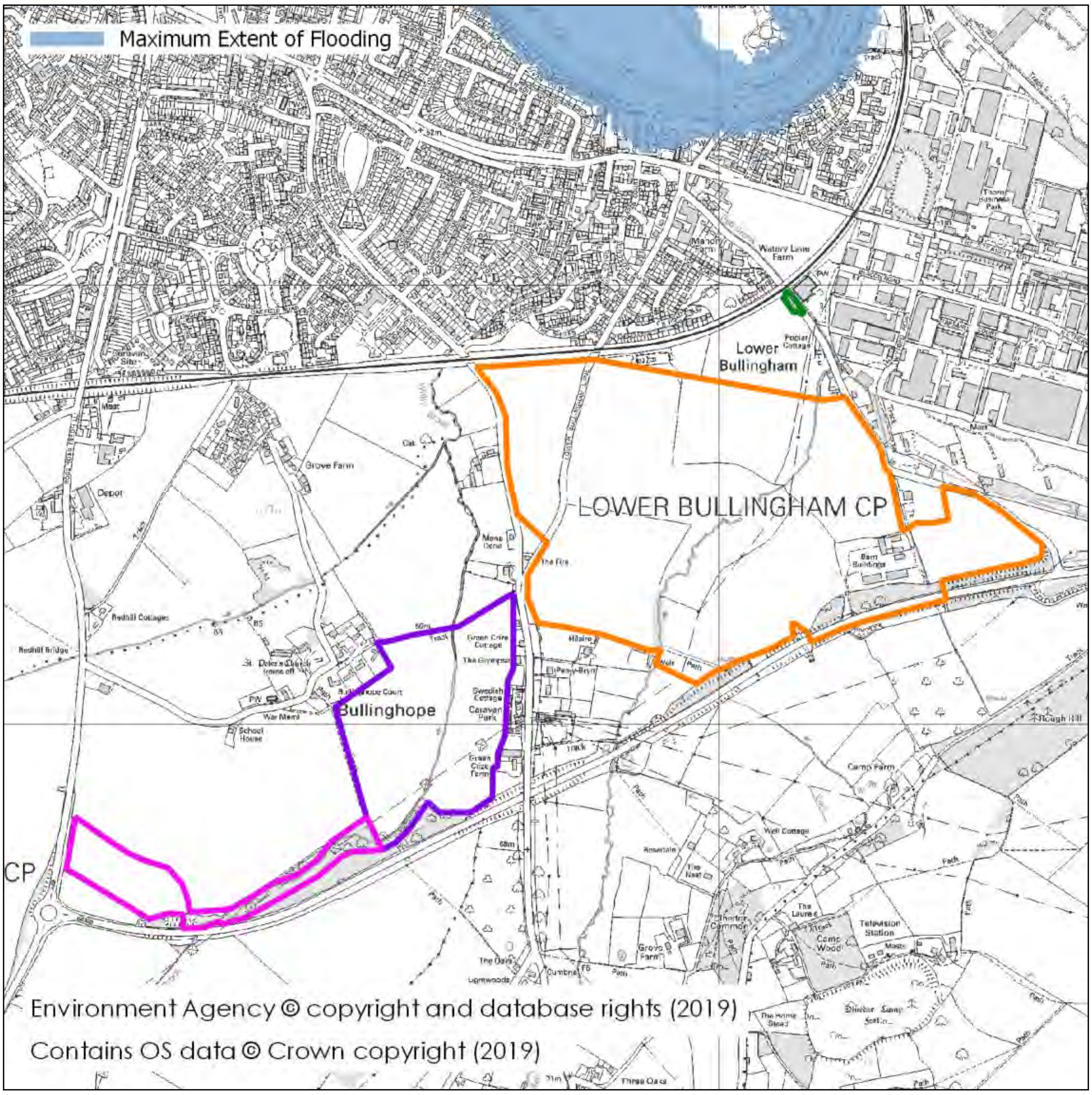


Figure 3.5 - Reservoir Failure Flood Risk Map

3.67 The site is shown to be located outside of the area at risk of reservoir flooding.

Pluvial Flood Risk

3.68 Pluvial flooding can occur during prolonged or intense storm events when the infiltration potential of soils, or the capacity of drainage infrastructure is overwhelmed leading to the accumulation of surface water and the generation of overland flow routes.

3.69 Risk of flooding from surface water mapping has been prepared, this shows the potential flooding which could occur when rainwater does not drain away through the normal drainage systems or soak into the ground, but lies on or flows over the ground instead. An extract from the mapping is included as Figure 3.6.

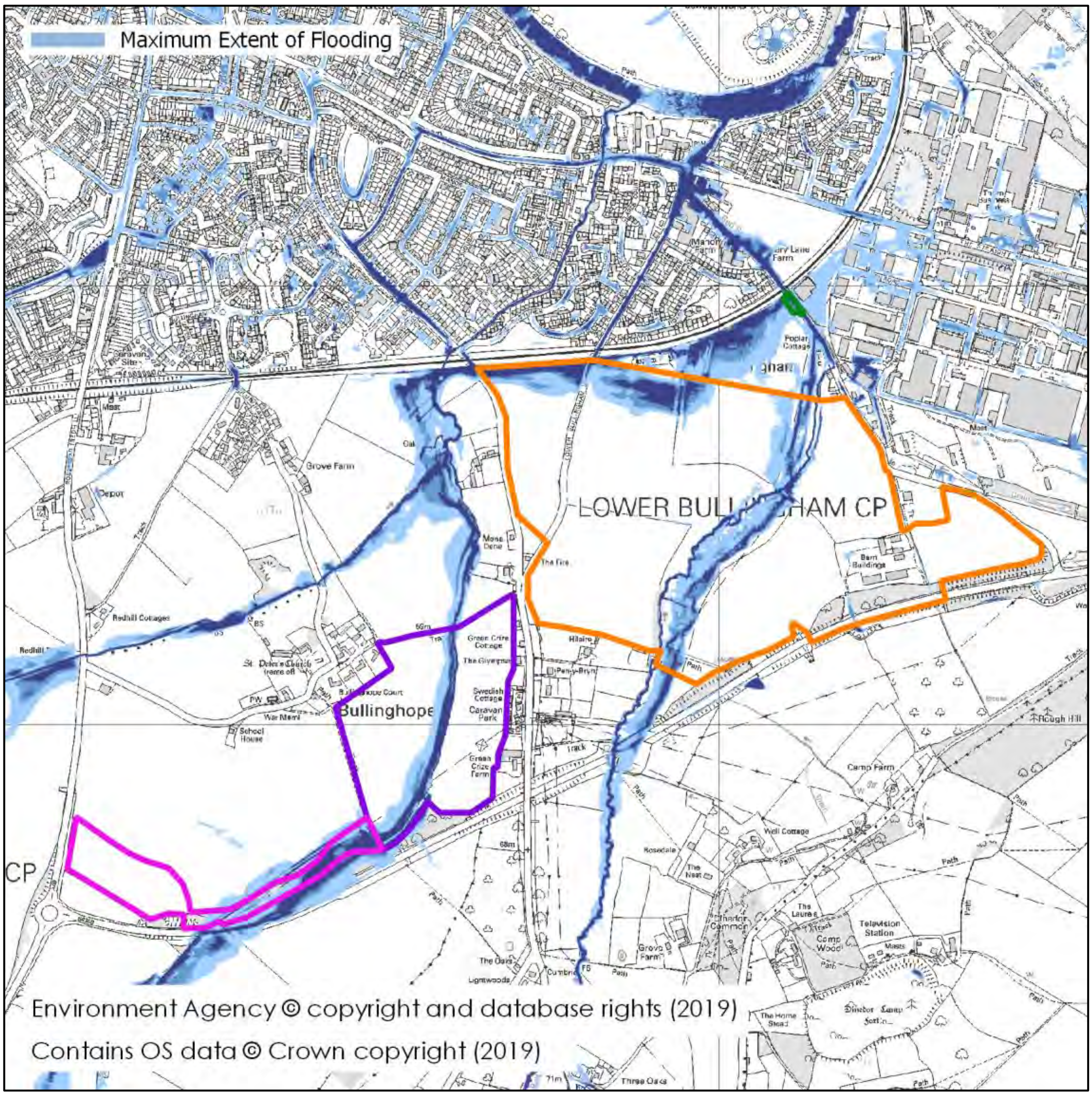


Figure 3.6 - Risk of Flooding from Surface Water Mapping

3.70 The surface water mapping shows the majority of the site to be at very low risk of flooding from surface water.

3.71 The areas at risk of flooding from surface water are representative of the floodplains associated with the minor watercourses, and the presence of the elevated B4399 on the southern boundary means that pluvial runoff outside of the site can only enter the site as part of the fluvial system. Therefore, this source of flood risk is considered as part of the fluvial flood modelling.

3.72 However, it is considered that pluvial runoff generated within the development itself could pose a potential flood risk.

3.73 The Herefordshire PFRA (2011) outlines that the local area is at 'significant' risk from surface water flooding. However, this is based on coarse mapping and is informed by the Flood Maps for Surface Water (FMfSW), which are 'indicative'.

3.74 The flood risk from surface water flooding is addressed within mitigation measures outlined in Section 4.0.

Flood Risk from Sewers

3.75 Sewer flooding can occur when the capacity of the infrastructure is exceeded by excessive flows, or as a result of a reduction in capacity due to collapse or blockage, or if the downstream system becomes surcharged. This can lead to the sewers flooding onto the surrounding ground via manholes and gullies, which can generate overland flows.

3.76 Welsh Water Sewer Records are included within Appendix 4. The local sewer network is predominately present within the residential and industrial areas downstream of the site. Given the difference in elevation between these areas and the site, this source of flood risk is considered to be generally low.

Effect of Development on Wider Catchment

Displacement of Floodplain

3.77 The development of the site will be sequential arranged to avoid the existing floodplain where possible. However, it is envisaged that some encroachment into the 1 in 100-year+35% floodplain could occur at locations where a bridge over a watercourse is required, or where the floodplain needs to be rearranged to form a more favourable development area.

3.78 Displacement of the floodplain reduces the volume of available floodplain, potentially leading to detriment within the wider area, unless appropriate mitigation measures are implemented. The mitigation measures proposed to address the displacement of the floodplain within the development are discussed within Section 4.0.

Impedance of Flood Flows

3.79 The development of the site has the potential to impede floodplain flows where a bridge crossing of a watercourse is proposed, unless appropriate mitigation measures are implemented. This has the potential to divert flood water into third party leading to detriment.

3.80 The mitigation measures proposed to address the displacement of the floodplain within the development are discussed within Section 4.0.

<u>Development Drainage</u>

3.81 The development will inevitably result in a significant increase in impermeable surfaces on site when compared to its existing greenfield state. This will require suitable mitigation measures which are discussed within Section 4.0.

3.82 The SFRA emphasises that importance of a detailed surface water management plan in order to address problematic and conflicting surface water and flood risk issues. In instances where it is not clearly established what the downstream risks may be, the SFRA outlines that the most appropriate option is to maintain the same runoff from the development site as that for the greenfield for the same event.

3.83 Downstream flooding issues exist as a result of the route of the Red Brook through the Watery Lane residential area. The SFRA states that any development on the south side of Bullingham will carry the potential to increase loadings on this watercourse. The proposed development drainage strategy will need to take this issue into account.

4. FLOOD RISK MITIGATION

4.1 Section 3.0 has identified the sources of flooding which could potentially pose a risk to the site and the proposed development. This section of the FRA sets out the mitigation measures which are to be incorporated within the proposed development to address and reduce the risk of flooding to within acceptable levels.

Sequential Arrangement

4.2 The illustrative development areas are mapped against the floodplain within Appendix 5.

<u>Western Parcel</u>

4.3 The area proposed for development on the Western Parcel will be arranged to fall on land outside of the modelled floodplain, on land within Flood Zone 1. Therefore, the park and choose will be at a low risk of fluvial flooding.

<u>Central Parcel</u>

4.4 The hydraulic modelling exercise has shown that the Central Development Parcel is at a high flood risk. However, the proposed development is a country park and is classified as 'Water Compatible' with no proposed built development, this is deemed to be acceptable under the NPPF.

<u>Eastern Parcel</u>

4.5 The site layout has been arranged in an attempt locate the proposed development outside of the 1 in 100-year + 35% floodplain (the design floodplain) where possible to minimise the risk of fluvial flooding.

4.6 There are thought to be a few locations where the development could encroach into the design floodplain. These include the proposed bridge crossing of the Red Brook, and the edge of a proposed surface water attenuation pond/basin. These areas are highlighted within Appendix 5.

Development Levels

4.7 Finished floor levels should be set at a minimum of 600mm above the adjacent 1 in 100-year + 35% flood level.

4.8 Peak flood levels are mapped and detailed within Appendix 3. This shows that the recommended 600mm freeboard is sufficient to offer resilience against the 1 in 100-year+70% and the 1 in 1000-year flood events, and also against the increased flood levels resulting from potential blockages of key structure and changes in floodplain and channel condition (roughness).

4.9 It is also recommended that finished floor levels are set a minimum of 150mm above adjacent ground levels, and that ground levels are profiled to encourage pluvial runoff and overland flows away from the built development and towards the nearest drainage point.

Safe Access and Egress

4.10 Safe dry access and egress will be achievable from the eastern parcel during all flood events via a new access from the B4399 road to the south, and also via Hoarwithy Road southwards to the north-west of the site, where necessary.

4.11 Safe dry access and egress will be achievable from the western parcel during all flood events via a new access from the B4399 or A49.

Watery Lane Vehicle Bypass Facility

4.12 As part of the traffic management solutions for the development it is proposed to stop-up Watery Lane at the railway line. To preserve the existing residents' access to the high ground on the southern side of the railway line during a flood event a gated layby arrangement is proposed.

Floodplain Compensation

4.13 Level for level floodplain compensation will be provided as required by the Environment Agency and SFRA. Approximate areas which could be used for future compensation are highlighted within Appendix 5.

4.14 As the development is only at an outline stage, the final extent of development/earthworks within the floodplain is currently unknown. Therefore, design of any necessary floodplain compensation has not yet been completed. It is envisaged that this will be undertaken at the detailed design stage.

4.15 However, as an informative at this outline stage, the illustrative parameter plan was used to raise land within the development parcels above flood levels within the hydraulic model. As a worst-case assessment no representation of floodplain compensation was included.

4.16 The comparative analysis is mapped within Appendix 3, for flood events up to and including the design flood (1 in 100-year+35%). As an informative the comparison also includes for the 1 in 100-year+70% and 1 in 1000-yrear events, but it should be noted that these are beyond typical design standard.

4.17 The comparative analysis shows that there are localised changes in flood levels centred around the proposed bridge crossing, but that any changes dissipate within a short distance.

4.18 In the 1 in 100-year, 1 in 75-year, and 1 in 50-year events some nominal impacts are predicted to the north of the application site. The impacts eminent from the proposed bridge crossing, but occur on land within the wider land ownership. Therefore, these are considered acceptable.

4.19 It should be noted that in reality floodplain compensation will be offered to offset the loss in floodplain resulting from the development, thereby reducing any potential impacts. But even with no floodplain compensation represented within the model, the developments impact on the floodplain outside of the site is minimal.

4.20 Additionally, attenuated surface water drainage in the form of SuDS will reduce the equative runoff from the development to the greenfield QBAR rate, thereby offering some betterment to the contributing runoff from the site to the downstream floodplain.

Surface Water Drainage

4.21 The surface water drainage strategy is discussed within the Sustainable Drainage Document, document reference BULL-BWB-ZZ-XX-RP-EN-0004_SDS, and an illustrative plan from the drainage strategy is provided in Appendix 5.

4.22 The potential infiltration rate of the site has been preliminarily investigated in the site investigations. This reported that two of the four tests within the site resulted in no infiltration, due to the clayey nature of the soil. The other two tests reported an initial infiltration rate within the superficial granular soils, but that this was short lived due to the clay substrate below. The shallow nature of the groundwater also means that this is likely to be a feasible method of discharging surface water from the development.

4.23 It is therefore proposed to continue to discharge surface water to the Red Brook and associated watercourses. Attenuated surface water drainage in the form of SuDS will reduce the equative runoff from the development to the greenfield QBAR rate, thereby offering betterment to the contributing runoff from the development to the overloaded fluvial system downstream of the site.

4.24 This approach could increase the risk of the site runoff coinciding with the River Wye flood peak, but it is believed that the relatively low discharge rate is nominal when compared to flood flows on the River Wye, and therefore the development should aim to aid the flood risk immediately downstream of the site.

4.25 A surface water drainage strategy will be implemented at the Western Parcel ('Park and Choose'). Surface water attenuated storage will be designed to accommodate the 100-year storm, plus an allowance for climate change. This will minimise impact on the receiving waterbody in all but extreme events.

4.26 Runoff from the proposed country park will drain naturally through a combination of infiltration and sheet runoff to the local watercourse, as existing.

4.27 It is proposed that surface water runoff from the Parcel is discharged into the Red Brook, and tributary watercourses, as existing. Surface water attenuated storage will be designed to accommodate the 100-year storm, plus an allowance for climate change. This will minimise any additional loading on the receiving waterbody in all but extreme events.

Foul Water Drainage

4.28 It is proposed to drain used water from the development separately to surface water.

4.29 It is proposed to work with the local surface operator to ensure sufficient capacity for the development is available within the sewage infrastructure prior to occupation.

Land Drainage

4.30 The flood risk posed by the shallow groundwater levels in the site will be mitigated through elevating the development levels above surrounding ground levels.

4.31 However, the presence of the shallow groundwater levels should be considered in the design of the earthworks, foundations, and below ground infrastructure.

4.32 The shallow groundwater should also be considered during the construction phase of the development, particularly during the excavations. It is recommended that groundwater levels are monitored during the construction phase, and where groundwater is encountered appropriate dewatering solutions should be employed.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 This Flood Risk Assessment (FRA) has been prepared in accordance with requirements set out in the National Planning Policy Framework (NPPF) and the associated Planning Practice Guidance. The FRA has been produced on behalf of Bloor Homes Limited in respect of a planning application for a mixed-use, residentially-led development at Bullingham, Hereford.

5.2 This FRA is intended to support an outline planning application and as such the level of detail included is commensurate and subject to the nature of the proposals.

5.3 This report demonstrates that the proposed development is not at significant flood risk, subject to the recommended flood mitigation strategies being implemented. The identified risks and mitigation measures are summarised within Table 5.1:

Table 5.1: Summary of Flood Risk Assessment

Flood Source	Proposed Mitigation Measures
Fluvial	The development has been arranged within the site to avoid the 1 in 100-year plus climate change floodplain, where possible. Finished floor and threshold levels of the development will be set a minimum of 600mm above the 1 in 100-year plus climate change flood level.
Groundwater	The development has been arranged within the site to avoid the low-lying floodplain and the underlying alluvium, where possible. Finished floor levels are to be set a minimum of 150mm above adjacent ground levels, and ground levels are profiled to encourage overland flows away from the built development and towards the nearest drainage point. The presence of the shallow groundwater levels should be considered in the design of the earthworks, foundations, and below ground infrastructure Where groundwater is encountered appropriate dewatering solutions will be employed.
Pluvial runoff	Finished floor levels are to be set a minimum of 150mm above adjacent ground levels, and ground levels are profiled to encourage pluvial runoff and overland flows away from the built development and towards the nearest drainage point.
Impact of the Development	Any loss in the 1 in 100-year+35% floodplain resulting from the development will be recreated in a level-for-level manner. Surface water runoff from the development will be limited to the equivalent greenfield QBAR runoff rate, and on-site attenuated storage will be provided outside of the floodplain up to the 1 in 100-year + climate change storm event.
This summary should be read in conjunction with BWB's full report. It reflects an assessment of the Site based on information received by BWB at the time of production.	

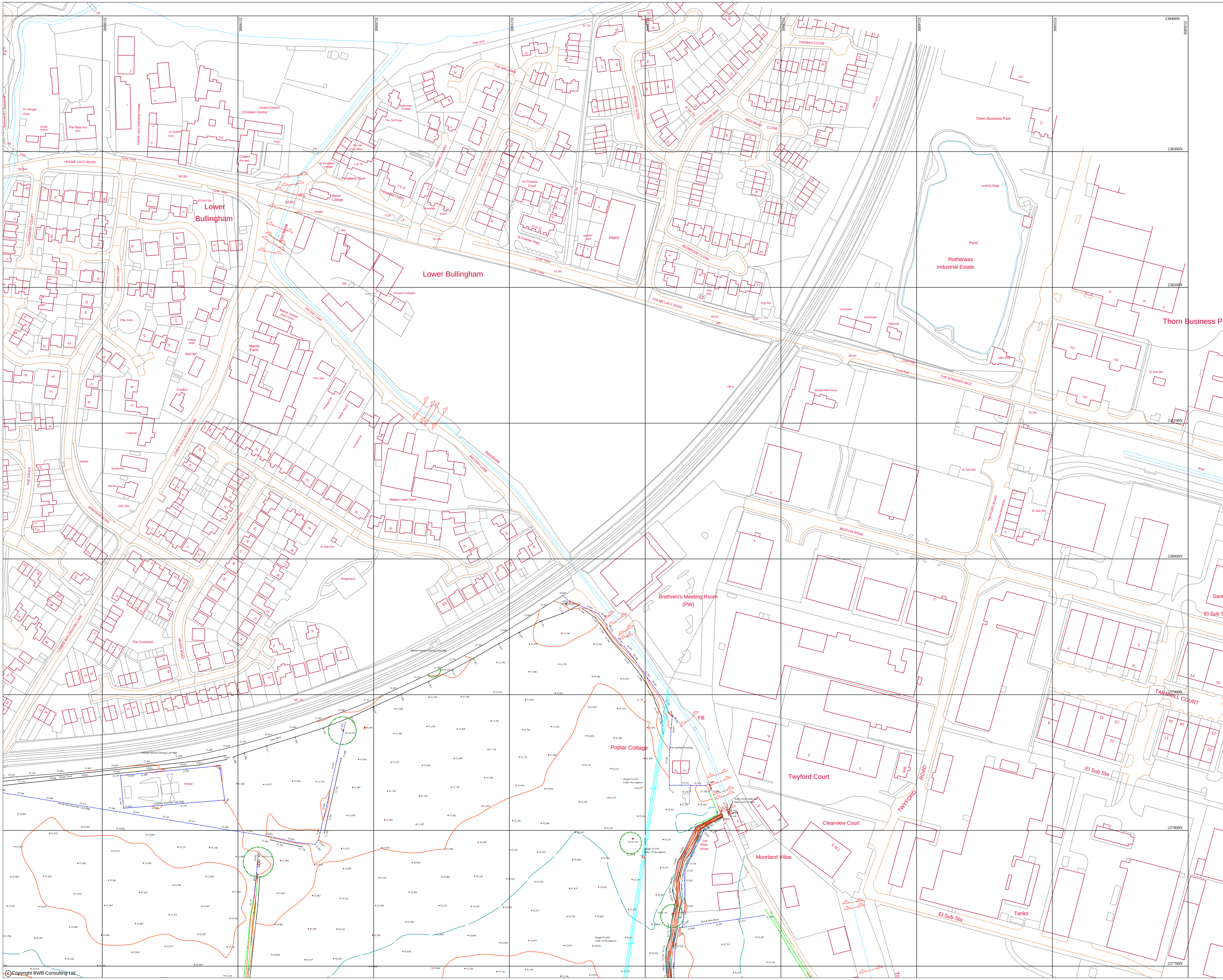
5.4 It is proposed to compensate for the loss in floodplain in a level-for-level manner, and designs should be prepared at the detailed design stage when the final extent of development is confirmed.

5.5 The development will include at least one bridge crossing of the watercourses. It is envisaged that the bridge parameters and appropriate floodplain compensation will be identified at the detailed design stage.

5.6 In compliance with the requirements of National Planning Policy Framework, and subject to the mitigation measures proposed, the development could proceed without being subject to significant flood risk. Moreover, the development will not increase flood risk to the wider catchment area as a result of suitable management of surface water runoff discharging from the site.

APPENDICES

APPENDIX 1: Topographical Survey



NOTES

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STATION COORDINATES

STN NAME	EASTINGS (m)	NORTHINGS (m)	HEIGHT (m)
BWB1	351817.940	236957.251	63.222
BWB2	351694.529	236895.027	64.788
BWB3	351849.644	237078.412	60.188
BWB4	351863.039	237127.336	59.926
BWB5	351998.782	237418.385	56.404
BWB6	352368.168	237630.496	52.410
BWB7	352312.794	237707.558	51.931
BWB8	352388.474	237574.969	55.210
BWB9	352476.916	237554.832	54.839
BWB10	352258.212	237809.263	52.547
BWB11	352235.086	237875.764	51.048
BWB12	352037.964	238103.705	49.952
PR6	352183.854	237947.573	50.603
PR7	351911.174	238223.021	49.385
PR9	351930.466	238275.248	50.230

LEGEND

	OS Buildings	Elec	Electric
	Surveyed Buildings	BT	British Telecom
	Buildings / walls	Fh	Fire Hydrant
	Kerb line	St	Stop tap
	Edge of surface	Sv	Stop valve
	Canopy / Overhang	Wo	Wash Out
	Line Marking	Wm	Water Meter
	Centre Line	Mkr	Service Marker
	Barrier	Re	Rodding eye
	Security Fence	Av	Air Valve
	Panel Fence	Cmp	Cable Marker
	Open Fence	Lp	Lamp Post
	Hedge	Sp	Sign Post
	Overhead Powerline	Ep	Electricity Post
	Chamber	Tp	Telegraph Post
	Woodland	TL	Traffic light
1	Station and Name	Bs	Bus Stop
100.000	Station Level	Fl	Floodlight
BM 100.00	Benchmark	Fp	Flagpole
BH 1	Borehole	Pb	Post box
TH 1	Trial Hole	Lb	Litter Bin
Bush Sap	Tree / Bush / Sapling	Bo	Bollard
	Area of Undergrowth	TCB	Telephone call box
	Gate	Fs	Flagstaff
IC	Inspection chamber	WL	Water level
CL	Cover level	ht	Height
IL	Invert level	IFL	Internal floor level
P.Inv ⌀0.25	Pipe invert (diameter)	THL	Threshold level
Gy	Gully	Re	Rodding Eye
Bg	Back Gully	Dk	Drop kerb
MH	Manhole	Gas	Gas
		Er	Earth rod

Rev	Date	Details of issue / revision	Drw	Rev

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Client
BWB Consulting Ltd

Project Title
Lower Bullingham

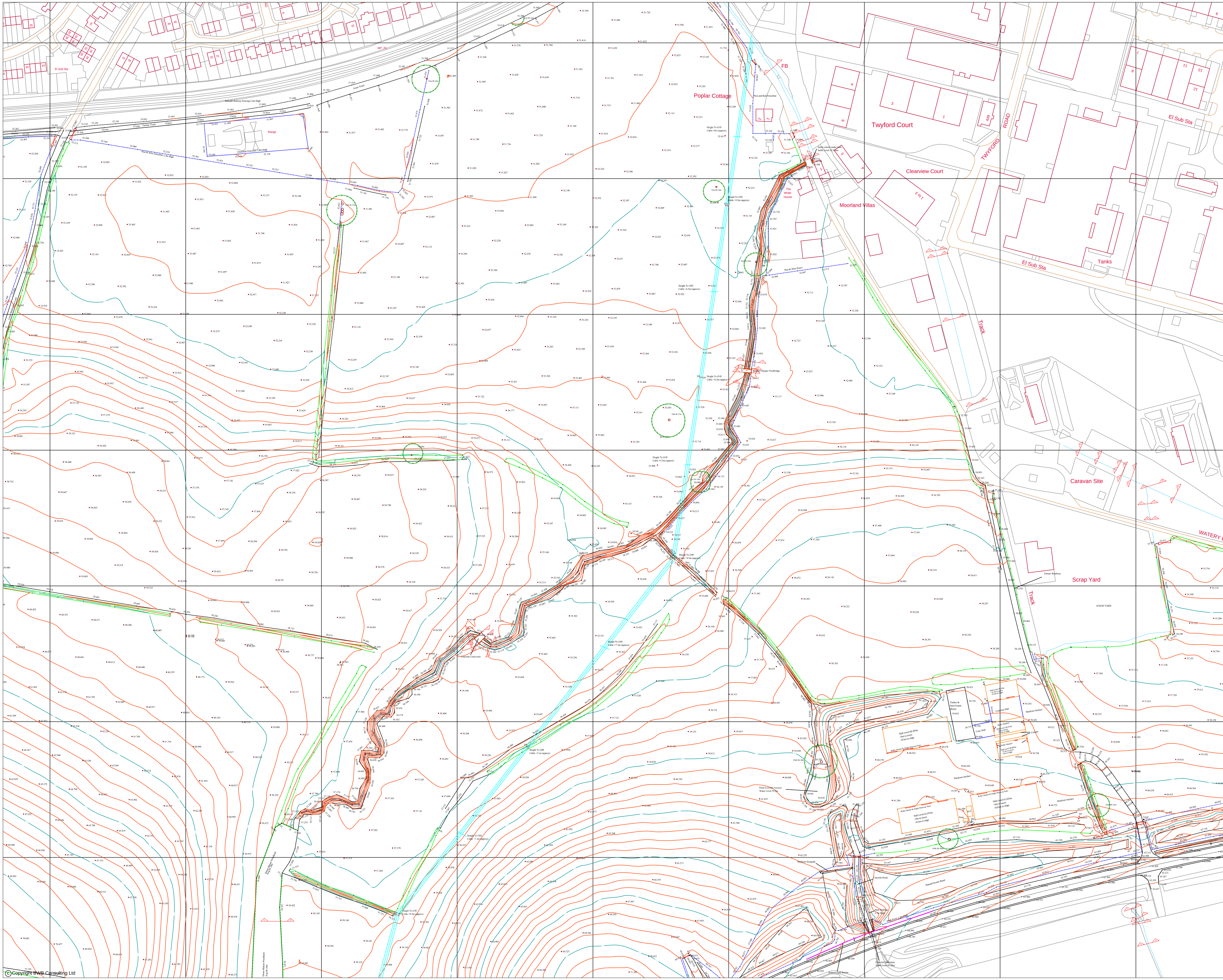
Drawing Title
Watercourse Sections

Scale	1:1250 @ A1	Drawn	JK2
Size	A1	Reviewed	B0894

Drawing Status
Final

Drawing No.
18102_OGL

Revision
0



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LEGEND

OS Buildings
Surveyed Buildings
Buildings / walls
Kerb line
Edge of surface
Canopy / Overhang
Line Marking
Centre Line
Barrier
Security Fence
Panel Fence
Open Fence
Hedge
Overhead Powerline
Chamber
Woodland
1 Station and Name
100.000 Station Level
BM 100.00 Benchmark
BH 1 Borehole
TH 1 Trial Hole
Bush Sap Tree / Bush / Sapling
Area of Undergrowth
Gate
IC Inspection chamber
CL Cover level
IL Invert level
P.Inv ø0.25 Pipe invert (diameter)
Gy Gully
Bg Back Gully
MH Manhole

Elec Electric
BT British Telecom
Fh Fire Hydrant
St Stop tap
Sv Stop valve
Wo Wash Out
Wm Water Meter
Mkr Service Marker
Re Rodding eye
Av Air Valve
Cmp Cable Marker
Lp Lamp Post
Sp Sign Post
Ep Electricity Post
Tp Telegraph Post
TL Traffic light
Bs Bus Stop
Fl Floodlight
Fp Flagpole
Pb Post box
Lb Litter Bin
Bo Bollard
TCB Telephone call box
Fs Flagstaff
WL Water level
ht Height
IFL Internal floor level
THL Threshold level
Re Rodding Eye
Dk Drop kerb
Gas Gas
Er Earth rod

Rev	Date	Details of issue / revision	Drw	Rev

ISSUES & REVISIONS

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Client
BWB Consulting Ltd

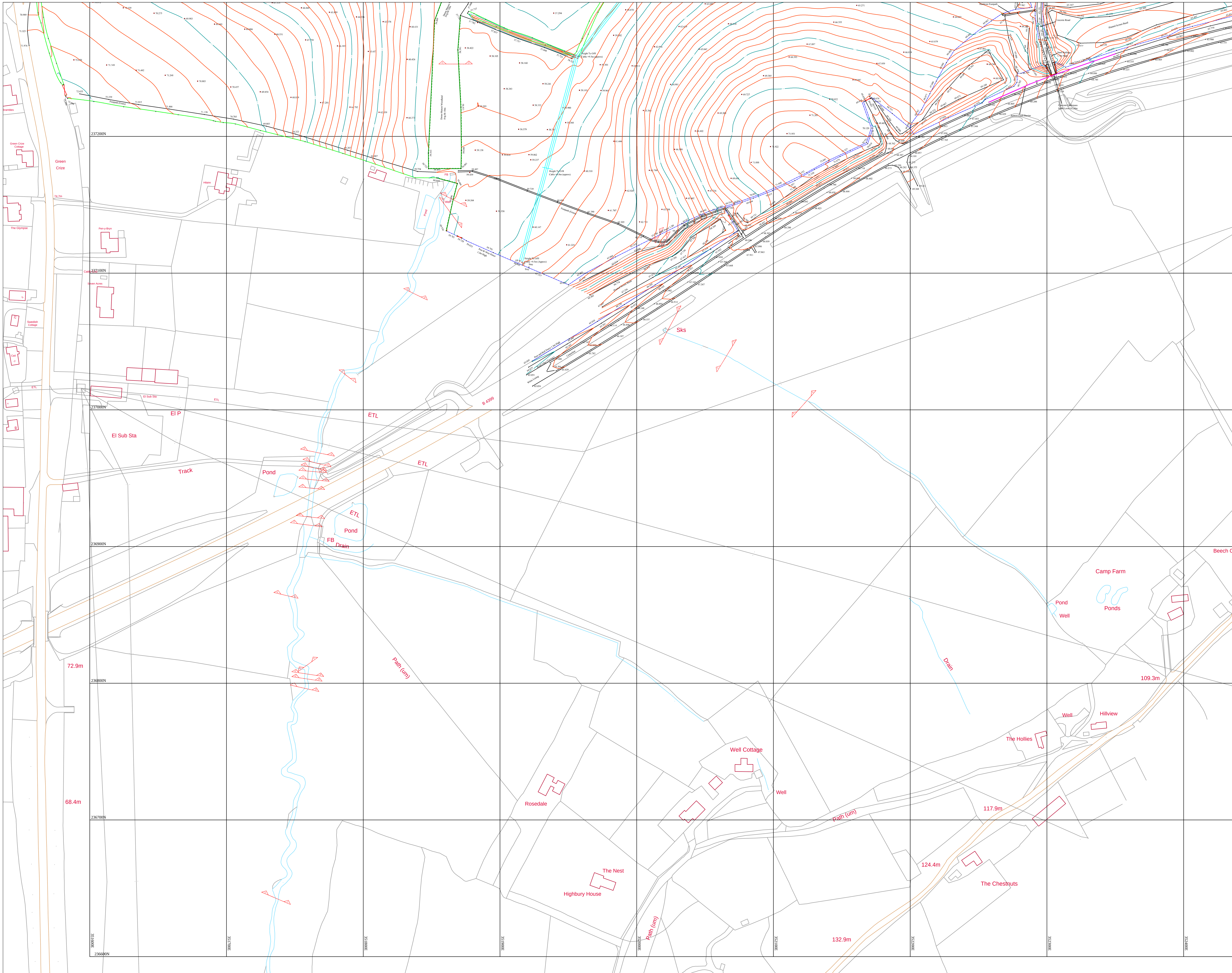
Project Title
Lower Bullingham

Drawing Title
Watercourse Sections

Scale	1:1250 @ A1	Drawn	JK2
Size	A1	Reviewed	B0894

Drawing Status
Final

Drawing No.	Revision
18102_OGL	0



NOTES

1. DO NOT SCALE THIS DRAWING. ALL DIMENSIONS MUST BE CHECKED/ VERIFIED ON SITE. IF IN DOUBT ASK.
2. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ALL RELEVANT ARCHITECTS, ENGINEERS AND SPECIALISTS DRAWINGS AND SPECIFICATIONS.
3. ALL DIMENSIONS IN METRES UNLESS NOTED OTHERWISE. ALL LEVELS IN METRES UNLESS NOTED OTHERWISE.
4. ANY DISCREPANCIES NOTED ON SITE ARE TO BE REPORTED TO THE ENGINEER IMMEDIATELY.
5. NO SCALE FACTOR HAS BEEN APPLIED TO THIS SURVEY, THEREFORE THE OS COORDINATES ARE TO BE TREATED AS ARBITRARY. PLEASE REFER TO SURVEY STATION INFORMATION BELOW FOR ON SITE CONTROL ESTABLISHMENT.

STATION COORDINATES

STN NAME	EASTINGS (m)	NORTHINGS (m)	HEIGHT (m)
BWB1	351817.940	236957.251	63.222
BWB2	351694.529	236895.027	64.788
BWB3	351849.644	237078.412	60.188
BWB4	351863.039	237127.336	59.926
BWB5	351998.782	237418.385	56.404
BWB6	352368.168	237630.496	52.410
BWB7	352312.794	237707.558	51.931
BWB8	352388.474	237574.969	55.210
BWB9	352476.916	237554.832	54.839
BWB10	352258.212	237809.263	52.547
BWB11	352235.086	237875.764	51.048
BWB12	352037.964	238103.705	49.952
PR6	352183.854	237947.573	50.603
PR7	351911.174	238223.021	49.385
PR9	351930.466	238275.248	50.230

LEGEND

	OS Buildings	Elec	Electric
	Surveyed Buildings	BT	British Telecom
	Buildings / walls	Fh	Fire Hydrant
	Kerb line	St	Stop tap
	Edge of surface	Sv	Stop valve
	Canopy / Overhang	Wo	Wash Out
	Line Marking	Wm	Water Meter
	Centre Line	Mkr	Service Marker
	Barrier	Re	Rodding eye
	Security Fence	Av	Air Valve
	Panel Fence	Cmp	Cable Marker
	Open Fence	Lp	Lamp Post
	Hedge	Sp	Sign Post
	Overhead Powerline	Ep	Electricity Post
	Chamber	Tp	Telegraph Post
	Woodland	TL	Traffic light
1	Station and Name	Bs	Bus Stop
100.000	Station Level	Fl	Floodlight
BM 100.00	Benchmark	Fp	Flagpole
BH 1	Borehole	Pb	Post box
TH 1	Trial Hole	Lb	Litter Bin
Bush Sap	Tree / Bush / Sapling	Bo	Bollard
	Area of Undergrowth	TCB	Telephone call box
	Gate	Fs	Flagstaff
IC	Inspection chamber	WL	Water level
CL	Cover level	ht	Height
IL	Invert level	IFL	Internal floor level
P.Inv ø0.25	Pipe invert (diameter)	THL	Threshold level
Gy	Gully	Re	Rodding Eye
Bg	Back Gully	Dk	Drop kerb
MH	Manhole	Gas	Gas
		Er	Earth rod

Rev	Date	Details of issue / revision	Drw	Rev

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Client
BWB Consulting Ltd

Project Title
Lower Bullingham

Drawing Title
Watercourse Sections

Scale	1:1250 @ A1	Drawn	JK2
Size	A1	Reviewed	B0894

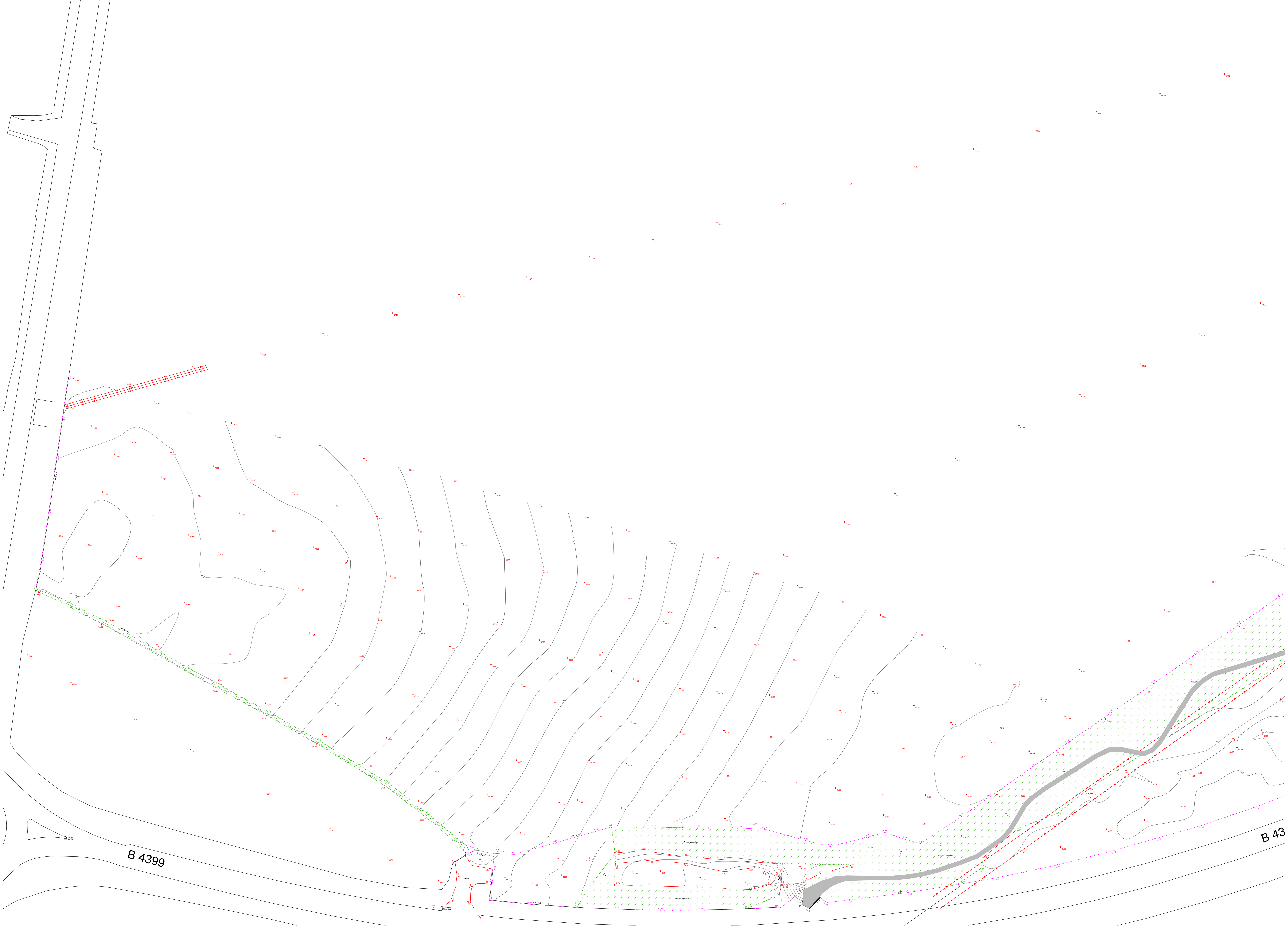
Drawing Status
Final

Drawing No.
18102_OGL

Revision
0

Station Coordinates

Station Name	Eastings (m)	Northings (m)	Height (m)
BWB01	350673.350	236536.303	65.429
BWB02	350520.089	236564.891	68.521
BWB03	351554.229	237240.099	72.952
BWB04	351552.216	237294.990	70.844



Notes

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6. All coordinates and height data relate to OSGB36(15). Control stations are coordinated by means of GPS receiving real time corrections via OS smart net.
7. All manhole data is collected from ground level therefore discrepancies may occur. More accurate data is only achievable via confined space entry.
8. OS license number: 100022432

Key Plan

Legend

OS Buildings
Surveyed Buildings
Building
Wall
Kerb Channel Line
Top of Kerb
Edge of Surface
Top of Bank
Bottom of Bank
Canopy / Overhang
Line Marking
Centre Line
Watercourse Centre Line
Barrier
Fence
Gate
Overhead Powerline
Overhead Utilities

Contour Lines
Inspection Chamber
0.25 Flow direction and pipe diameter
1 Station and Name
BH 1 Monitoring Borehole
Tree / Bush / Sapling
Area of Vegetation/ Extent of Tree Canopy
Hedge
Body of Water
Body of Water from OS
+50.00 Spot Level
Assumed Surface Water Drainage Line
Surface Water Drainage Line

AP	Anchor Point	FBW	Fence Barbed Wire	LB	Litter Bin
BG	Back Gully	FCB	Fence Closed Board	LP	Lamp Post
BO	Bollard	FCL	Fence Chain Link	MH	Manhole
BS	Bus Stop	FEL	Fence Electric	Mkr	Service Marker
BT	British Telecom	FMP	Fence Metal Panel	PB	Post Box
C	Crest	FMR	Fence Metal Railing	PT	Post
CL	Cover Level	FOB	Fence Open Board	RE	Rodding Eye
CMP	Cable Marker Post	FPW	Fence Post & Wire	SP	Sign Post
CCTV	Security Camera	FSP	Fence Steel Palisade	ST	Stop Tap
CTV	Cable TV	FWM	Fence Wire Mesh	SV	Stop Valve
DC	Drainage Channel	FFL	Finished Floor Level	TCB	Telephone Call Box
DK	Drop Kerb	FP	Flagpole	THL	Threshold Level
DP	Down Pipe	Gas	Gas	TL	Traffic Light
Elec	Electric	GV	Gas Valve	TP	Telegraph Post
EP	Electricity Post	GY	Gully	TS	Traffic Signal
ER	Earth Rod	Ht	Height	UTS	Unable to Survey
FH	Fire Hydrant	IC	Inspection Chamber	WL	Water Level
FL	Floodlight	IFL	Internal Floor Level	WM	Water Meter
		IL	Invert Level (as a reduced level)	WO	Wash Out

P1	16.10.17	First Isssue	SDS	DS
Rev	Date	Details of issue / revision	Drw	Rev

Issues & Revisions

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Client
Bloor Homes Limited

Project Title
Bullingham
Hereford

Drawing Title
Existing Site Plan
Sheet 1 of 4

Drawn:	S. D. Shreeves	Reviewed:	D.Smith		
BWB Ref:	BMW2135	Date:	16.10.17	Scale@A0:	1:500

Drawing Status
INFORMATION

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
BULL-BWB-00-01-DR-G-001	S2	P1

X:\BMW\BMW2135_Bullingham, Hereford\Design and Calculations\IM Survey\7. WIP\Topographic Survey\BULL-BWB-00-ZZ-M2-G-001-Existing_Site_2D_Model.dwg

Station Coordinates			
Station Name	Eastings (m)	Northings (m)	Height (m)
BWB01	350673.350	236536.303	65.429
BWB02	350520.089	236564.891	68.521
BWB03	351554.229	237240.099	72.952
BWB04	351552.216	237294.990	70.844

Notes

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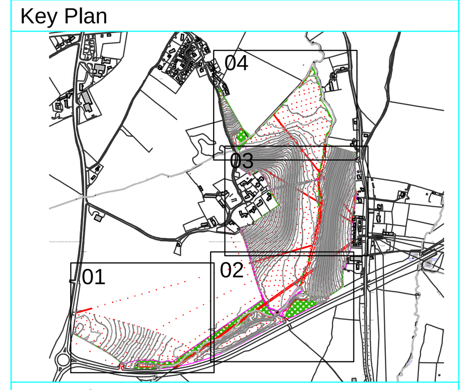
7. All manhole data is collected from ground level therefore discrepancies may occur. More accurate data is only achievable via confined space entry.
8. OS license number: 100022432

Key Plan



Legend

OS Buildings
Surveyed Buildings
Building
Wall
Kerb Channel Line
Top of Kerb
Edge of Surface
Top of Bank
Bottom of Bank
Canopy / Overhang
Line Marking
Centre Line
Watercourse Centre Line
Barrier
Fence
Gate
Overhead Powerline
Overhead Utilities
Contour Lines
Inspection Chamber
Flow direction and pipe diameter (0.25)
Station and Name (1)
Monitoring Borehole (BH 1)
Tree / Bush / Sapling
Area of Vegetation/ Extent of Tree Canopy
Hedge
Body of Water
Body of Water from OS
Spot Level (+50.00)
Assumed Surface Water Drainage Line
Surface Water Drainage Line

AP	Anchor Point	FBW	Fence Barbed Wire	LB	Litter Bin
BG	Back Gully	FCB	Fence Closed Board	LP	Lamp Post
BO	Bollard	FCL	Fence Chain Link	MH	Manhole
BS	Bus Stop	FEL	Fence Electric	Mkr	Service Marker
BT	British Telecom	FMP	Fence Metal Panel	PB	Post Box
C	Crest	FMR	Fence Metal Railing	PT	Post
CL	Cover Level	FOB	Fence Open Board	RE	Rodding Eye
CMP	Cable Marker Post	FPW	Fence Post & Wire	SP	Sign Post
CCTV	Security Camera	FSP	Fence Steel Palisade	ST	Stop Tap
CTV	Cable TV	FWM	Fence Wire Mesh	SV	Stop Valve
DC	Drainage Channel	FFL	Finished Floor Level	TCB	Telephone Call Box
DK	Drop Kerb	FP	Flagpole	THL	Threshold Level
DP	Down Pipe	Gas	Gas	TL	Traffic Light
Elec	Electric	GV	Gas Valve	TP	Telegraph Post
EP	Electricity Post	GY	Gully	TS	Traffic Signal
ER	Earth Rod	Ht	Height	UTS	Unable to Survey
FH	Fire Hydrant	IC	Inspection Chamber	WL	Water Level
FL	Floodlight	IFL	Internal Floor Level	WM	Water Meter
		IL	Invert Level (as a reduced level)	WO	Wash Out

Rev	Date	Details of issue / revision	Drw	Rev
P1	16.10.17	First Isssue	SDS	DS

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Client
Bloor Homes Limited

Project Title
Bullingham Hereford

Drawing Title
Existing Site Plan Sheet 2 of 4

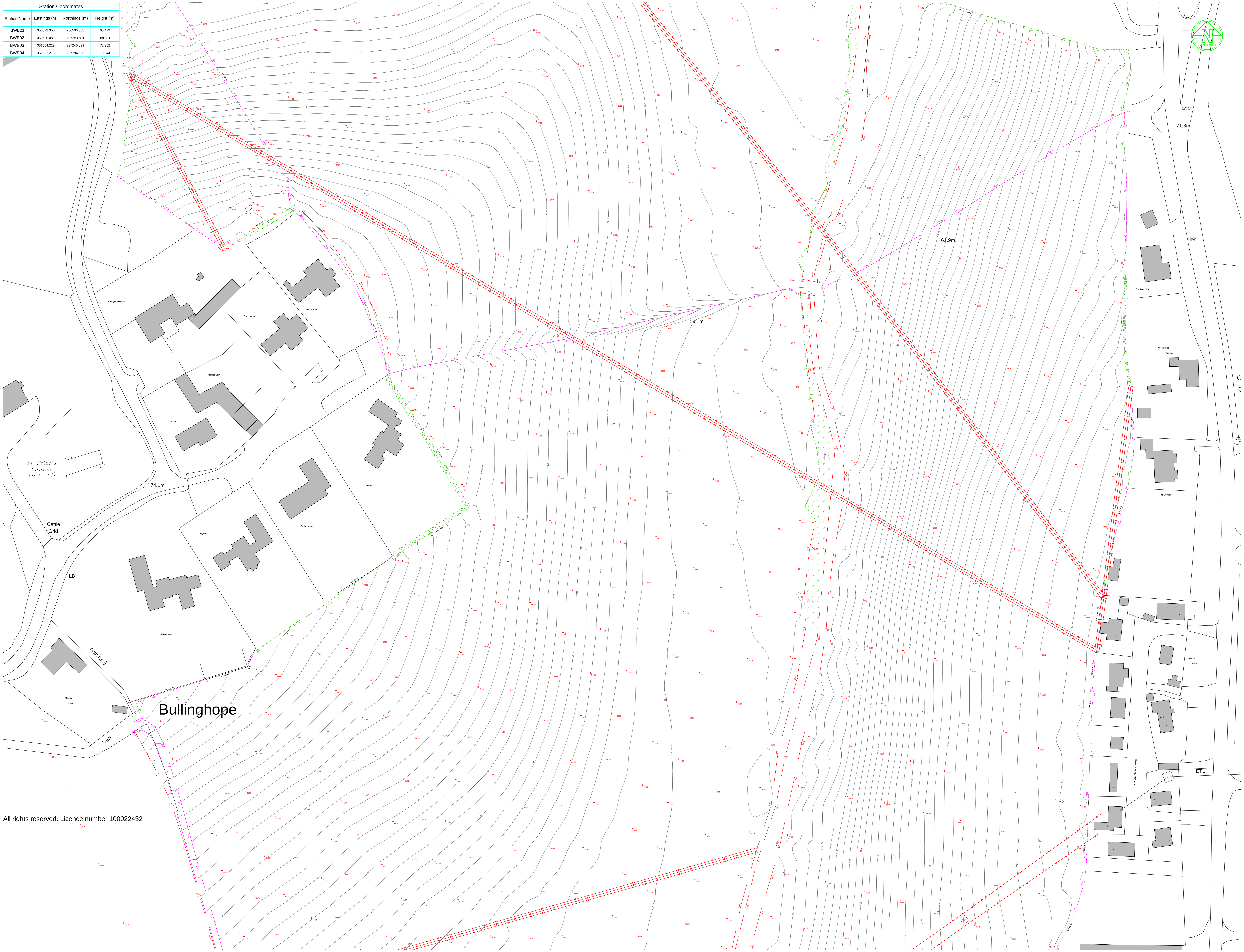
Drawn:	S. D. Shreeves	Reviewed:	D.Smith		
BWB Ref:	BMW2135	Date:	16.10.17	Scale@A0:	1:500

Drawing Status
INFORMATION

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
BULL-BWB-00-02-DR-G-001	S2	P1

Station Coordinates

Station Name	Eastings (m)	Northings (m)	Height (m)
BWB01	350673.350	236536.303	65.429
BWB02	350520.089	236564.891	68.521
BWB03	351554.229	237240.099	72.952
BWB04	351552.216	237294.990	70.844



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7. All manhole data is collected from ground level therefore discrepancies may occur. More accurate data is only achievable via confined space entry.
8. OS license number: 100022432

Key Plan

Legend

OS Buildings
Surveyed Buildings
Building
Wall
Kerb Channel Line
Top of Kerb
Edge of Surface
Top of Bank
Bottom of Bank
Canopy / Overhang
Line Marking
Centre Line
Watercourse Centre Line
Barrier
Fence
Gate
Overhead Powerline
Overhead Utilities
Contour Lines
Inspection Chamber
Flow direction and pipe diameter (0.25)
Station and Name (1)
Monitoring Borehole (BH 1)
Tree / Bush / Sapling
Area of Vegetation/ Extent of Tree Canopy
Hedge
Body of Water
Body of Water from OS
Spot Level (50.00)
Assumed Surface Water Drainage Line
Surface Water Drainage Line

AP	Anchor Point	FBW	Fence Barbed Wire	LB	Litter Bin
BG	Back Gully	FCB	Fence Closed Board	LP	Lamp Post
BO	Bollard	FCL	Fence Chain Link	MH	Manhole
BS	Bus Stop	FEL	Fence Electric	Mkr	Service Marker
BT	British Telecom	FMP	Fence Metal Panel	PB	Post Box
C	Crest	FMR	Fence Metal Railing	PT	Post
CL	Cover Level	FOB	Fence Open Board	RE	Rodding Eye
CMP	Cable Marker Post	FPW	Fence Post & Wire	SP	Sign Post
CCTV	Security Camera	FSP	Fence Steel Palisade	ST	Stop Tap
CTV	Cable TV	FWM	Fence Wire Mesh	SV	Stop Valve
DC	Drainage Channel	FFL	Finished Floor Level	TCB	Telephone Call Box
DK	Drop Kerb	FP	Flagpole	THL	Threshold Level
DP	Down Pipe	Gas	Gas	TL	Traffic Light
Elec	Electric	GV	Gas Valve	TP	Telegraph Post
EP	Electricity Post	GY	Gully	TS	Traffic Signal
ER	Earth Rod	Ht	Height	UTS	Unable to Survey
FH	Fire Hydrant	IC	Inspection Chamber	WL	Water Level
FL	Floodlight	IFL	Internal Floor Level	WM	Water Meter
		IL	Invert Level (as a reduced level)	WO	Wash Out

Rev	Date	Details of issue / revision	Drw	Rev
P1	16.10.17	First Isssue	SDS	DS

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Project Title

Bullingham Hereford

Drawing Title

Existing Site Plan Sheet 3 of 4

Drawn:	S. D. Shreeves	Reviewed:	D.Smith		
BWB Ref:	BMW2135	Date:	16.10.17	Scale@A0:	1:500

Drawing Status

INFORMATION

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
BULL-BWB-00-03-DR-G-001	S2	P1

Station Coordinates			
Station Name	Eastings (m)	Northings (m)	Height (m)
BWB01	350673.350	236536.303	65.429
BWB02	350520.089	236564.891	68.521
BWB03	351554.229	237240.099	72.952
BWB04	351552.216	237294.990	70.844

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7. All manhole data is collected from ground level therefore discrepancies may occur. More accurate data is only achievable via confined space entry.
8. OS license number: 100022432

Key Plan

Legend

OS Buildings
Surveyed Buildings
Building
Wall
Kerb Channel Line
Top of Kerb
Edge of Surface
Top of Bank
Bottom of Bank
Canopy / Overhang
Line Marking
Centre Line
Watercourse Centre Line
Barrier
Fence
Gate
Overhead Powerline
Overhead Utilities
Contour Lines
Inspection Chamber
0.25 Flow direction and pipe diameter
1 Station and Name
BH 1 Monitoring Borehole
Tree / Bush / Sapling
Area of Vegetation/ Extent of Tree Canopy
Hedge
Body of Water
Body of Water from OS
50.00 Spot Level
Assumed Surface Water Drainage Line
Surface Water Drainage Line

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		FSP	Fence Steel Palisade	ST	Stop Tap
CCTV	Security Camera	FWM	Fence Wire Mesh	SV	Stop Valve
CTV	Cable TV	FFL	Finished Floor Level	TCB	Telephone Call Box
DC	Drainage Channel	FP	Flagpole		
		Gas	Gas	THL	Threshold Level
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DP	Down Pipe	GY	Gully	TP	Telegraph Post
Elec	Electric	Ht	Height	TS	Traffic Signal
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ER	Earth Rod	IFL	Internal Floor Level	WL	Water Level
FH	Fire Hydrant	IL	Invert Level (as a reduced level)	WM	Water Meter
FL	Floodlight			WO	Wash Out

Rev	Date	Details of issue / revision	Drw	Rev
P1	16.10.17	First Isssue	SDS	DS

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Client
Bloor Homes Limited

Project Title
Bullingham
Hereford

Drawing Title
Existing Site Plan
Sheet 4 of 4

Drawn:	S. D. Shreeves		Reviewed:	D.Smith	
BWB Ref:	BMW2135	Date:	16.10.17	Scale@A0:	1:500

Drawing Status
INFORMATION

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
BULL-BWB-00-04-DR-G-001	S2	P1

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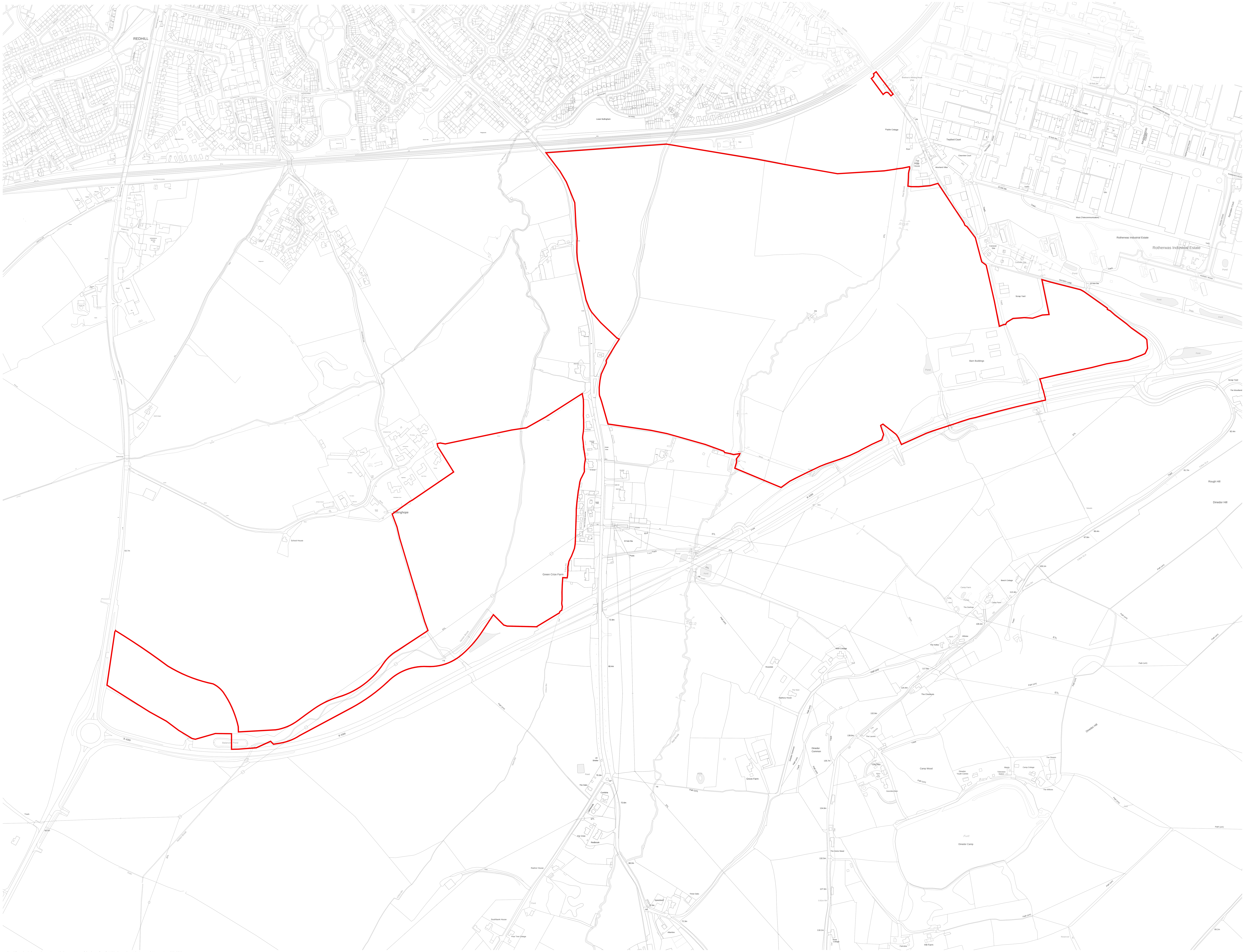
APPENDIX 2: Development Proposals

The scaling of this drawing cannot be assured

Revision		Date	Drn	Ckd
G	Application boundary updated	05.08.19	KU	BW



Application Boundary 75.64 Ha

0 20 40 60 80 100m

N

Project
Lower Bullingham
Hereford

Drawing Title
Site Location Plan

Date	Scale	Drawn by	Check by
23.01.19	1:2500@A0	KT	BW

Project No	Drawing No	Revision
26218	9000	G

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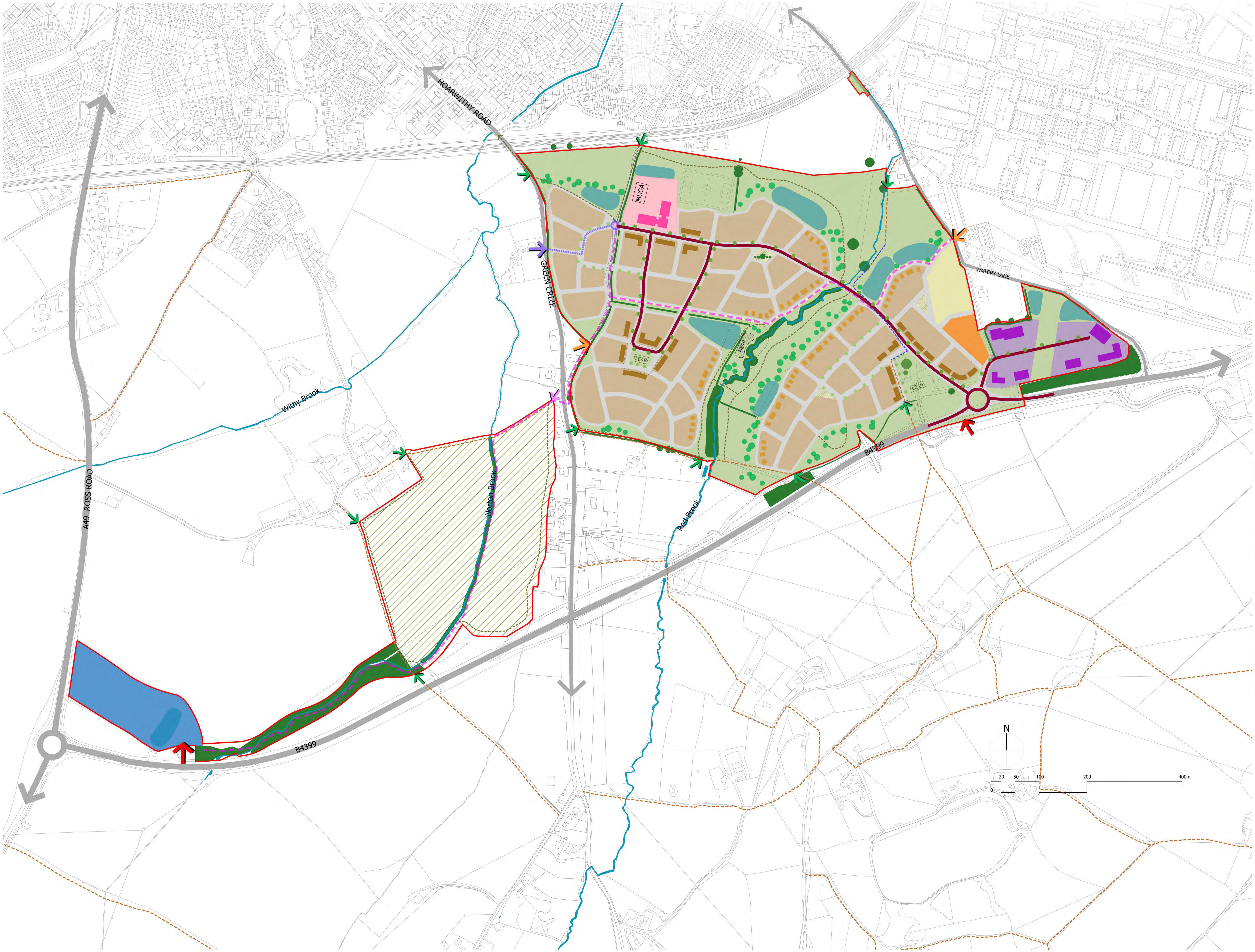
The scaling of this drawing cannot be assured

Revision		Date	Drn	Ckd
AG	Phase 1 layer turned off	01.10.2019	KU	BW



Application Boundary		75.64 Ha
Residential		26.58 Ha
School (1FE)		1.10 Ha
Specialist Accommodation		1.00 Ha
Gross Employment land area (including area of open space)		4.08 Ha
Neighbourhood Community Hub		0.50 Ha
Public Open Space including informal play areas and sports provision		22.83 Ha
Country Park		16.38 Ha
Park & Choose		3.17 Ha
Local Square		
Residential frontage on key space		
Residential frontage on open space		
Drop off parking area		
Retained trees and hedgerows		
Primary street trees		
Secondary street trees		
Parkland trees		
Location of attenuation ponds		
Watercourse		
Main vehicular access		
A secondary vehicular access point to serve 100 dwellings and potentially the proposed Primary School		
Emergency vehicular access only and pedestrian/cycle access		
Pedestrian / cycle access		
Pedestrian access		
Public Right of Way		
Diverted Public Right of Way		
Proposed Footpath		
Key Footpath/cycleway link		
Primary routes		
Bus route		
Potential bus gate		

Project
Lower Bullingham
Hereford
Drawing Title
Concept Masterplan

Date	Scale	Drawn by	Check by
24.01.19	1:2500@A0	KT	CW
Project No	**Drawing No**		**Revision**
26218	9300		AG

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APPENDIX 3: Hydraulic Modelling report

BETTER SOLUTIONS, INTELLIGENTLY ENGINEERED

ENVIRONMENT

Bloor Homes

Lower Bullingham

Hereford

Hydraulic Flood Modelling Report

BWB

ENVIRONMENT

Bloor Homes
Lower Bullingham
Hereford
Hydraulic Flood Modelling Report

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APPENDICES

1. INTRODUCTION

1.1 BWB Consulting Ltd has been commissioned by Bloor Homes to undertake a hydraulic river modelling exercise to investigate the fluvial flood risk at a future development site within the Lower Bullingham area of Hereford. The modelling exercise will be used to inform the masterplanning of the site as well as in supporting a Flood Risk Assessment of the development.

1.2 The site is located on the southern edge of Hereford, approximately 2.5km from the city centre. The site is split into three main parcels – a 'Park and Choose' car parking area located to the west, a country park located centrally, and a mixed-use development located on the largest parcel to the east. A fourth smaller parcel is located on Watery Lane. This comprises a bypass facility is for use by existing residents along Watery Lane in time of flood, to ensure their egress route to higher land is preserved.

1.3 A site location plan is illustrated within Figure 1.1.

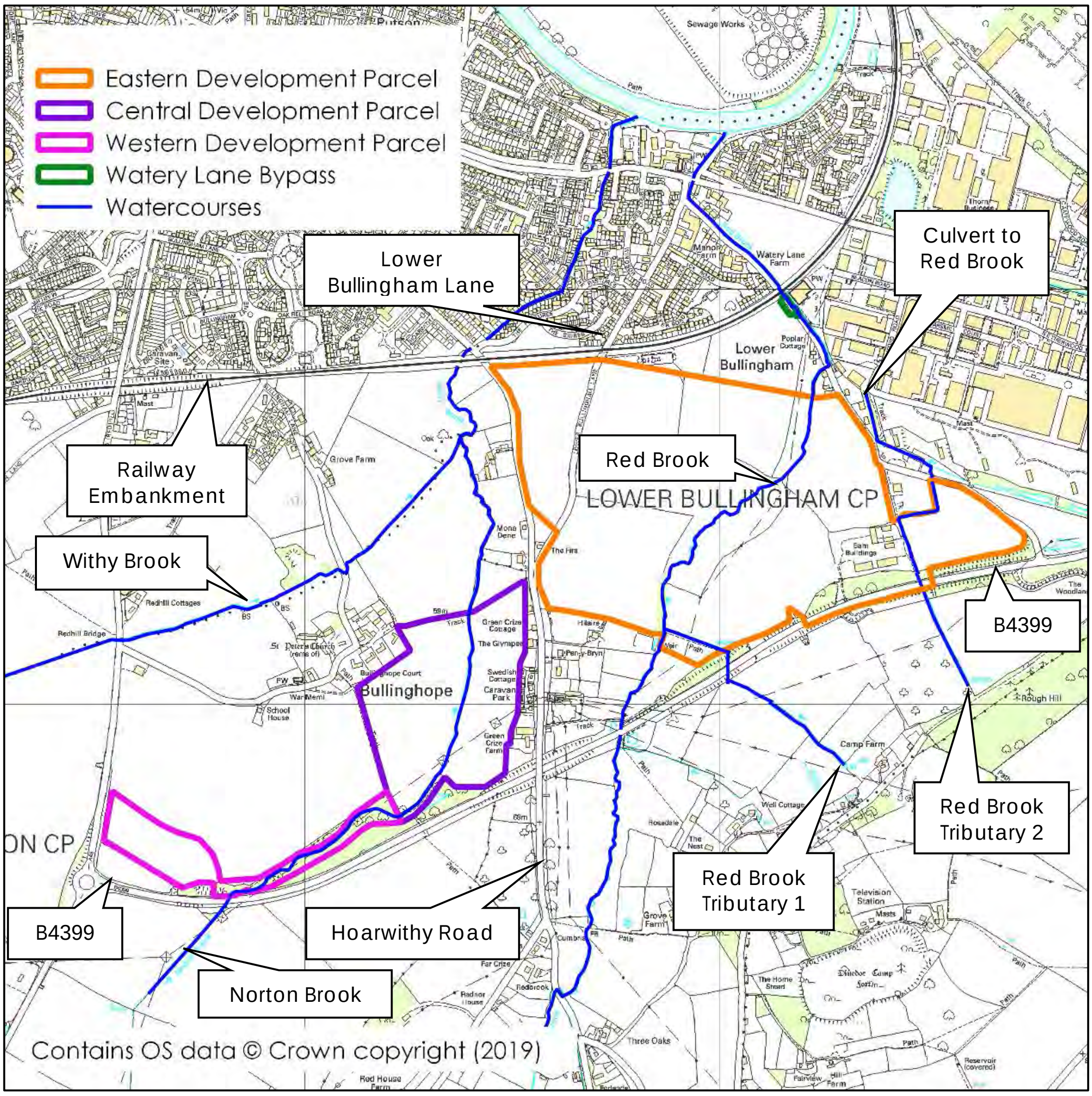


Figure 1.1: Site Location

1.4 The River Wye is located approximately 500m to the north of the site, this is the nearest main river. A series of ordinary watercourses flow through the site in a northerly direction and ultimately outfall to the River Wye, as follows:

i. The Norton Brook flows past the western parcel and through the central parcel, before flowing into the Withy Brook.
ii. The Red Brook flows through the centre of the eastern parcel.
iii. A small tributary of the Red Brook flows under the B4399 and enters the eastern parcel at its southern boundary.
iv. A secondary tributary of the Red Brook is also located within the eastern parcel. This flows under the B4399, through the site, and beneath Watery Lane, before it is culverted to meet the Red Brook as it flows next to Watery Water upstream of the railway line.

Previous Studies & Available Data

<u>2013 BWB Hydraulic Model – Red Brook & Withy Brook</u>

1.5 A hydraulic model of the Red Brook, Withy Brook, and smaller tributary ditches was prepared by BWB Consulting in 2013 to assess the fluvial flood risk to the eastern development parcel. This took the form of a dynamically linked 1D-2D Flood Modeller-TUFLOW model. The model was peer reviewed by the Environment Agency under ref: *PAC/MI/WE/00002 (SV/2013/107280/02)*.

1.6 The previous model forms the basis of this updated study. In order to assess the fluvial flood risk to the western and central parcels, the hydraulic model has been extended and the flood hydrology revisited, the details of which are the subject of this report.

<u>2007 Halcrow Hydraulic Model - Withy Brook & Norton Brook</u>

1.7 Halcrow Group Ltd produced a Flood Risk Assessment for a site to the west of Hoarwithy Road in 2007 for the client. As part of this assessment a 1D flood model of the Withy and Norton Brook was produced. The model has been made available for use within this exercise.

<u>2012 Strategic Flood Risk Mapping - River Wye</u>

1.8 The SFRM2 (2012) version of the one-dimensional (1D) ISIS hydraulic model of the River Wye was obtained from the Environment Agency (EA). This includes the Wye through Hereford as well as the reach adjacent to the site; it does not include any representation of the Red Brook or Withy Brook fluvial systems.

<u>Flood Maps for Planning</u>

1.9 The Environment Agency Flood Maps for planning include the Red Brook, Withy Brook and Norton Brook within the study site. It is understood that these are not based on detailed hydraulic modelling and should only be used at a strategic scale. An extract of the mapping is included as Figure 1.2. This shows that the site falls across Flood Zone 3, 2 and 1.

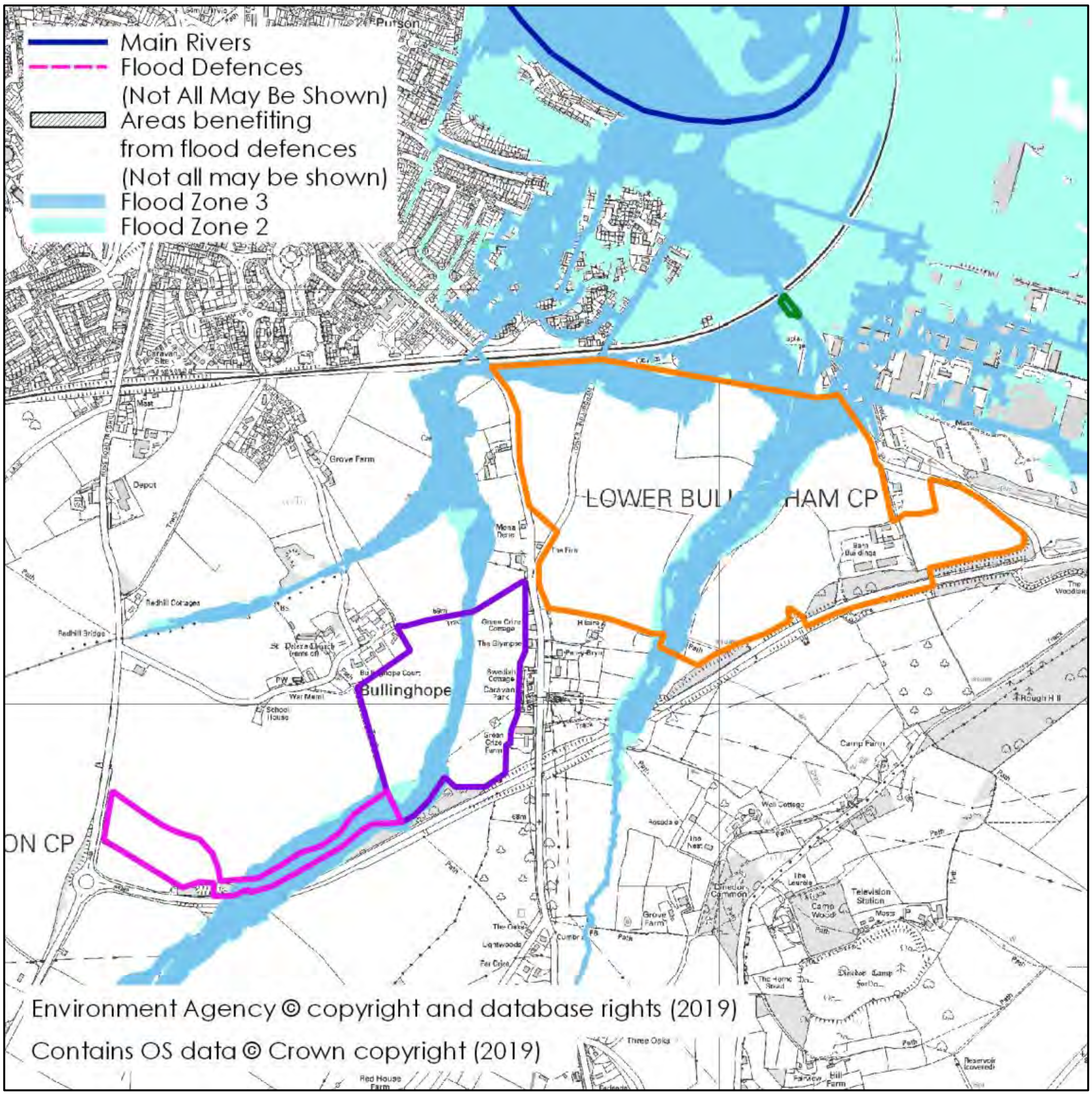


Figure 1.2: Flood Map for Planning

<u>Other Sources of Data</u>

1.10 The following additional datasets were used within the hydraulic modelling exercise:

- EA 1m LiDAR Digital Terrain Model (DTM)
- Topographic survey of the site
- Watercourse cross-sectional survey of the Red Brook, Withy Brook and Norton Brook
- Flood Estimation Handbook Catchment Descriptions
- CEH National River Flow Archive ‘Hi-Flows’ data
- Ordnance Survey 1:25,000 scale mapping
- Ordnance Survey 1:10,000 scale mapping
- Illustrative historic flood outlines for the 1929/30,1947 and 1960 events provided by the EA

1.11 Consultation with the EA did not return any additional historical flood outlines or hydrometric data applicable to the site.

1.12 The Herefordshire 2019 Strategic Flood Risk Assessment identifies recent flood history of Lower Bullingham Lane and Watery Lane, in: 2007, 2008, 2012, 2014. The report notes that the 2007, 2012 and 2014 coincided with River Wye flood events.

1.13 A review of news articles also identified additional road closures on Bullingham Lane and Watery Lane due to flooding in 2015 and 2018.

Aims and Objectives

1.14 The aim of this exercise is to establish a good hydrological and hydraulic representation of the fluvial flooding mechanisms and magnitude within the site. The model will be used to inform the site layout and a Flood Risk Assessment of the development.

1.15 To achieve this aim, the following objectives have been identified:

- Extend the current 1D element of the model (in-channel environment) to include the Withy and Norton Brook within the vicinity of the western and central development parcels.
- Extend the current 2D representation of the floodplain to include the Withy and Norton Brook within the vicinity of the western and central development parcels.
- Combine and link the updated 1D and 2D model domains.
- Undertake a hydrological review of the Withy Brook, Norton Brook, Red Brook and the unnamed ditch to estimate peak flows and generate flood hydrograph profiles, where necessary.
- Simulate flood events, including the latest climate change scenarios, within the EA River Wye Model. Utilise results as a downstream boundary to the 1D and 2D model domains.
- Simulate flood events within the combined 1D-2D model to establish a set of baseline conditions.
- Verify the results against the available historic data within the site.
- Simulate sensitivity tests and residual risks within the model, to include: roughness coefficients; blockage scenarios; 1 in 100-year flows; and impact of the development on the floodplain.

2. HYDROLOGICAL REVIEW

2.1 In the previous BWB Consulting model, the flood hydrology was derived using a hybrid approach. Peak flows were estimated using the Flood Estimation Handbook (FEH) Statistical approach, and the Revitalised Flood Hydrography rainfall-runoff model was used to provide an appropriate hydrograph shape.

2.2 As the modelled domain has been extended to include additional watercourses, the hydrological assessment has been revisited.

Method Statement

2.3 Flood flow estimates are required to support a hydraulic modelling exercise. The hydraulic model will be used to identify floodplain extents and peak flood levels through the study site and surrounding area.

2.4 The hydraulic assessment will model unsteady flood flows, therefore hydrographs as well as peak flood levels are required.

2.5 The Red Brook, Norton Brook and Withy Brook are un-gauged catchments, therefore there are no hydrometric records of river flows and levels on which a hydrological assessment of flood flows can be made.

2.6 This updated hydrological analysis is therefore based on industry standard methodologies which utilise the FEH catchment descriptors: the FEH Statistical Analysis; and the ReFH2 (Revitalised Flood Hydrograph) rainfall-runoff model.

2.7 Other methodologies such as IH124, and the Modified Rational method were dismissed due to the size and rural nature of the catchment. The FEH rainfall-runoff hydrological model was not utilised as this has been superseded by the ReFH2 model.

2.8 The catchments as delimited at the downstream extent of the study site were assessed in this analysis. This approach means that only flows generated upstream or within the site will be applied to the hydraulic model.

2.9 Flow estimates from the catchments will be applied at the upstream of the modelled reaches, a 'lumped' approach.

2.10 As the flow estimates will be supporting a Flood Risk Assessment in support of a planning application a conservative approach to the decision making will be made where applicable.

Catchment(s) Review

Norton Brook Catchment Area

2.11 Catchment descriptors were extracted immediately upstream of the confluence with the Withy Brook.

2.12 A review of the Norton Brook watershed was undertaken against Ordnance Survey contour data (see Figure 2.1). A fair correlation between the contour derived watershed and the FEH catchment was observed, and an adjustment was not required.

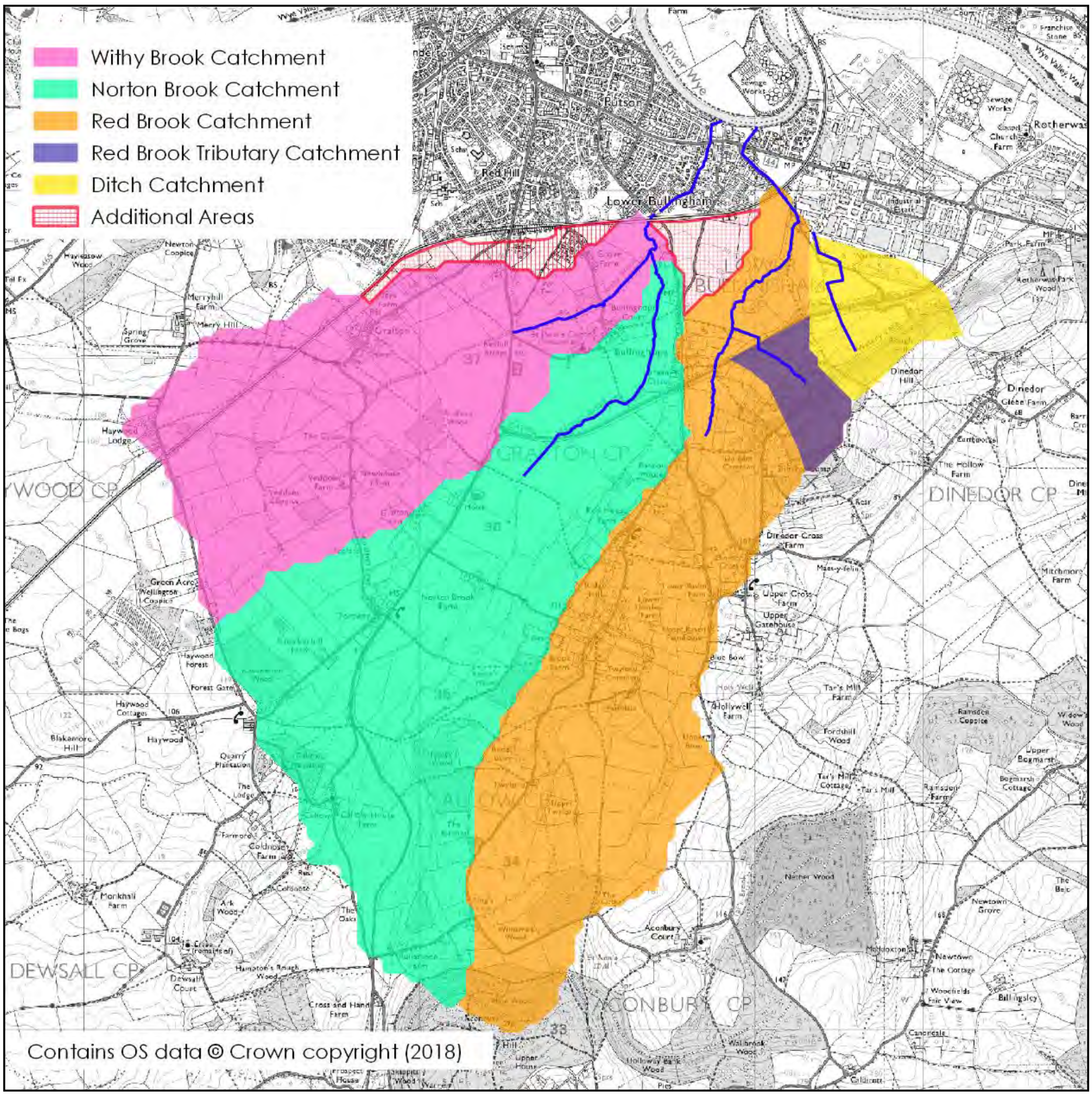


Figure 2.1: Catchment Schematic

2.13 Key catchment descriptors for the Norton Brook are summarised within Table 2.1.

Table 2.1: Norton Brook Key Catchment Descriptors

Descriptor	
AREA (km^2)	4.783
BFIHOST – Base Flow Index	0.579
FARL – Flood attenuation from reservoirs & lakes	1
FPEXT – Floodplain extent	0.0763
PROPWET – Proportion of time that soils are wet	0.33
SAAR – Standard Average Annual Rainfall	677

Descriptor	
SPR_{HOST} – Standard Percentage Runoff (Host soils classification)	37.76
$URBEXT_{1990}$ – Fraction of Urban Extent	0.0042
$URBEXT_{2000}$ – Fraction of Urban Extent	0.0016

Withy Brook Catchment Area

2.14 Catchment descriptors were extracted at the culvert under the railway. The railway embankment effectively acts as a catchment break preventing flows generated downstream of the railway impacting the site.

2.15 To avoid considering the Norton Brook again, it was necessary to 'subtract' the Norton Brook from the Withy Brook catchment and amend the catchment descriptors accordingly using the methodologies outlined in Section 7, Volume 5 of the FEH.

2.16 A review of the Withy Brook watershed was undertaken against Ordnance Survey contour data. This is illustrated within Figure 2.1.

2.17 Generally, a fair correlation between the contour derived watershed and the FEH catchment was observed. However, due to the elevated nature of the railway line, it was considered prudent to manually extend the catchment to meet this barrier to flows.

2.18 This resulted in additional $0.24km^2$ being assigned to the catchment upstream of the railway – this is only a small percentage change of the overall catchment; therefore, it was not considered necessary to alter the other catchment descriptors.

2.19 Key catchment descriptors for the amended Withy Brook are summarised within Table 2.2.

Table 2.2: Withy Brook Key Catchment Descriptors

Descriptor	
AREA (km^2)	3.726
BFIHOST – Base Flow Index	0.57
FARL – Flood attenuation from reservoirs & lakes	0.998
FPEXT – Floodplain extent	0.072
PROPWET – Proportion of time that soils are wet	0.33
SAAR – Standard Average Annual Rainfall	666
SPR_{HOST} – Standard Percentage Runoff (Host soils classification)	39.153
$URBEXT_{1990}$ – Fraction of Urban Extent	0.005
$URBEXT_{2000}$ – Fraction of Urban Extent	0.004

Red Brook & Tributary 1 Catchment Area

2.20 Catchment descriptors were extracted at the culvert under the railway, downstream of the site. The FEH catchment included the "Red Brook Tributary 1" watercourse. The catchment will be assessed as a whole, and the resultant flow prorated on an area basis within the hydraulic model.

2.21 A review of the Red Brook watershed was undertaken against Ordnance Survey contour data (see Figure 2.1), A fair correlation between the contour derived watershed and the FEH catchment. However, due to the elevated nature of the railway line, it was considered prudent to manually extend the catchment to meet this barrier to flows.

2.22 This resulted in additional 0.21km^2 of catchment being assigned to the catchment upstream of the railway. This represents only a small change of the overall catchment therefore it was not considered necessary to alter the other catchment descriptors.

2.23 Key catchment descriptors are summarised within Table 2.3.

Table 2.3: Red Brook & Tributary Key Catchment Descriptors

Descriptor	
AREA (km^2)	4.561
BFIHOST – Base Flow Index	0.612
FARL – Flood attenuation from reservoirs & lakes	1
FPEXT – Floodplain extent	0.0339
PROPWET – Proportion of time that soils are wet	0.33
SAAR – Standard Average Annual Rainfall	684
SPR_{HOST} – Standard Percentage Runoff (Host soils classification)	33.75
$URBEXT_{1990}$ – Fraction of Urban Extent	0.0055
$URBEXT_{2000}$ – Fraction of Urban Extent	0.0006

Red Brook Tributary 2 Catchment Area

2.24 The second tributary watercourse which runs through the eastern proportion of the site does not appear on the FEH, due to its small scale. Therefore, its catchment extent was estimated using the available Ordnance Survey data (see Figure 2.1).

2.25 It is believed this catchment will have similar hydrological characteristics to the Red Brook, as it is essentially an extension to its catchment. Therefore, the peak flows for the ditch will be derived from the Red Brook's estimates on an area basis.

Geology & Urban Influence

2.26 British Geological Society (BGS) geological mapping indicates that the all the catchments are underlain by Raglan Mudstone Formation overlain by River Terrace and Alluvial Fan deposits. This underlying geology suggests that the BFI_{HOST} and SPR_{HOST} values from the FEH are reasonable.

2.27 The BFI_{HOST} and SPR_{HOST} values identify that the catchments are not classified as permeable. These values do not necessitate any special measures in the FEH procedures, nor do they prohibit the use of either the ReFH or FEH Statistical Approach.

2.28 URBEXT values are low indicating predominantly rural catchments. These relatively low values do not necessitate any special measures in the application of the FEH procedures, nor do they prohibit the use of either the ReFH or FEH Statistical Approach.

FEH-Statistical Analysis

2.29 WINFAP version 4 was utilised to undertake a statistical analysis of each of the catchments using a hydrometric record of gauged catchments with similar descriptors. The February 2018 version of the Hi-Flow dataset was used to provide an up-to-date hydrometric record. Appendix 1 contains extracts from the statistical procedure illustrating the methodology and detailing the composition of the pooling groups.

Pooling Group Development

2.30 A group of hydrologically similar gauged sites was generated for each catchment by the software from the 'OK for Pooling' dataset. In each instance the group was identified as 'heterogenous' to 'strongly heterogeneous' - this does not mean that the group is inappropriate, just that it should be reviewed.

2.31 The groups were reviewed to identify sites which may be inappropriate due to being significantly hydrologically dissimilar to the study site(s), or if they have any inaccuracies, uncertainties or limitations in their data record.

2.32 In all cases, three stations within the pooling groups were identified as permeable catchments (BFI_{HOST}>0.80, SPR_{HOST}<20%): Gypsey Race (26802), South Winterbourne (44008), and Brompton Beck (36010). However, a review of their respective growth curves showed that they are responsive to storm events, therefore their retention in the pooling group was considered acceptable.

2.33 All other stations in the pooling groups were considered to be acceptable: they were all identified as having sufficient record length, and to be of sufficient hydrological similarity for the purpose of this study (i.e.: no other sites within the Hi-Flows dataset are believed to be more representative). The sites were of a rural nature, had similar flood seasonality, and were not of a permeable nature. It is believed that the heterogeneous nature of the pooling groups is a result of the limited number of small gauged sites which are available in the record.

2.34 Following the reviews, the resultant record length for the pooling groups exceeded 500-years, which meets the recommended guidelines on minimum record length.

2.35 In line with the generally accepted approach, the 'generalised logistic' distribution (regarded as the best fit for most UK catchments) was selected to derive a growth curve from each pooling group.

QMED Development

2.36 The updated catchment descriptors were initially used to estimate the rural QMED of the catchments ($QMED_{CDS}$) using the revised equation from Science Report SC050050[1].

2.37 The Hi-Flows dataset was used to generate a list of 10 potential donor sites from the "OK for QMED & Pooling" dataset for each catchment. It is the recommended procedure to use six Donor Stations to refine the estimation of QMED. This resulted in an adjusted QMED ($QMED_{ADS}$).

2.38 To account for the influence of the urban extent, the $QMED_{ADS}$ value was updated using an Urban Adjustment Factor (UAF) based upon the Urban Extent of each catchment.

2.39 Change in QMED estimation through this process are summarised within Table 2.4.

Table 2.4: QMED Development

Catchment	$QMED_{CDS}$ (m^3/s)	$QMED_{ADJ}$ (m^3/s)	UAF	$QMED_{URBAN}$ (m^3/s)
Withy Brook	1.135	1.481	1.005	1.489
Norton Brook	0.704	0.924	1.002	0.925
Red Brook	0.616	0.812	1.001	0.812

2.40 The growth curve derived from each the pooling group was also adjusted to reflect the urban influence, using the standard recommended approach[2].

2.41 The $QMED_{URBAN}$ was applied to the adjusted growth curve to derive a flood frequency curve. The peak flood flow estimates are detailed in Table 2.5 and Table 2.6.

Revitalised Flood Hydrograph Analysis

2.42 The ReFH2 Revitalised Flood Hydrograph Modelling tool (version 2.2) was utilised to undertake an estimation of the peak flows from the catchment. This makes use of the latest changes to the rainfall-runoff model to incorporate the FEH13 Depth Duration Frequency rainfall model.

2.43 A critical duration of 5.5hrs was identified at a 0.5hr timestep for all of the catchments. Due to the rural nature of the catchments a winter storm profile was adopted; all parameters were left as default.

2.44 The resultant peak flood flow estimates are detailed in Table 2.5 and Table 2.6.

[1] Kjeldsen, T.R., Jones, D. A. and Bayliss, A.C. (2008) Improving the FEH statistical procedures for flood frequency estimation. Science Report SC050050, Environment Agency.

[2] Kjeldsen, T.K., 2010. Modelling the impact of urbanization on flood frequency relationships in the UK. Hydrology Research, volume 41, issue 5, pp391-405

Discussion

2.45 Flow estimates for the Withy and Norton Brook are summarised within Table 2.5. This shows that the FEH Statistical approach has generated higher flow estimates than the ReFH2. To promote a conservative assessment the FEH Statistical flows were adopted within the hydraulic model.

2.46 The combined Withy and Norton Brook peak flows are compared against the flows adopted in the previous 2013 hydraulic model. This shows that the flow predictions are essentially the same, if slightly higher under the latest estimates.

Table 2.5: Withy and Norton Brook Flow Estimation Comparison (m^3/s)

Return Period	Withy Brook		Norton Brook		Combined Withy and North Brook Catchment	
	FEH-Stat	ReFH2	FEH-Stat	ReFH2	2013 Estimate	Updated assessment
2	0.79	0.68	1.01	0.82	1.57	1.65
5	1.10	0.92	1.41	1.11	2.25	2.28
20	1.66	1.31	2.16	1.57	3.24	3.29
50	1.98	1.64	2.56	1.96	4.00	4.11
75	2.17	1.82	2.82	2.17	4.36	4.53
100	2.32	1.96	3.02	2.34	4.64	4.85
1000	3.98	3.66	5.19	4.38	7.42	8.34

2.47 Flow estimates for the Red Brook & the Red Brook tributary 1 watercourse are summarised within Table 2.6. This shows that the FEH Statistical approach has again generated higher flow estimates than the ReFH2. To promote a conservative assessment the FEH Statistical flows were adopted within the hydraulic model. Additionally, a comparison against the previous modelled flows shows that the latest estimates are consistent.

2.48 To allow for the modelling of unsteady flows, the FEH statistical peak flows were applied to the original ReFH hydrographs. The ReFH hydrographs were compared to the hydrographs generated by ReFH2 and were found to have identical shapes. The ReFH hydrographs adopted due to their ease to apply within the model, and because ReFH2 requires an additional license agreement. The final hydrograph plots applied within the model are included as Appendix 2.

Table 2.6: Red Brook & Tributary Catchment Flow Estimation Comparison (m^3/s)

Return Period	Red Brook & Tributary		
	FEH-Stat	ReFH2	2013 Estimate
2	0.89	0.72	0.85
5	1.24	0.97	1.21
20	1.92	1.38	1.78
50	2.28	1.72	2.23
75	2.52	1.91	2.46
100	2.71	2.07	2.63
1000	4.78	3.89	4.46

2.49 Peak flows for the unnamed ditch were derived from the Red Brook's statistical analysis on a prorated area basis – this is detailed within Table 2.7.

Table 2.7: Flow Estimates for the Unnamed Ditch (m^3/s)

Return Period	Red Brook Flow per km^2 (cumecs/Km^2)	Unnamed Ditch Peak Flow (0.66km^2)
2	0.20	0.13
5	0.27	0.18
20	0.42	0.28
50	0.50	0.33
75	0.55	0.36
100	0.59	0.39
1000	1.04	0.69

Climate Change

2.50 In February 2016 the predicted future change in peak river flows were updated by the Environment Agency[3]. This replaced the previous national 20% allowance used in the previous hydraulic model, with a range of projections applied to regionalised 'river basin districts'.

2.51 The modelled catchments fall within the Severn river basin district. Table 2.8 identifies the relevant peak river flow allowances.

Table 2.8: Peak River Flow Allowance for the Severn River Basin District

Allowance Category	Total potential change anticipated for the **'2020s' (2015 to 2039)**	Total potential change anticipated for the **'2050s' (2040 to 2069)**	Total potential change anticipated for the **'2080s' (2070 to 2115)**
Upper End	25%	40%	70%
Higher Central	15%	25%	35%
Central	10%	20%	25%

[3] Environment Agency. 2016. Flood risk assessments: climate change allowances. [ONLINE]. Available at: https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances#table-1. [Accessed 24 February 16].

2.52 When determining the appropriate allowance for use in a Flood Risk Assessment the Flood Zone classification, the flood risk vulnerability, and the anticipated lifespan of the development should be considered. Table 2.9 provides a matrix summarising the Environment Agency's guidance on determining the appropriate allowances.

Table 2.9: Application of the Appropriate Climate Change Allowance

Flood Zone	Essential Infrastructure	Highly Vulnerable	More Vulnerable	Less Vulnerable	Water Compatible
1	Use the central allowance				Use none of the allowances
2	Use the higher central and upper end to assess a range of allowances	Use the higher central and upper end to assess a range of allowances	Use the central and higher central to assess a range of allowances	Use the central allowance	Use none of the allowances
3a	Use the upper end allowance	Development should not be permitted	Use the higher central and upper end to assess a range of allowances	Use the central and higher central to assess a range of allowances	Use the central allowance
3b	Use the upper end allowance	Development should not be permitted	Development should not be permitted	Development should not be permitted	Use the central allowance
*If development is considered appropriate when not in accordance with Flood Zone vulnerability categories, then it would be appropriate to use the upper end allowance.					

2.53 The proposed development is for mixed use and includes residential use (more vulnerable) with an anticipated lifespan of over 60 years, therefore the total potential change for the '2080s' will be adopted. The site includes areas is located in Flood Zone 3, therefore the higher central (35%) and the upper end (70%) allowances will be considered.

The Design Flood

2.54 Developments should be designed to provide adequate flood risk management, mitigation, and resilience against the 'design flood' for their lifetime. The design event for fluvial flooding is generally taken as the 1 in 100-year event (1% AEP) [4].

2.55 To allow the development's flood risk management strategy to be adequately designed for its lifetime the climate change the allowances discussed previously will be applied to the baseline (present day) 1 in 100-year hydrograph.

[4] Planning Practice Guidance. http://planningguidance.planningportal.gov.uk/. Paragraph: 054 & 055

Flow Distribution

2.56 Flow estimates from the catchments were applied at the upstream of the modelled reaches, a 'lumped' approach. A lumped approach is considered to be conservative as the site is subjected to all flows in the sub-catchment, not just those generated upstream.

3. HYDRAULIC MODEL UPDATE

3.1 The previous hydraulic model included for the Red Brook, its tributary watercourses, and a length of the Withy Brook.

3.2 To provide sufficient representation of the larger study site, the model geometry needed to be extended upstream on the Withy and Norton Brook.

3.3 The following section discusses the changes made to existing model to meet this objective.

The 1D In-Channel Domain – Flood Modeller Pro

3.4 The in-channel conditions and hydraulic structures are modelled within a one-dimensional (1D) Flood Modeller Pro (FMP) domain.

3.5 The original model was based on survey data collated in 2012 and 2013. To extend the model domain, a supplementary cross-sectional survey of the watercourse channels was completed in October 2017.

3.6 The Withy Brook was extended 700m upstream through the addition of 11 river sections and 2 hydraulic structures.

3.7 A 1.85km stretch of the Norton Brook was added in the form of 19 river sections and 3 hydraulic structures.

Table 3.1 - Table of Structures

Structure	Model ID	Details	Photograph
Withy Brook Footbridge	WB1592BU	Domain: FMP Unit Type: USBPR1978 U/S IL: 57.47mAOD D/S IL: 57.47mAOD Length: 2.3m Blockage: 0%	None available
Withy Brook Bullingham Lane Culvert	WB1506BU	Domain: FMP Unit Type: USBPR1978 U/S IL: 57.34mAOD D/S IL: 57.34mAOD Length: 6.7m Blockage: 0%	None available

Norton Brook B4399 Culvert	NB1533C	Domain: FMP Unit Type: Conduit Rectangular U/S IL: 60.8mAOD D/S IL: 60.84mAOD Length: 23m Blockage: 0%	
Norton Brook Footbridge	Not included as not deemed to be hydraulically significant	Domain: N/A Unit Type: N/A U/S IL: 58.72mAOD D/S IL: 58.88mAOD Length: 1.2m Blockage: N/A	

Norton Brook Track Culvert	NB1000C	Domain: FMP Unit Type: Conduit Rectangular U/S IL: 58.75mAOD D/S IL: 58.74mAOD Length: 5m Blockage: 0%	
Norton Brook Track Culvert	NB0480C	Domain: FMP Unit Type: Conduit Circular U/S IL: 56.28mAOD D/S IL: 56.22mAOD Length: 6m Blockage: 0%	

3.8 The out of channel lengths of the river sections were de-activated to remove the floodplain representation from the 1D environment.

3.9 The roughness values of the floodplain were set to be consistent with the original model, with the Manning's n for the 1D domain being based on the catchment walkover and visual inspection, and the 2D domain based on Ordnance Survey 1 to 10,000 series mapping.

3.10 The downstream connectivity of the "Red Brook Tributary 2" watercourse was previously unknown, and the model terminated at the industrial estate. For this model update, Herefordshire County Council were able to provide confirmation that the watercourse is culverted to meet the Red Brook by Watery Lane. The model was updated to reflect this through the additional of a culvert conduit between the two open channel reaches.

The 2D Floodplain Domain – TUFLOW

3.11 In line with the previous model, Environment Agency 1m resolution LiDAR DTM (Digital Terrain Model) data was used to set elevations of the 2D floodplain.

3.12 A topographical survey of the eastern development parcel was conducted in 2012, with the central and western parcels surveyed in 2017. These topographical surveys were prepared as ground models and incorporated into the 2D domain.

3.13 The original 5.0m resolution grid was retained for the TUFLOW model as this is considered to be sufficient to capture out of bank flows and represent the narrow channel.

3.14 Surveyed river banks levels were reinforced using 'Z-line' commands, as per the original modelling approach.

3.15 The B4399 crossing of the Norton Brook, was not captured within the Environment Agency's 1m resolution LiDAR DTM. Therefore, the carriageway level, as surveyed, was manually added to the model in the form of a 'Z-Shape'.

3.16 The roughness values of the floodplain were set to be consistent with the original model. The material layers were extended where appropriate.

3.17 The change in model extent is illustrated within Figure 3.1.

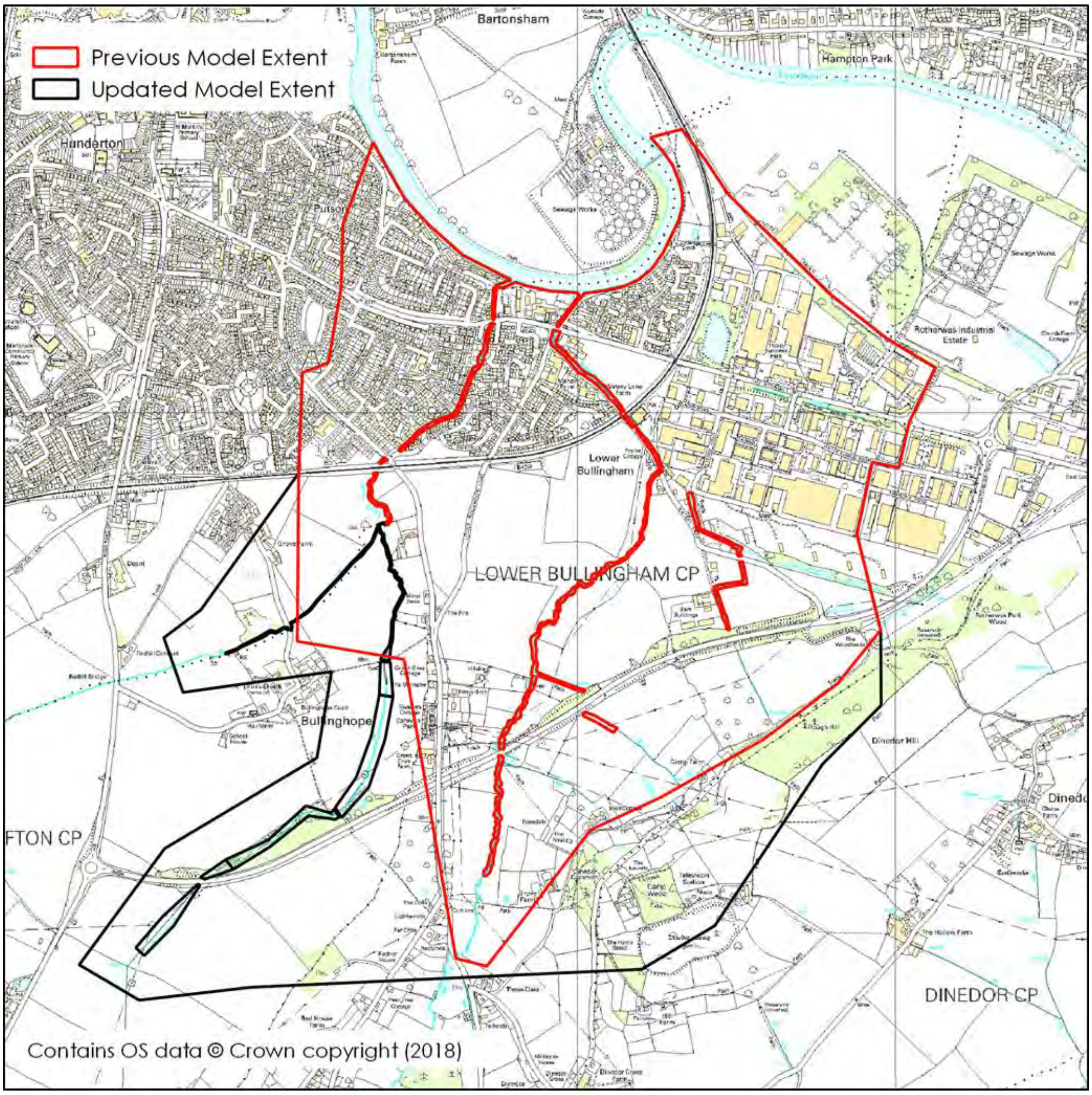


Figure 3.1: Updated Model Extents

Boundary Conditions

3.18 The FMP-TUFLOW interface was digitised on top of bank lines; a HX (External Head) boundary was adopted as the interface type.

3.19 The 1D channel was removed from the TUFLOW domain using a 'code' layer, and 'NWK' and 'WLL' layers were used to display the ESTRY results within TUFLOW to aid in floodplain mapping.

3.20 Inflows into the model were applied using the results of the hydrological assessment as detailed previously. FMP event files were used for inflows at the upstream extent of the FMP domain.

3.21 The EA River Wye model was used to extract stage hydrographs for the Lower Bullingham floodplain reservoir (node: S1.040RR), from the '91-hour duration defended' design events. These represent the worst-case flood levels within the vicinity of the site.

These were used as the downstream boundary to represent the interactions with the Wye.

3.22 The downstream boundary conditions were varied depending on the flood return period, and the same return period was adopted for each boundary (e.g.: the 100-year event on the ordinary watercourses were simulated against the 100-year Wye event). This is considered to be a conservative approach as in reality a storm would generate very different magnitude flood events on each catchment.

3.23 The inflows to the model were delayed by approximately 74 hours so that the peak flows coincided with the peak water level within the River Wye. In reality it is likely that an event on the smaller ordinary watercourses would have passed long before the Wye reached peak, therefore this approach is also considered to be conservative.

3.24 Downstream of the railway embankment a flow-head boundary (HQ) was applied to the floodplain, this allowed flows to exit the model domain while still accounting for the backwater effects from the downstream floodplain. The boundary was based upon a gradient of 1 in 1000 which was informed from the LiDAR. The downstream boundary was located 800m from the lowest areas of the site, and 200m away from the eastern corner of the site. This was considered acceptable given the height difference of almost 10m between the downstream boundary and the site in this location. This is the same approach as previously accepted.

Model Calibration

3.25 As no hydrometric data is available for the watercourses the model could not be directly calibrated against historic flood events.

3.26 Coarse flood outlines for the 1929/30, the 1947 and the 1960 events were provided by the EA, and overlaying the model results shows that there are some inconsistencies between them and the present day flood outlines, as illustrated within Figure 3.2.

3.27 Given the anecdotal and unknown quality of the outlines as well as the significant changes which have occurred within the floodplain and catchment over the past 60+ years it is considered that this historic data does not offer a reliable verification/calibration data source.

3.28 Anecdotal reports of regular flooding from the Red Brook onto Watery Lane were reported at a public consultation event in March 2018. Specific material to calibrate against was not available, but the model predicates that Watery Lane is at risk of flooding in at very small events (<1 in 5-year) and it is believed that this agrees with the anecdotal reports.

3.29 Additionally, Herefordshire County Council have reported that the industrial estate adjacent to Watery Lane has flooded five times since 1990. Again, the model predicts that the industrial estate is risk of flooding in at very small events (<1 in 5-year) and it is believed that this agrees with the anecdotal reports.

3.30 Despite the lack of hydrometric calibration material, it is believed that the conservative approach to the model build (worst-case hydrology, coinciding return periods and flood peaks on all catchments) should offer a sufficiently robust model for the purposes of assessing fluvial flood risk to the study site.

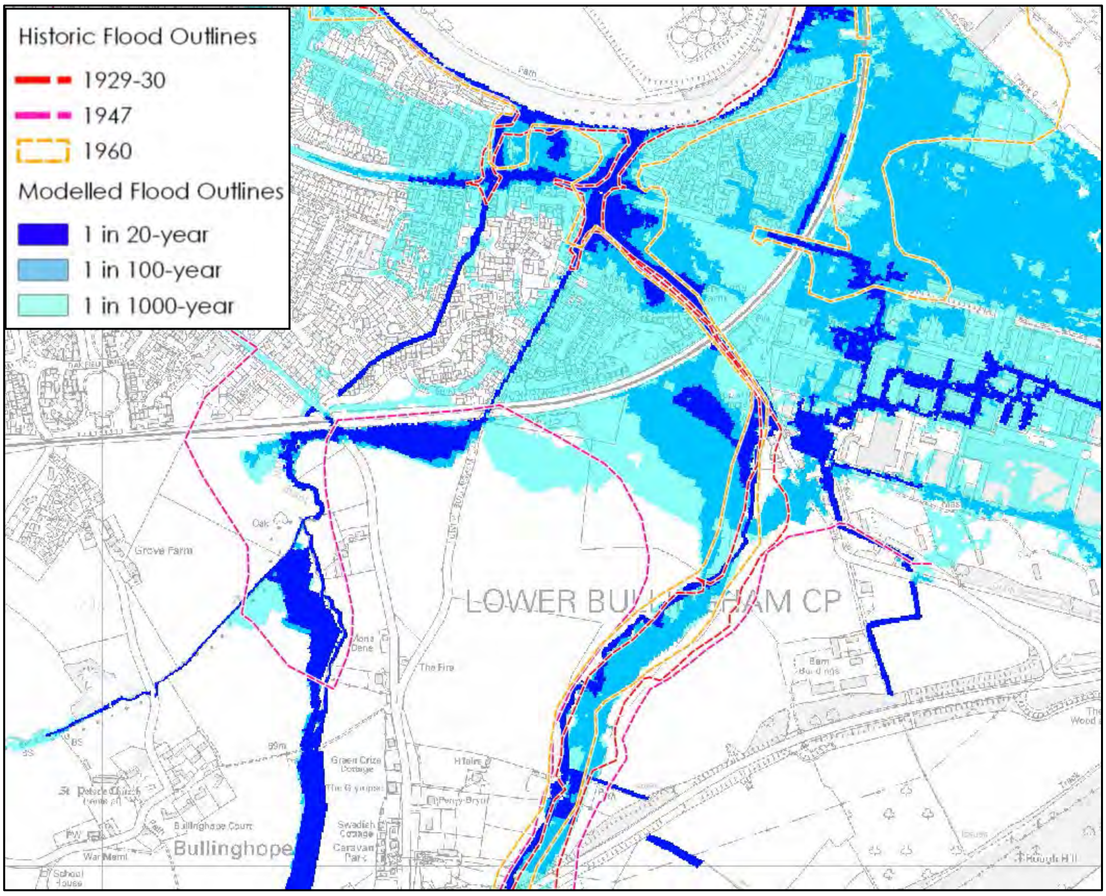


Figure 3.2: Historic Flood Record

Design Events

3.31 The model was simulated against the following key design flood events:

- 1 in 5-year
- 1 in 20-year
- 1 in 50-year
- 1 in 75-year
- 1 in 100-year
- 1 in 100-year + 25%
- 1 in 100-year + 35%
- 1 in 100-year + 70%
- 1 in 1000-year

3.32 For information purposes an alternative set of simulations at the same return period events were also performed without the influence of the River Wye.

Model Stability and Limitations

Simulation Parameters

3.33 TUFLOW version 2018-AE-iDP-W64 and FMP version 4.5 were used in all simulations.

3.34 A time step of 1.0 seconds was adopted for the TUFLOW and FMP domains, this is representative of 1/5 of the grid size and is therefore within the typical range.

3.35 All TUFLOW parameters were retained as default.

3.36 Most Flood Modeller simulation parameters were retained as default except for the following, these are consistent with the original modelling approach:

- The height of dummy vertical wall (DFlood) was increased from 3m to 5m to accommodate the significant depths generated by the River Wye on the lower reaches
- The maximum number of iterations (Maxitr) was raised from 6 to 13 to allow for more computations
- 'Theta' was raised from 0.7 to 0.9 to smooth the water surface and aid stability.
- An automated Preissmann slot was utilised to prevent the channel 'drying out' under low flow conditions

Stability

3.37 During all simulated events, there were no recorded negative depths, and the final cumulative mass error was between -0.31% and 0.00%, which is well within the typical tolerance limits.

Limitations

3.38 The modelling exercise has made use of the available data at the time of construction and simulation.

3.39 The model contains no formal representation of the conveyance within minor watercourses or ditches other than that captured by the model grid and within the FMP model domain.

3.40 Due to the lack of hydrometric data, the model has not been calibrated. However, a conservative approach to the model build has been adopted where possible, and a range of sensitivity tests have been undertaken to help to compensate for this limitation. In addition to this, the model results have been compared to anecdotal reports from local residents where appropriate.

3.41 The 5.0m resolution of the model may negate any small scale topographic features, although all the significant features are believed to have been captured.

3.42 The baseline floodplain levels are derived from LiDAR which has limited accuracy (+/-0.15m). This is considered to be more than sufficient for the purpose of this exercise.

3.43 The exercise has taken a worst-case approach when modelling flood events by forcing the flood hydrograph on the Withy Brook, Norton Brook, Red Brook and ditch to coincide with peak flood levels on the River Wye.

3.44 A conservative approach has also been adopted when determining the joint probability of events, by applying the same return period event to all watercourses, as well as by delaying the hydrographs of the watercourses so that they all coincide with the Wye peak.

3.45 This modelling exercise has been undertaken to produce a good representation of flood risk mechanisms in and around the site. It has not been designed to accurately map fluvial flooding in the wider catchment or flooding from other sources within the site.

Results Parameters

3.46 TUFLOW maximum results were output for water levels, depths, and UK Hazard Rating. UK Hazard rating was derived from the following equation[5]:

$$\text{Hazard Rating} = D * (V+0.5) + DF$$

Where:
D = depth
V = velocity
DF = Debris Factor

3.47 Table 3.2 identifies the recommended debris factors from FD2321/TR1. The debris factor has been set at 'Conservative', which is considered suitable for informing a Flood Risk Assessment of the site.

Table 3.2: Guidance Debris Factors (Ref: FD2321/TR1)

Depths	Pasture/Arable	Woodland	Urban	Conservative*
0 to 0.25 m	0	0	0	0.5
0.25 to 0.75 m	0	0.5	1	1
d>0.75 m and/or v>2	0.5	1	1	1

3.48 Table 3.3 identifies the thresholds of the flood hazard categories as identified within DEFRA guidance document FD2320 and the "*Supplementary Note on Flood Hazard*

[5] DEFRA R&D Outputs: Flood Risks to People Phase Two Draft FD2321/TR1 and TR2

Ratings and Thresholds for Development Planning and Control Purpose" (DEFRA, 2008) which have been adopted within this exercise.

Table 3.3: Hazard to People[6]

Threshold for Flood Hazard Rating	Degree of Flood Hazard	Description
< 0.75	Low	Caution "Flood zone with shallow flowing water or deep standing water"
0.75 - 1.25	Moderate	Danger for some (i.e.: children, the elderly and the infirm) "Danger: Flood Zone with deep or fast flowing water"
1.25 - 2.0	Significant	Danger for most (includes the general public) "Danger: Flood Zone with deep fast flowing water"
2.0 >	Extreme	Danger for all (includes the emergency services) "Extreme Danger: Flood Zone with deep fast flowing water"

[6] 2008, DEFRA. Supplementary Note on Flood Hazard Ratings and Thresholds for Development Planning and Control Purposes.

4. BASELINE RESULTS

River Wye, Red Brook, Withy Brook, & Norton Brook

4.1 Floodplain maps for the baseline conditions are provided within Appendix 3, and Figure 4.1 provides a summary of the floodplain extents at the study site for the key events.

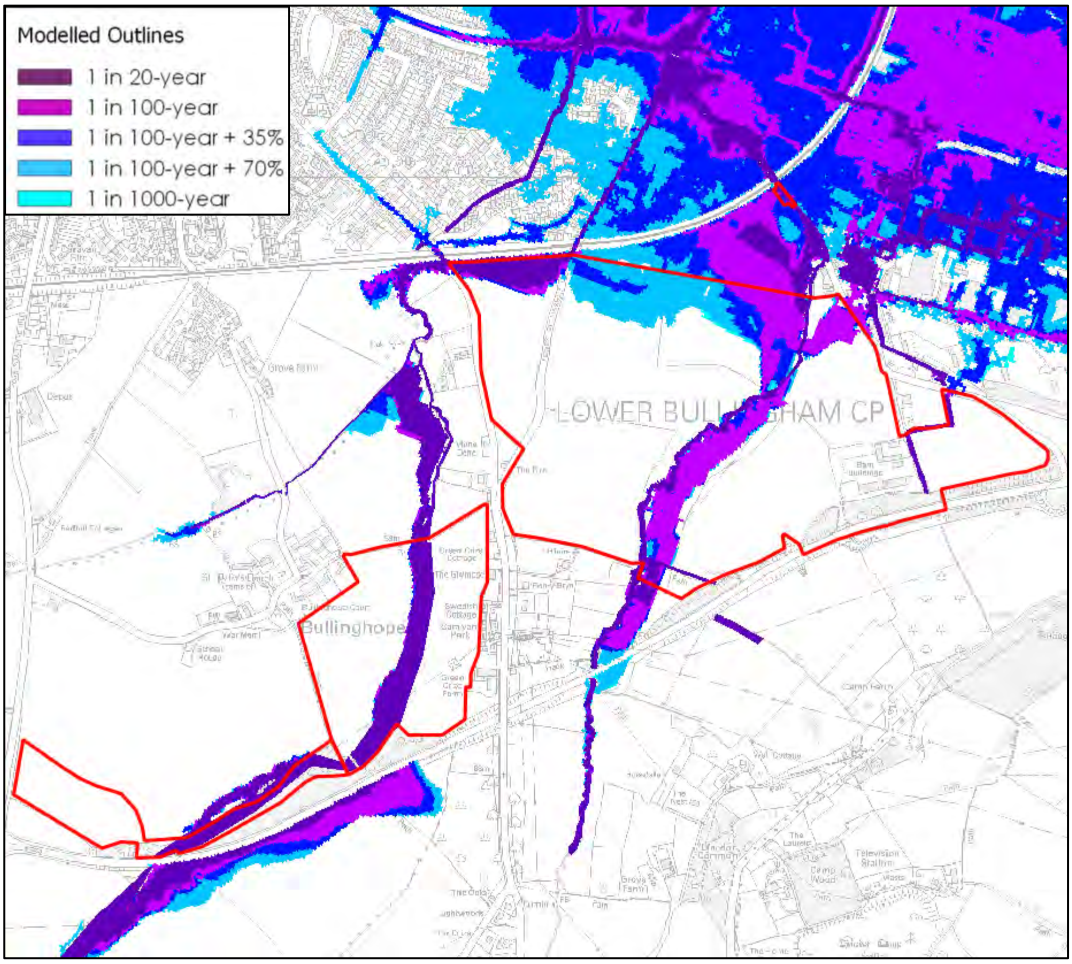


Figure 4.1: Baseline Modelled Flood Extents – River Wye, Red Brook, Withy Brook & Norton Brook

4.2 The fluvial flooding mechanisms are detailed below:

i. The Norton Brook is shown to be constrained by the B4399 culvert, which leads to some flooding of the upstream side of the highway in events greater than the 1 in 5-year.

ii. Immediately downstream of the B4399 flows largely remain within bank, and the western development parcel is shown to fall outside of the floodplain.

iii. As the Norton Brook flows through the central development area a narrow floodplain is present in events at and above the 1 in 20-year.

iv. Downstream of the central development area, at the confluence of Norton and Withy Brooks, some out of bank flows also occur in events at and above the 1 in 20-year.

v. The Withy Brook is shown to be constrained by the culvert under the railway embankment. This leads to out of bank flows crossing Hoarwithy Road and entering the eastern development parcel in the 1 in 20-year event and above.

vi. The flood route from the Withy Brook leaves the eastern development parcel and flows north under the railway embankment via Lower Bullingham Lane.

vii. At events over the 1 in 100-year+25%, the Withy Brook floodplain overtops Lower Bullingham Lane and continues further into the eastern development parcel.

viii. The Red Brook channel within the eastern development parcel is located on the left extremity of the floodplain, therefore the majority of the out of bank flows occur in the right bank floodplain. Out of bank flooding is generally predicted to occur in events over the 1 in 20-year. Due to the constrained valley floor the extents of the 1 in 100, 1 in 100 + 35%, 1 in 100 + 70% and the 1 in 1000-year flood events are relatively similar.

ix. As the topography flattens out in the northern half of the site, a wide and relatively shallow flood route from the left bank of the Red Brook is generated at the 1 in 20-year event and above. This joins up with the flood route from Withy Brook before flowing onto Watery Lane.

x. A smaller flood route from the right bank of the Red Brook is also generated at and above the 1 in 20-year, this flows on to Watery Lane and into the industrial estate around Twyford Road.

xi. The in-channel and left bank floodplain flows of the Red Brook leave the site via Watery Lane, but then pass under the railway embankment. Due to the flat nature of the floodplain downstream of the railway there is some interaction between the Red Brook and the River Wye.

xii. Watery Lane is shown to be at flood risk from the River Wye and Red Brook in all modelled scenarios

xiii. During events in excess of the 1 in 100-year flood, the River Wye flood levels reverse the flow direction through the railway embankment, in these instances flood water is directed off Watery Lane and into the industrial around Twyford Road (i.e.: away from the site).

xiv. Flood flows from the Red Brook Tributary 2 are predicted to remain in bank through the eastern development parcel but flooding of the downstream industrial estate is predicted at all tested scenarios due to the limited capacity of the downstream culvert. Watery Lane is predicted to flood from the tributary watercourse at and above the 1 in 20-year due to the restrictive culvert on Watery Lane.

Red Brook, Withy Brook, & Norton Brook (no River Wye)

4.3 As an informative an alternative set of simulations at the same return period events were also performed without the influence of the River Wye. Floodplain maps for are provided within Appendix 4, and Figure 4.1 provides a summary of the floodplain extents at the study site for the key events.

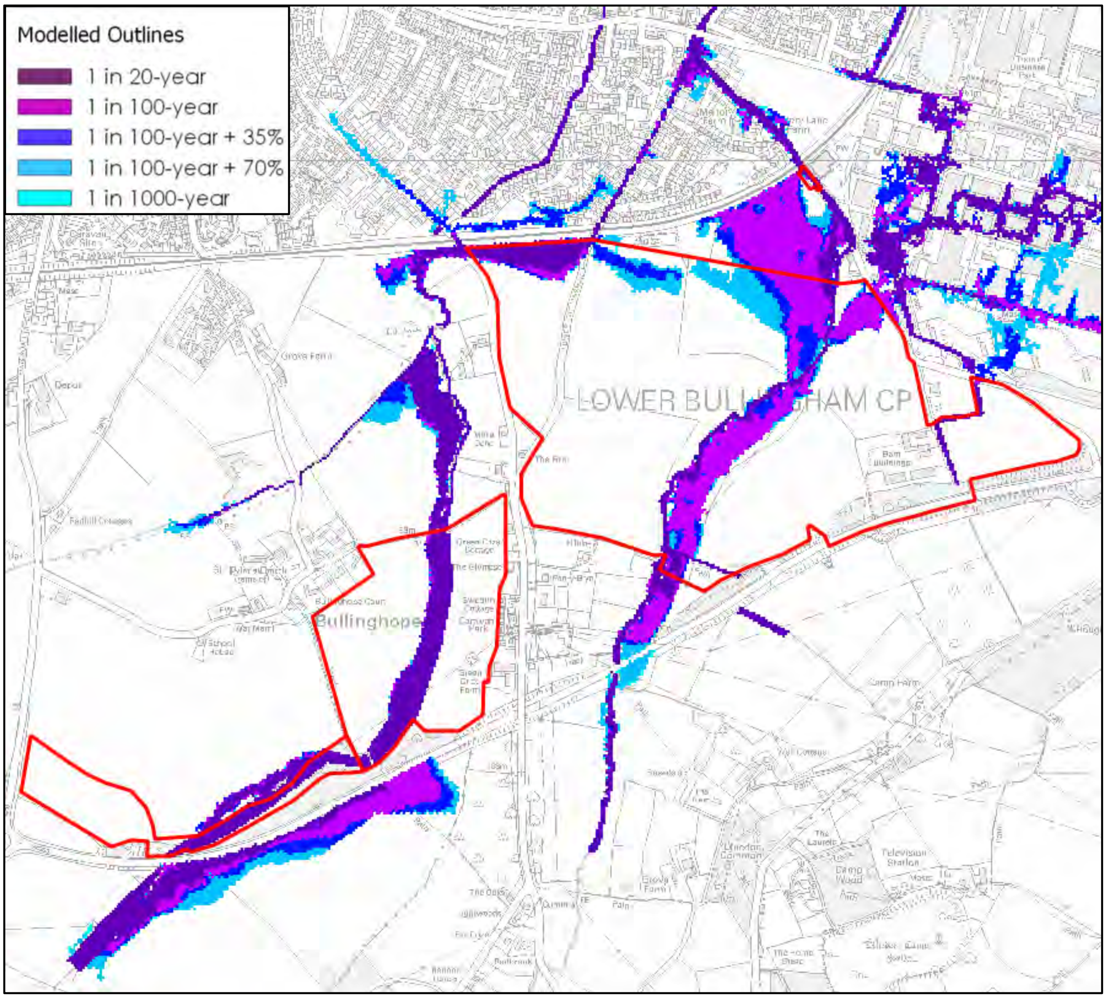


Figure 4.2: Baseline Modelled Flood Extents – Red Brook, Withy Brook & Norton Brook

4.4 The results show the same extents and flood mechanism in the south of the site, where the flooding is primarily a product of the minor watercourse. In the north of the site and the land beyond, floodplain extents are reduced without the influence of the River Wye.

4.5 To promote a conservative and robust assessment the site and proposed development are to be assessed against the results which include for the River Wye.

5. SENSITIVITY TESTING

5.1 To account for the seasonal variations in vegetation, and the risk of bridge/culvert blockages a series of sensitivity tests were conducted against the baseline conditions using the 1 in 100-year flows.

5.2 It was not considered necessary to undertake blockage scenarios on the minor footbridges within the model domain due to their narrow decks which can be easily bypassed by out of bank flows. It was also not considered necessary to test the other structures outside from the site as these are unlikely to have a significant influence on the flood risk within the site.

5.3 It was not considered necessary to undertake sensitivity analysis on the predicted flood flow estimates as a range of climate change allowances have been included within the design events.

5.4 It was not considered necessary to undertake sensitivity tests on the downstream boundary conditions as a conservative approach had been adopted within the design events by adopting the same return period for all watercourses and by delaying flows so that all events coincide with the River Wye peak.

5.5 The change in peak water level from the baseline conditions are mapped within Appendix 5.

Manning's n – Channel & Floodplain Roughness

5.6 The modelling has shown that a decrease in channel and floodplain roughness (representative of winter seasonal conditions or following maintenance) results in a decrease in flood depths of between to 10-200mm within the site, and a significant reduction in floodplain extents. This is a result of the ordinary watercourses becoming more efficient and capable of conveying more flow within bank.

5.7 An increase in Manning's N (representative of summer seasonal conditions, and a period without maintenance) is shown to result in an increase in flood depths of up to 10-90mm within the site. The floodplain extents are also shown to generally increase within the site, although the main increases occur in the flatter northern proportion of eastern parcel.

5.8 These tests show that the ordinary watercourses within the site are influenced by changes in roughness. Therefore, any alternations to the channel or floodplain which are proposed as part of the development will need testing within the flood model.

Sensitivity Tests – Blockage Scenarios

5.9 A blockage of the railway culvert on the Withy Brook (BL1) shows that this would lead to a significant increase in the overland flows being directed towards the eastern parcel of site along the railway embankment. This leads to an increase of up to 150mm in peak flood levels within the north of the site, and an increase to the predicted floodplain extents. Given this impact, the residual risk posed by such an occurrence should be considered within the flood mitigation strategy of a future development on the site.

5.10 A blockage of the Watery Lane culvert on the Red Brook (BL2) is shown to increase flood levels by up to 140mm within the channel immediately upstream. However, any impacts are shown to be local to the structure, which is removed from the future development areas, therefore this residual risk should not increase the flood risk to the development.

5.11 A blockage of the B4399 culvert on the Red Brook (BL3) is shown to increase upstream flood levels by up to 410mm which results in a slight increase in floodplain extents. However, this is shown to have no negative impacts on flood risk within the site.

5.12 A blockage of the B4399 culvert on the Red Brook Tributary (BL4) is shown to increase flood levels by up to 260mm upstream of the site and 15mm within the site. However, no additional out of bank flooding is shown to occur within the site.

5.13 A blockage of the Water Lane culvert on the unnamed ditch course (BL5) is shown to increase upstream flood levels by up to 112mm as well as increasing flows over Watery Lane into the downstream industrial estate. However, no additional out of bank flooding is shown to occur within the site.

5.14 A blockage of the farm access track culvert on the unnamed ditch course (BL6) is not predicted to effect flood levels within the site.

5.15 A blockage of the B4399 culvert on the Norton Brook (BL7) is shown to increase upstream flood levels by up to 480mm which results in a slight increase in floodplain extents. However, this is shown to have no negative impacts on flood risk within the site.

5.16 A blockage of the access track culvert on the Norton Brook (BL8) is predicted to result in a localised increase in flood levels of up to 460mm. This is accompanied by an increase in floodplain extents. While this scenario increases flood levels, the impact occurs within the Central Development Parcel, where no built development is proposed.

6. PROPOSED DEVELOPMENT CONDITIONS

6.1 A mixed used development is proposed within the study site. The development parameters at this outline planning stage are as follows:

- Western Development Parcel – Park and Choose Scheme (car parking facilities).
- Central Development Parcel – County Park (footpath improvements, no built development)
- Eastern Development Parcel – a mixed use including residential, primary school, and commercial areas.
- Watery Lane Vehicle Bypass Facility – Watery Lane is to be stopped-up as part of the traffic management scheme for the development. This gated bypass track ensures that the existing residents on Watery Lane will still be able to access the high land to the south of the railway line during a flood event.

6.2 The proposed built development has been arranged sequentially to fall on land outside of the 1 in 1000-year floodplain wherever possible – this is illustrated within Figure 6.1.

6.3 However, to meet the required development numbers from the allocation in the Local Plan, the Eastern Development Parcel does encourage into the 1 in 1000-year and 1 in 100-year+35% floodplains in a few isolated areas:

- The very northern tip of the development parcel to the east of Lower Bullingham Lane. Flood depths at the 1 in 100-year+35% flood event are under 100mm in this area.
- A marginal encroachment by a surface water drainage basin, which is to be elevated above flood levels. Flood depths at the 1 in 100-year+35% flood event are all under 100mm in this area.
- A crossing of the Red Brook floodplain to create a new bridged connection across the floodplain. Flood depths at the 1 in 100-year+35% flood event fall between 100 to 500mm in this area. Due to the nature of a bridge crossing, this feature also encroaches into the 1 in 100, 1 in 75, 1 in 50, and 1 in 20-year floodplains.

6.4 It is proposed that any loss of in the 1 in 100-year +35% floodplain, resulting from the development, will be recreated in a level-for-level manner within the site, and any bridge or culvert crossings will be analysed within the hydraulic model to assess their impact on flow conveyance.

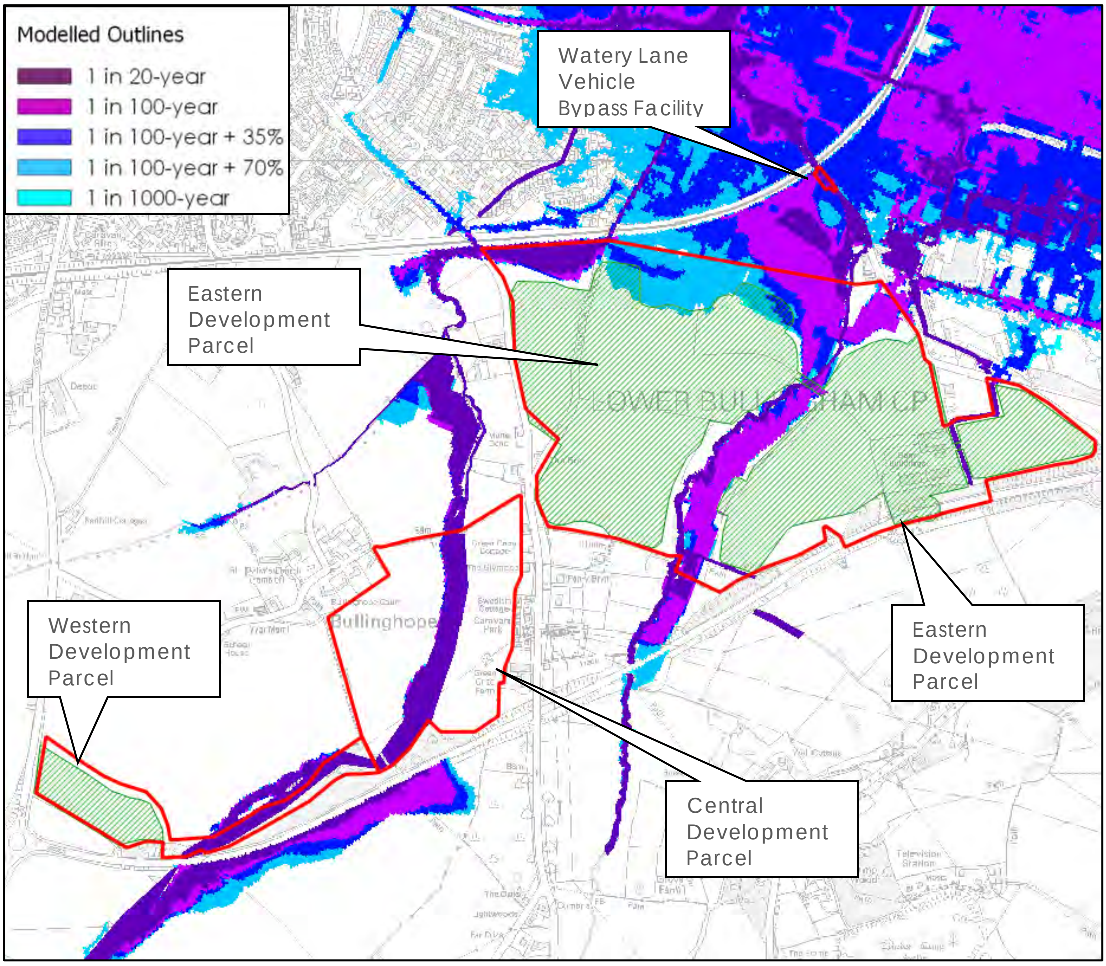


Figure 6.1: Proposed Development Parcels

Post-Development Hydraulic Modelling

6.5 As the development is only at an outline stage, the final extent of development/earthworks within the floodplain is currently unknown. Therefore, design of any necessary floodplain compensation has not yet been completed. It is envisaged that this will be undertaken at the detailed design stage.

6.6 However, as an informative to assess the sensitivity of the floodplain to the expected development encroachments, the illustrative parameters plan was used to raise land within the development parcels above flood levels.

6.7 As a worst-case assessment no representation of floodplain compensation was included.

6.8 Initial model simulations found that the Red Brook floodplain was sensitive to the left-hand bank abutment of the proposed bridge. Therefore, this outline model scenario assumes that the only the right-hand bank abutment and highway embankment will displace floodplain. It is assumed that the channel and left-hand bank floodplain will be clear spanned by a bridge. The final arrangement of the new Red Brook crossing will be determined at the detailed design stage.

6.9 The updated model geometry was simulated against flood events and the resultant peak water levels were compared against the baseline conditions. The comparative analysis is mapped within Appendix 6, for flood events up to and including the design flood (1 in 100-year+35%).

6.10 As an informative the comparison also includes for the 1 in 100-year+70% and 1 in 1000-yrear events, but it should be noted that these are beyond typical design standard.

6.11 The comparative analysis shows that there are localised changes in flood levels centred around the proposed bridge crossing, but that any changes dissipate within a short distance.

6.12 In the 1 in 100-year, 1 in 75-year, and 1 in 50-year events some nominal impacts are predicted to the north of the application site. The impacts eminent from the proposed bridge crossing, but occur on land within the wider land ownership. Therefore, these are considered acceptable.

6.13 It should be noted that in reality floodplain compensation will be offered to offset the loss in floodplain resulting from the development, thereby reducing any potential impacts. But even with no floodplain compensation represented within the model, the developments impact on the floodplain outside of the site is minimal.

6.14 Additionally, attenuated surface water drainage in the form of SuDS will reduce the equative runoff from the development to the greenfield QBAR rate, thereby offering betterment to the contributing runoff from the site to the downstream floodplain. This is also not currently represented within the flood model.

Tabulated Flood Levels

6.15 A table of peak flood levels from key flood events is provided within Appendix 7, along with a map illustrating their location. It is recommended that these are considered within the Flood Management Strategy for the development.

6.16 It is envisaged that the final flood mitigation strategy will be confirmed at the detailed design stage once the final layout is fixed.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 An existing hydraulic model of the Red Brook, its associated unnamed tributary, the Withy Brook, and a small unnamed ditch have been updated and extended to include the Norton Brook. The model includes for the influence of the River Wye.

7.2 The update to the model has included a hydrological review, and the incorporation of the latest topographical surveys and climate change allowances.

7.3 It is believed that the aim of the modelling exercise has been achieved and a good hydrological and hydraulic representation of the fluvial flooding mechanisms and floodplain extents within the study site has been produced.

7.4 The modelling has adopted a conservative approach where necessary: an example of which is applying the same return period event to all watercourses including the River Wye, and by delaying the flood hydrographs of the Red Brook, Withy Brook and unnamed ditch to coincide with the peak water level on the Wye.

7.5 Hydraulic tests have shown that the floodplain is sensitive to blockages of the Withy Brook culvert beneath the railway, as well as changes in floodplain and channel condition (roughness).

7.6 The development has been sequentially arranged to fall outside of the floodplain where possible, but due to the need to meet the required allocation numbers some marginal encroachment into the design floodplain occurs (the 1 in 100-year+35% floodplain).

7.7 It is proposed to compensate for the loss in floodplain in a level-for-level manner, and designs should be prepared at the detailed design stage when the final extent of development is confirmed.

7.8 The development will include a bridge crossing of the Red Brook. It is envisaged that the bridge parameters and appropriate floodplain compensation will be identified at the detailed design stage. Similarly, any other bridge crossing in the wider development area will be assessed in the same manner at the detailed design stage.

7.9 At this outline stage, a test of the developments potential impact with no floodplain compensation has been undertaken as a worst-case analysis. This has shown that the potential impacts on the fluvial flood risk are nominal and are contained within the site or the wider land ownership.

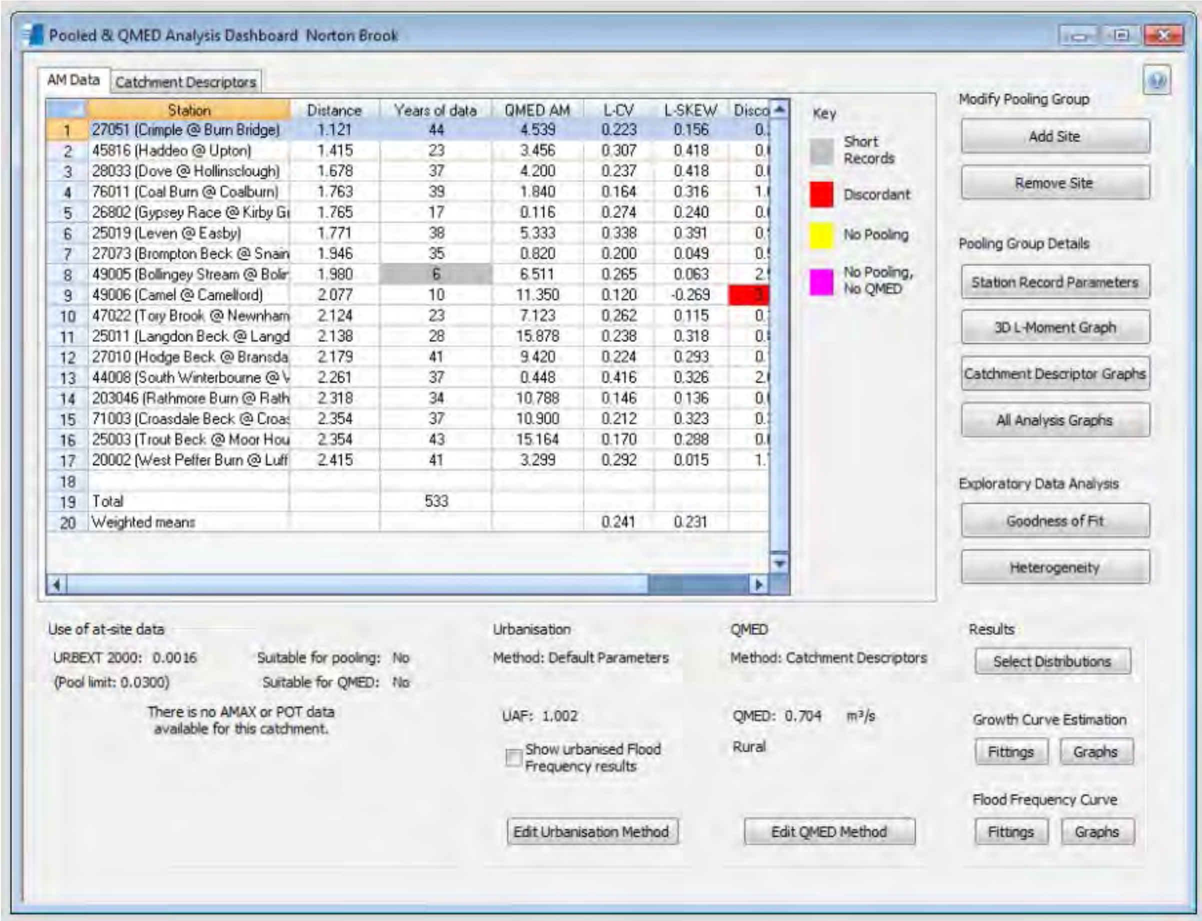
7.10 To minimise the flood risk to the future development of the site it is recommended that the 1 in 100 year + 35% flood levels are used to inform the development's flood mitigation strategy (e.g.: finished floor levels, access/egress routes, etc.). Additionally, freeboard levels should be compared against peak flood levels from the sensitivity tests and the +70% climate change event to ensure the development will be resilient against residual sources of fluvial flood risk.

7.11 The fluvial floodplain within the site has proven to be sensitive to changes in roughness, therefore any proposed changes to the channel or floodplain land use should be run through the flood model to confirm that it will have no negative impacts.

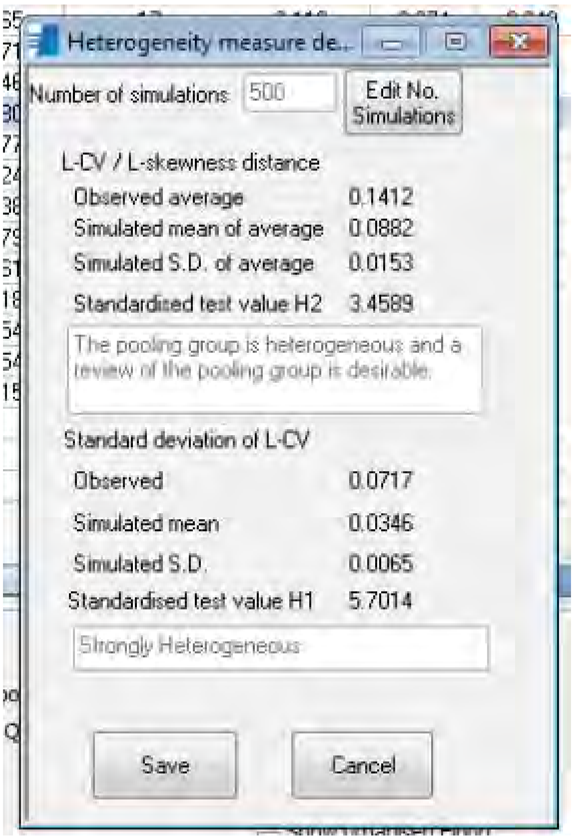
APPENDICES

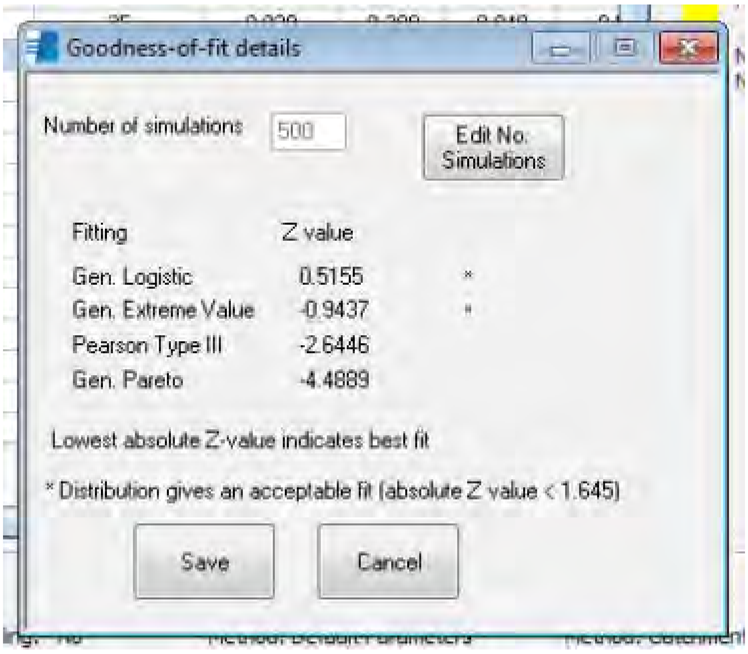
APPENDIX 1: WINFAP FEH Statistical Approach

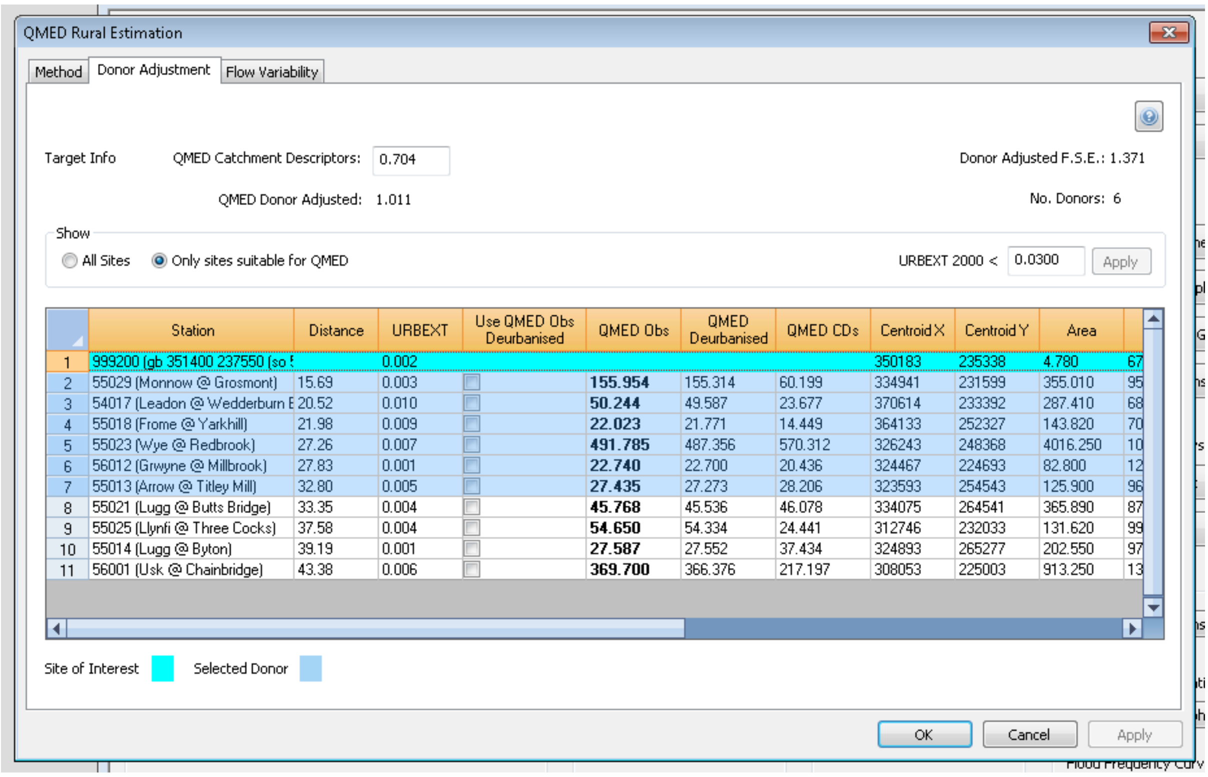
Norton Brook



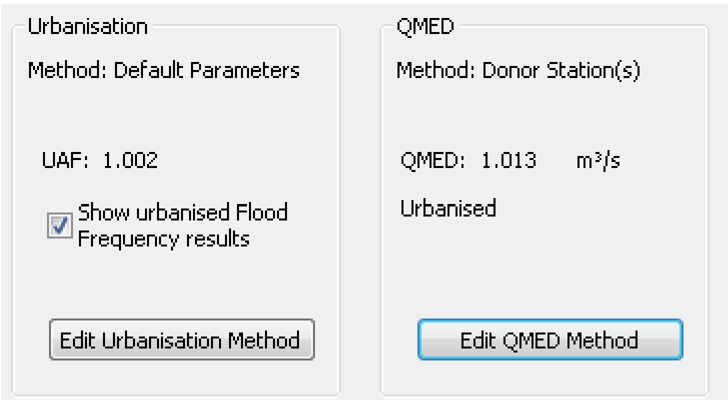
	Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Disco
1	27051 (Crimple @ Burn Bridge)	1.121	44	4.539	0.223	0.156	0.
2	45816 (Haddeo @ Upton)	1.415	23	3.456	0.307	0.418	0.
3	28033 (Dove @ Hollinsclough)	1.678	37	4.200	0.237	0.418	0.
4	76011 (Coal Burn @ Coalburn)	1.763	39	1.840	0.164	0.316	1.
5	26802 (Gypsey Race @ Kirby Gi	1.765	17	0.116	0.274	0.240	0.
6	25019 (Leven @ Easby)	1.771	38	5.333	0.338	0.391	0.
7	27073 (Brompton Beck @ Snain	1.946	35	0.820	0.200	0.049	0.
8	49005 (Bollingey Stream @ Bolir	1.980	6	6.511	0.265	0.063	2.
9	49006 (Camel @ Camelford)	2.077	10	11.350	0.120	-0.269	3
10	47022 (Tory Brook @ Newnham	2.124	23	7.123	0.262	0.115	0.
11	25011 (Langdon Beck @ Langd	2.138	28	15.878	0.238	0.318	0.
12	27010 (Hodge Beck @ Bransda	2.179	41	9.420	0.224	0.293	0.
13	44008 (South Winterbourne @ V	2.261	37	0.448	0.416	0.326	2.
14	203046 (Rathmore Burn @ Rath	2.318	34	10.788	0.146	0.136	0.
15	71003 (Croasdale Beck @ Croas	2.354	37	10.900	0.212	0.323	0.
16	25003 (Trout Beck @ Moor Hou	2.354	43	15.164	0.170	0.288	0.
17	20002 (West Peffer Burn @ Luff	2.415	41	3.299	0.292	0.015	1.
18							
19	Total		533				
20	Weighted means				0.241	0.231	







	Station	Distance	URBEXT	Use QMED Obs Deurbanised	QMED Obs	QMED Deurbanised	QMED CDs	Centroid X	Centroid Y	Area	
1	999200 (gb 351400 237550 (so 5		0.002					350183	235338	4.780	67
2	55029 (Monnow @ Grosmont)	15.69	0.003	☐	**155.954**	155.314	60.199	334941	231599	355.010	95
3	54017 (Leadon @ Wedderburn E	20.52	0.010	☐	**50.244**	49.587	23.677	370614	233392	287.410	68
4	55018 (Frome @ Yarkhill)	21.98	0.009	☐	**22.023**	21.771	14.449	364133	252327	143.820	70
5	55023 (Wye @ Redbrook)	27.26	0.007	☐	**491.785**	487.356	570.312	326243	248368	4016.250	10
6	56012 (Grwyne @ Millbrook)	27.83	0.001	☐	**22.740**	22.700	20.436	324467	224693	82.800	12
7	55013 (Arrow @ Titley Mill)	32.80	0.005	☐	**27.435**	27.273	28.206	323593	254543	125.900	96
8	55021 (Lugg @ Butts Bridge)	33.35	0.004	☐	**45.768**	45.536	46.078	334075	264541	365.890	87
9	55025 (Llynfi @ Three Cocks)	37.58	0.004	☐	**54.650**	54.334	24.441	312746	232033	131.620	99
10	55014 (Lugg @ Byton)	39.19	0.001	☐	**27.587**	27.552	37.434	324893	265277	202.550	97
11	56001 (Usk @ Chainbridge)	43.38	0.006	☐	**369.700**	366.376	217.197	308053	225003	913.250	13



Growth Curve Fittings

Standardisation details

Standardised by median

Growth Curve L-moments

L-CV 0.241   L-skewness 0.231

Fitted parameters

	Location	Scale	Shape	Bound
GL	1.000	0.242	-0.231	-0.047
GEV	0.869	0.350	-0.093	-2.899

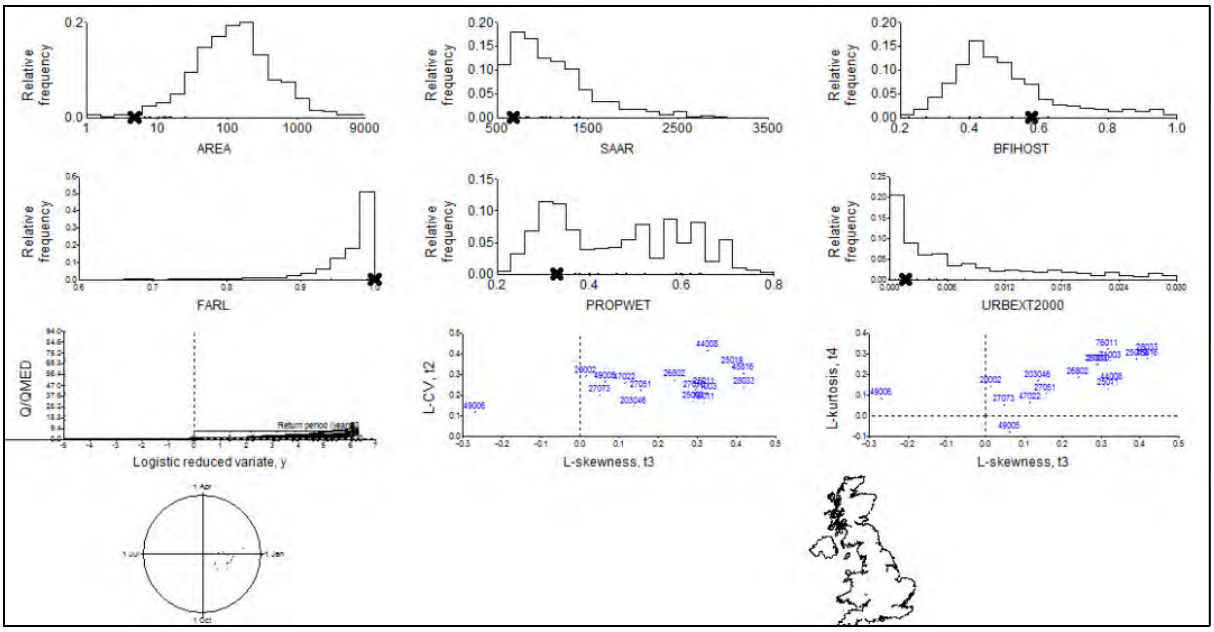
Return periods

	GL	GEV
5	1.395	1.433
10	1.692	1.746
25	2.135	2.175
50	2.526	2.517
75	2.783	2.727
100	2.980	2.881
200	3.510	3.267
500	4.352	3.816
1000	5.118	4.264

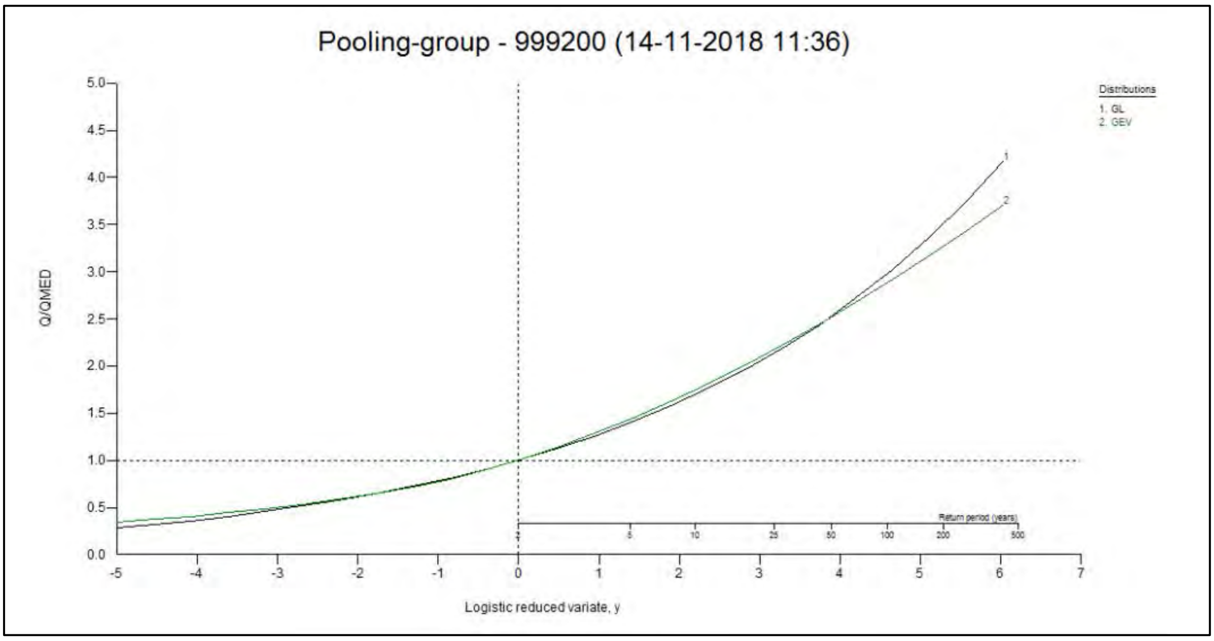
Fittings for FFC

Return periods

	GL	GEV
2	1.013	1.013
5	1.414	1.452
10	1.715	1.770
25	2.163	2.203
50	2.560	2.551
75	2.820	2.764
100	3.020	2.919
200	3.557	3.310
500	4.410	3.867
1000	5.185	4.320

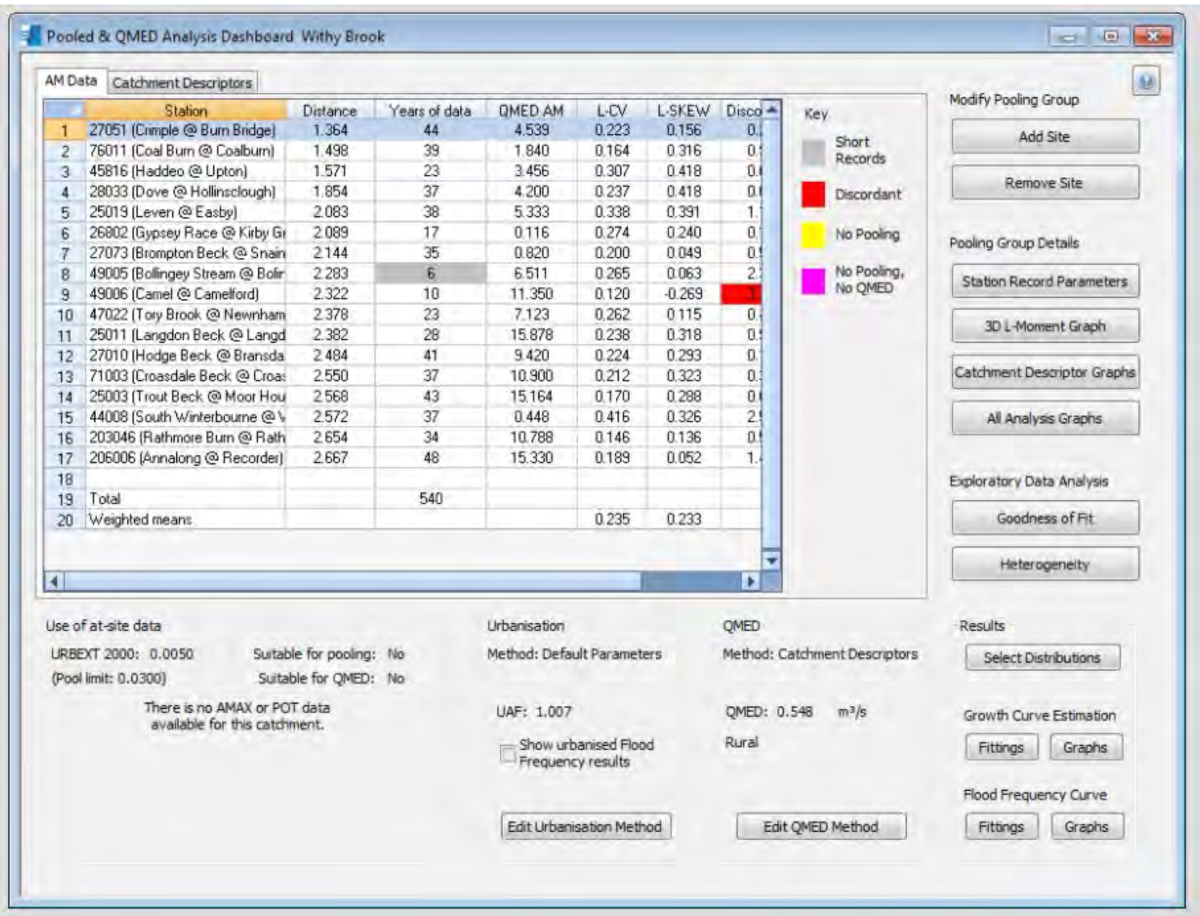


Relative frequency
AREA
SAAR
BFIHOST
FARL
PROPWET
URBEXT2000
Q/QMED
Logistic reduced variate, y
L-CV, t2
L-skewness, t3
L-kurtosis, t4
1 Apr
1 Jul
1 Jan
1 Oct

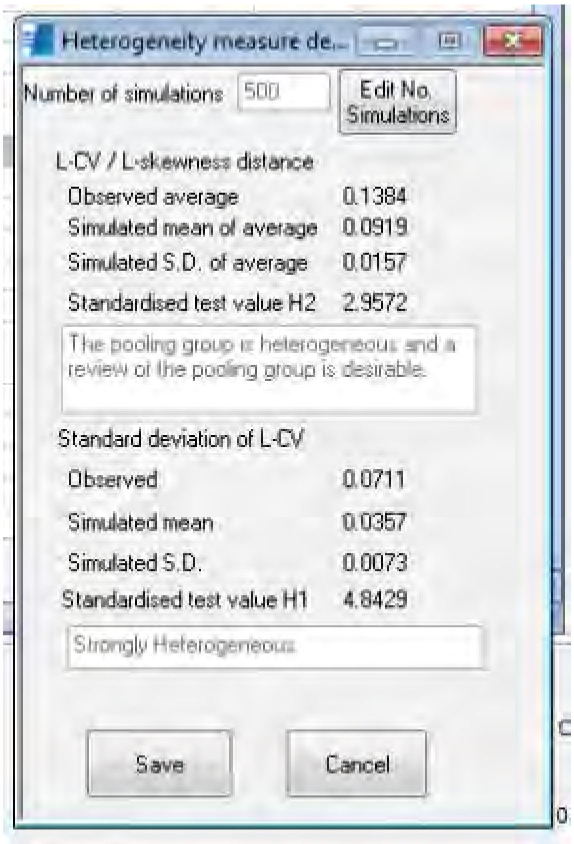


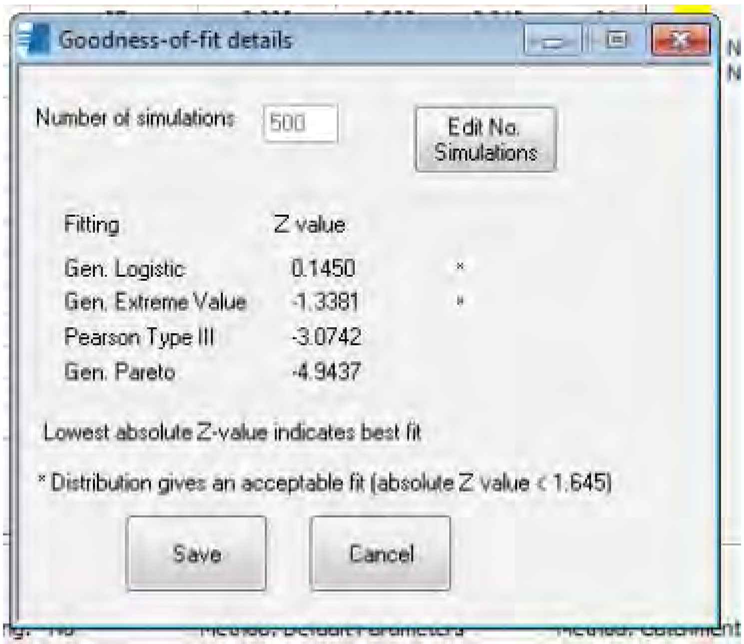
Pooling-group - 999200 (14-11-2018 11:36)
Distributions
1. GL
2. GEV
Q/QMED
Return period (years)
Logistic reduced variate, y

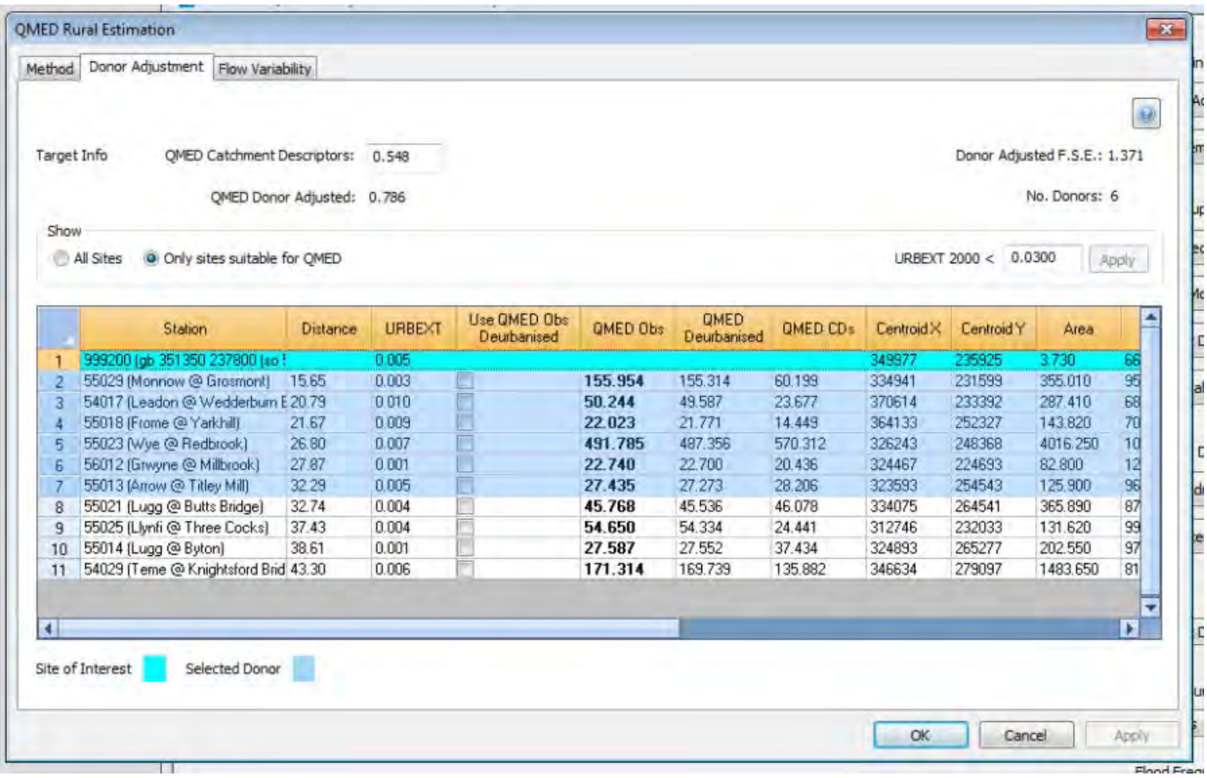
Withy Brook



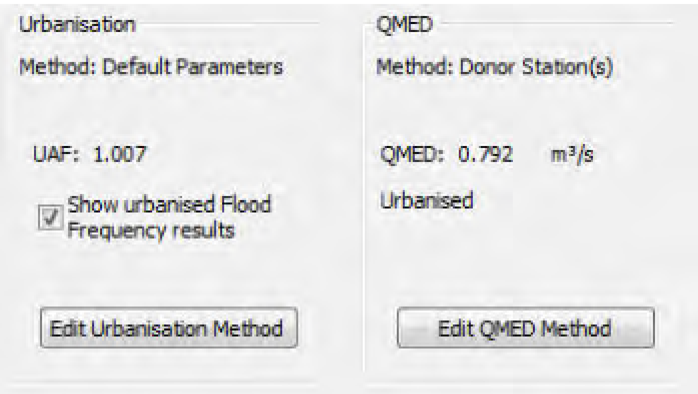
	Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Disco
1	27051 (Crimple @ Burn Bridge)	1.364	44	4.539	0.223	0.156	0.
2	76011 (Coal Burn @ Coalburn)	1.498	39	1.840	0.164	0.316	0.
3	45816 (Haddeo @ Upton)	1.571	23	3.456	0.307	0.418	0.
4	28033 (Dove @ Hollinsclough)	1.854	37	4.200	0.237	0.418	0.
5	25019 (Leven @ Easby)	2.083	38	5.333	0.338	0.391	1.
6	26802 (Gypsey Race @ Kirby Gr	2.089	17	0.116	0.274	0.240	0.
7	27073 (Brompton Beck @ Snain	2.144	35	0.820	0.200	0.049	0.
8	49005 (Bollingey Stream @ Bolir	2.283	6	6.511	0.265	0.063	2.
9	49006 (Camel @ Camelford)	2.322	10	11.350	0.120	-0.269	3
10	47022 (Tory Brook @ Newnham	2.378	23	7.123	0.262	0.115	0.
11	25011 (Langdon Beck @ Langd	2.382	28	15.878	0.238	0.318	0.
12	27010 (Hodge Beck @ Bransda	2.484	41	9.420	0.224	0.293	0.
13	71003 (Croasdale Beck @ Croas	2.550	37	10.900	0.212	0.323	0.
14	25003 (Trout Beck @ Moor Hou	2.568	43	15.164	0.170	0.288	0.
15	44008 (South Winterbourne @ V	2.572	37	0.448	0.416	0.326	2.
16	203046 (Rathmore Burn @ Rath	2.654	34	10.788	0.146	0.136	0.
17	206006 (Annalong @ Recorder)	2.667	48	15.330	0.189	0.052	1.
18							
19	Total		540				
20	Weighted means				0.235	0.233	

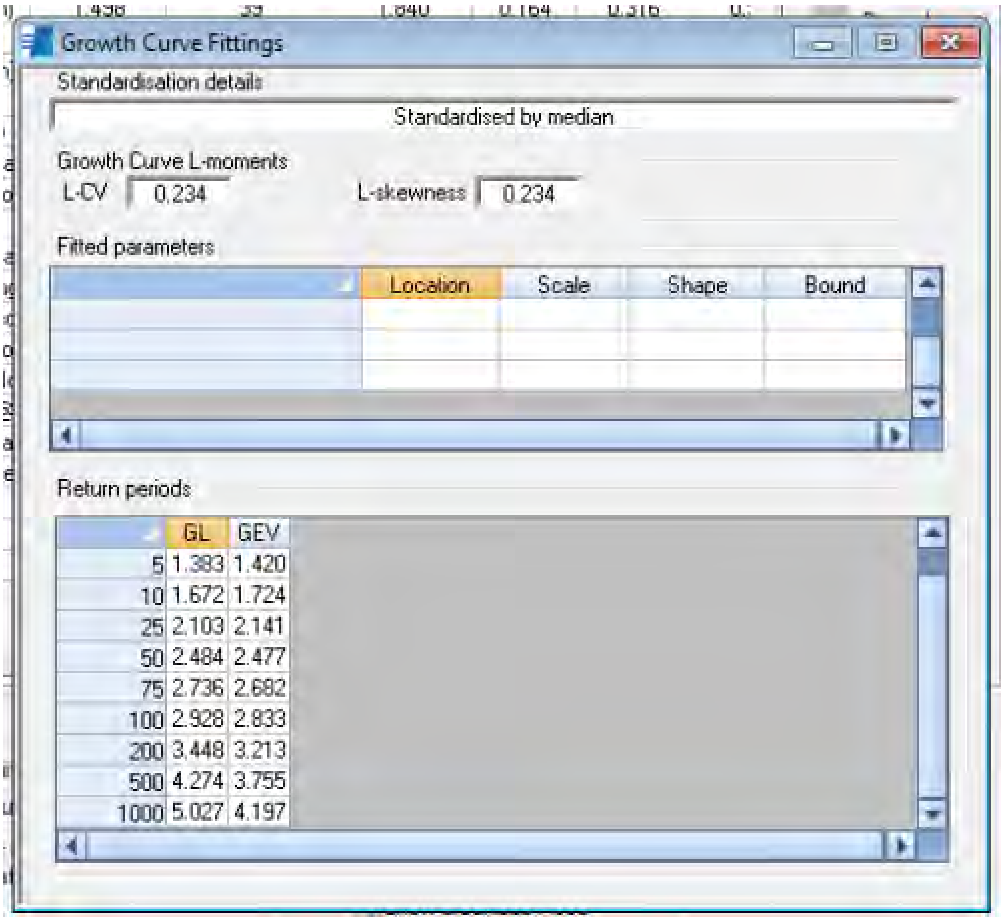






	Station	Distance	URBEXT	Use QMED Obs Deurbanised	QMED Obs	QMED Deurbanised	QMED CDs	Centroid X	Centroid Y	Area	
1	999200 (gb 351350 237800 (so 5		0.005					349977	235925	3.730	66
2	55029 (Monnow @ Grosmont)	15.65	0.003		**155.954**	155.314	60.199	334941	231599	355.010	95
3	54017 (Leadon @ Wedderburn E	20.79	0.010		**50.244**	49.587	23.677	370614	233392	287.410	68
4	55018 (Frome @ Yarkhill)	21.67	0.009		**22.023**	21.771	14.449	364133	252327	143.820	70
5	55023 (Wye @ Redbrook)	26.80	0.007		**491.785**	487.356	570.312	326243	248368	4016.250	10
6	56012 (Grwyne @ Millbrook)	27.87	0.001		**22.740**	22.700	20.436	324467	224693	82.800	12
7	55013 (Arrow @ Titley Mill)	32.29	0.005		**27.435**	27.273	28.206	323593	254543	125.900	96
8	55021 (Lugg @ Butts Bridge)	32.74	0.004		**45.768**	45.536	46.078	334075	264541	365.890	87
9	55025 (Llynfi @ Three Cocks)	37.43	0.004		**54.650**	54.334	24.441	312746	232033	131.620	99
10	55014 (Lugg @ Byton)	38.61	0.001		**27.587**	27.552	37.434	324893	265277	202.550	97
11	54029 (Teme @ Knightsford Brid	43.30	0.006		**171.314**	169.739	135.882	346634	279097	1483.650	81




Growth Curve Fittings

Standardisation details

Standardised by median

Growth Curve L-moments

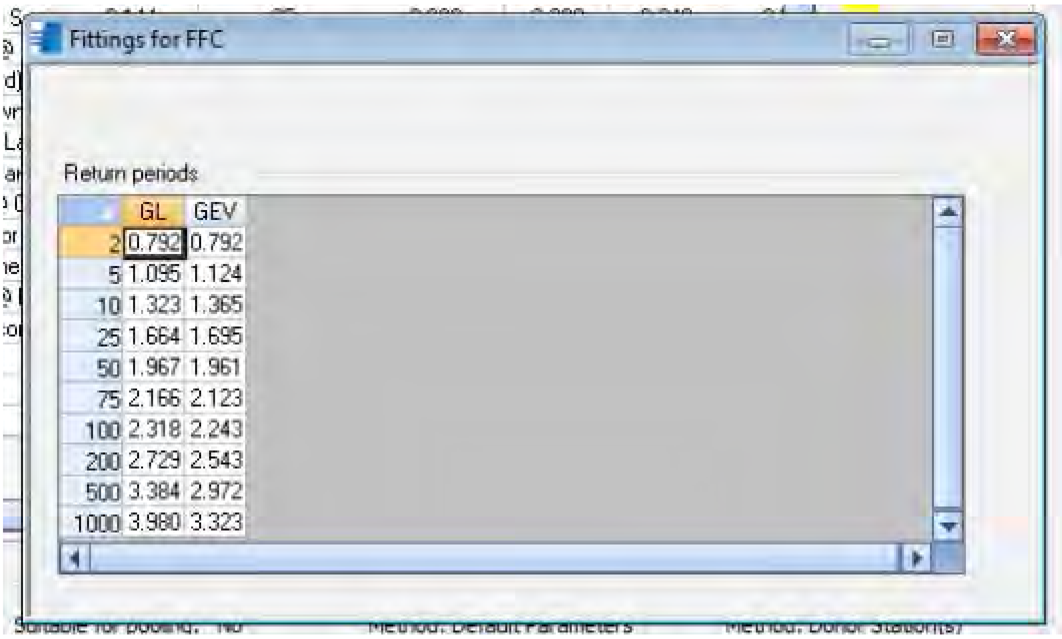
L-CV 0.234 L-skewness 0.234

Fitted parameters

	Location	Scale	Shape	Bound

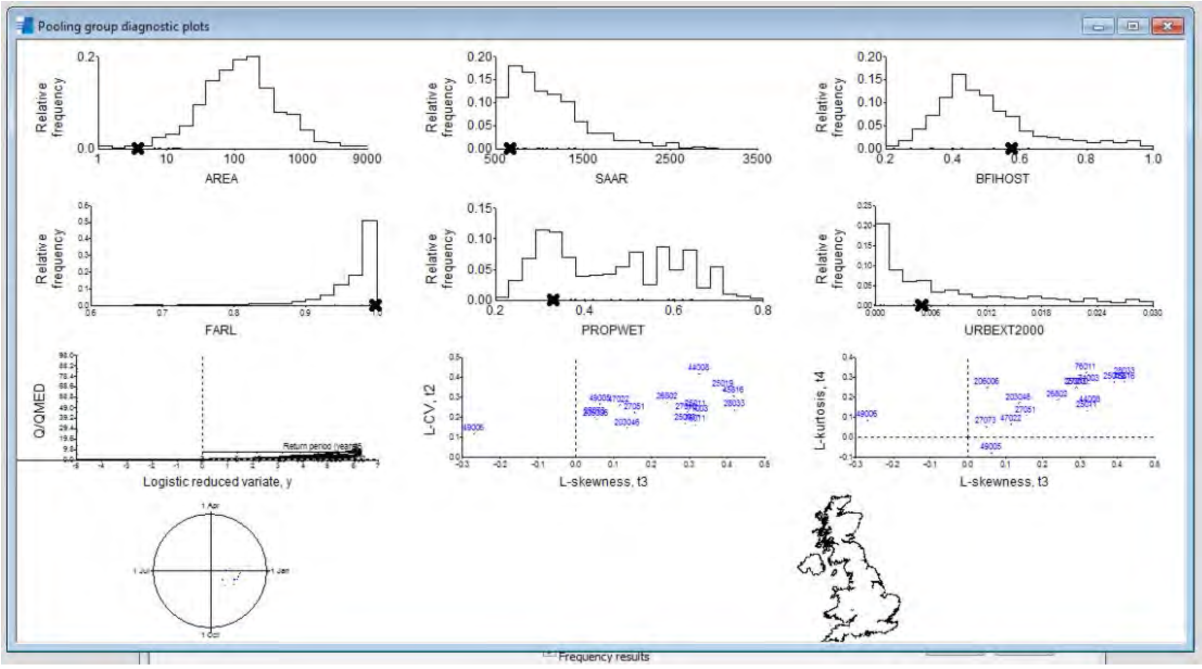
Return periods

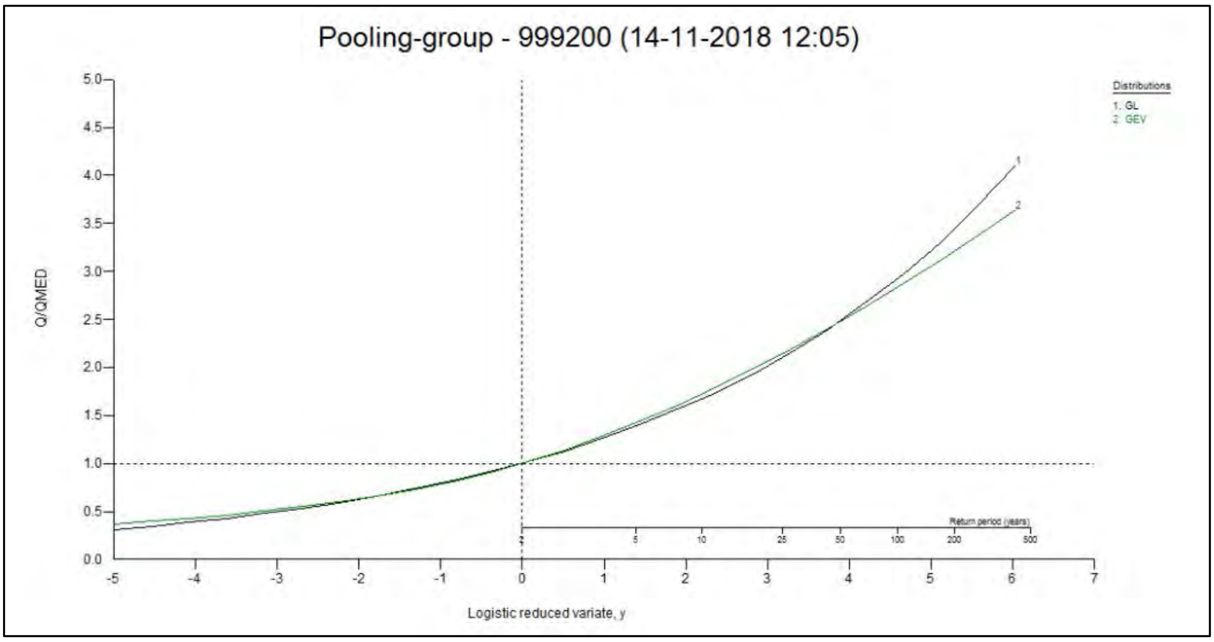
	GL	GEV
5	1.383	1.420
10	1.672	1.724
25	2.103	2.141
50	2.484	2.477
75	2.736	2.682
100	2.928	2.833
200	3.448	3.213
500	4.274	3.755
1000	5.027	4.197


Fittings for FFC

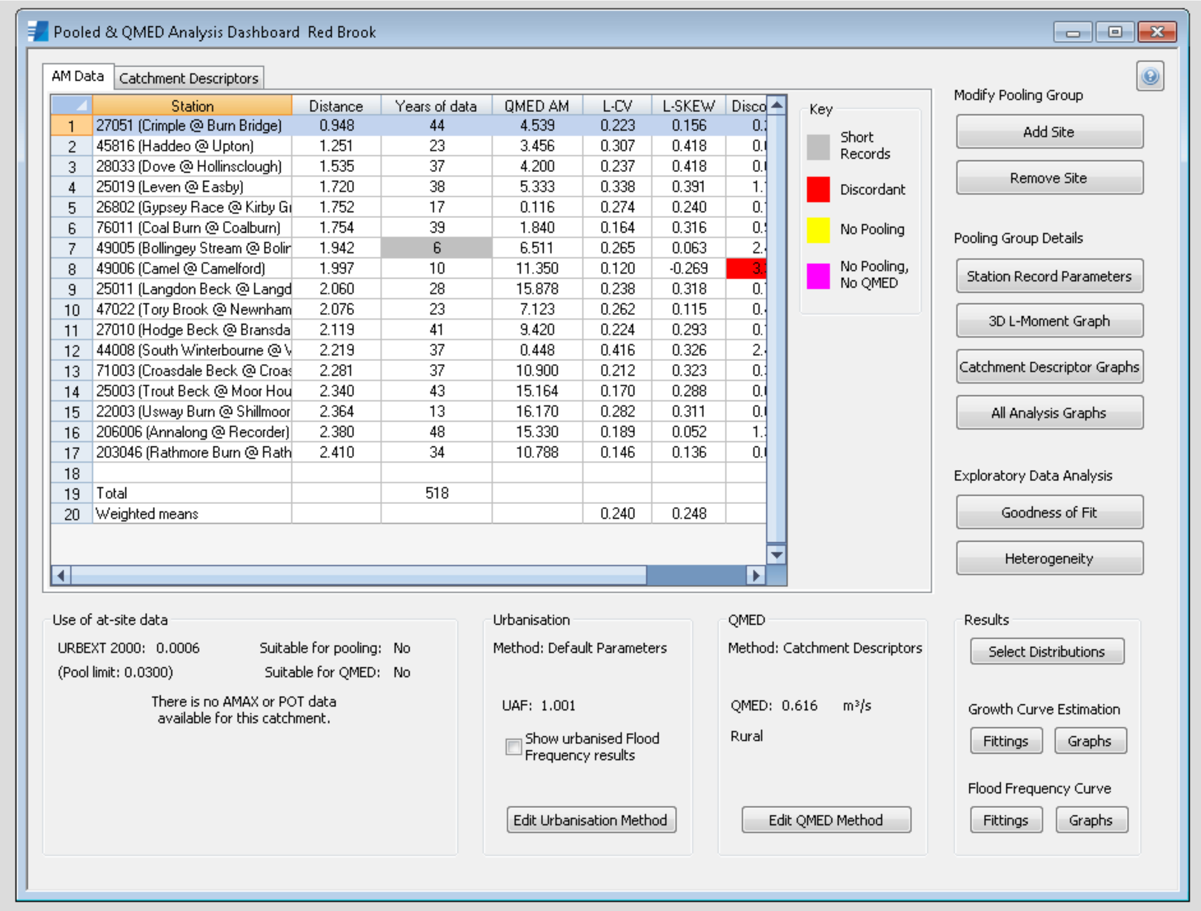
Return periods

	GL	GEV
2	0.792	0.792
5	1.095	1.124
10	1.323	1.365
25	1.664	1.695
50	1.967	1.961
75	2.166	2.123
100	2.318	2.243
200	2.729	2.543
500	3.384	2.972
1000	3.980	3.323

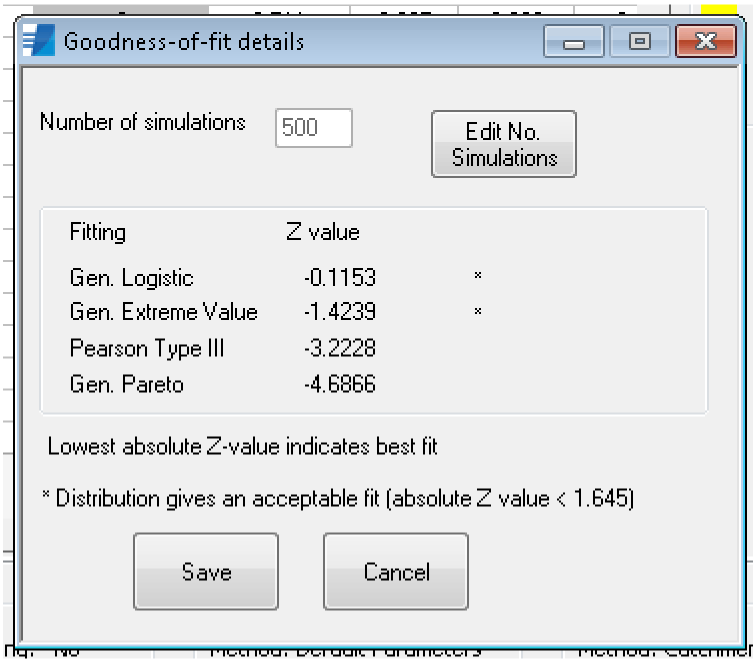

Pooling group diagnostic plots
AREA
SAAR
BFIHOST
FARL
PROPWET
URBEXT2000
Relative frequency
Q/QMED
Logistic reduced variate, y
L-CV, t2
L-skewness, t3
L-kurtosis, t4
Frequency results

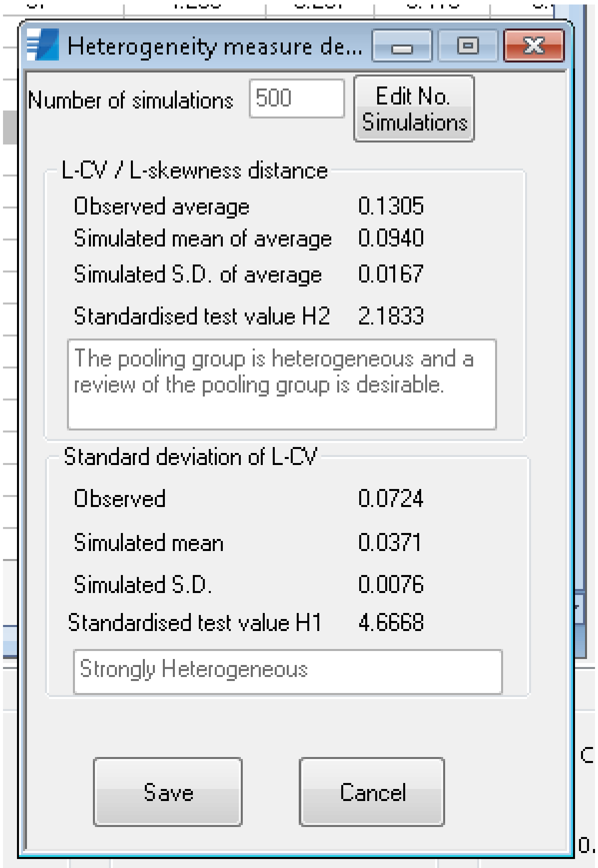

Pooling-group - 999200 (14-11-2018 12:05)
Distributions
1. GL
2. GEV
Q/QMED
Return period (years)
Logistic reduced variate, y

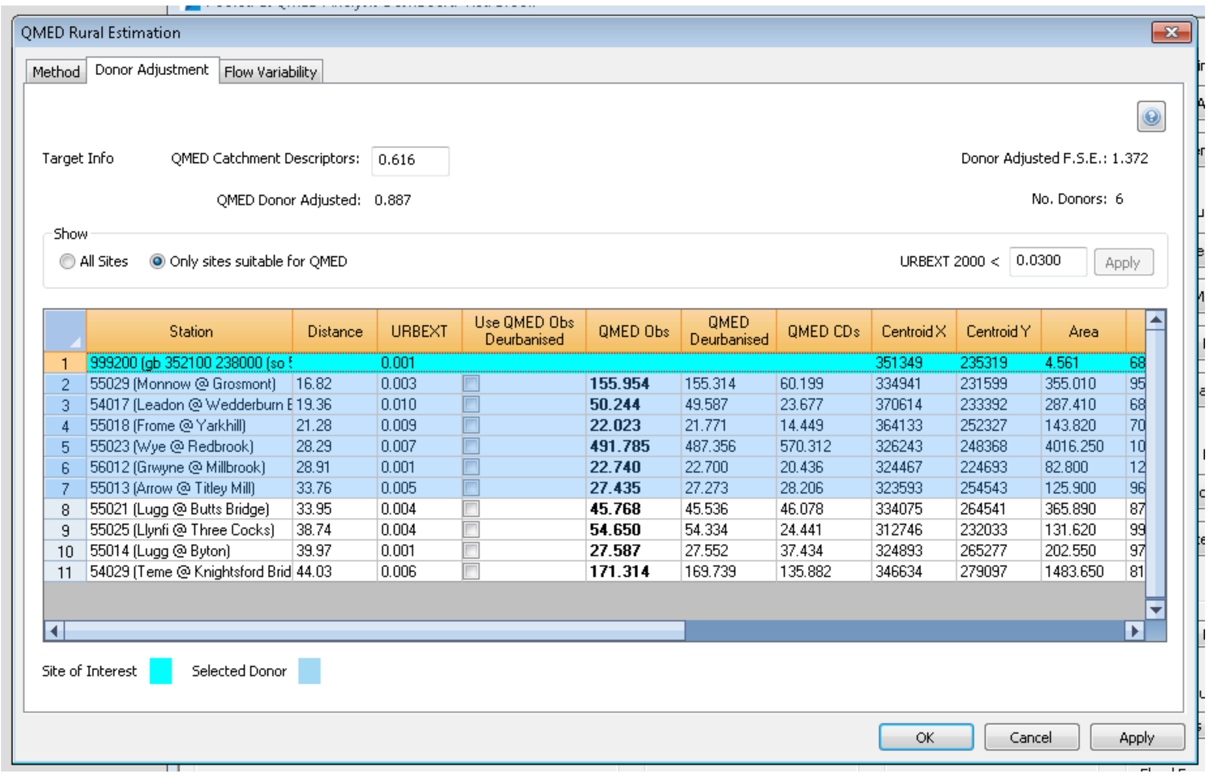
Red Brook

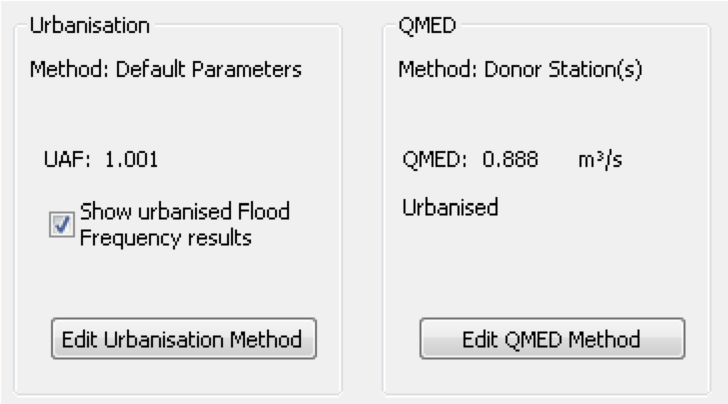


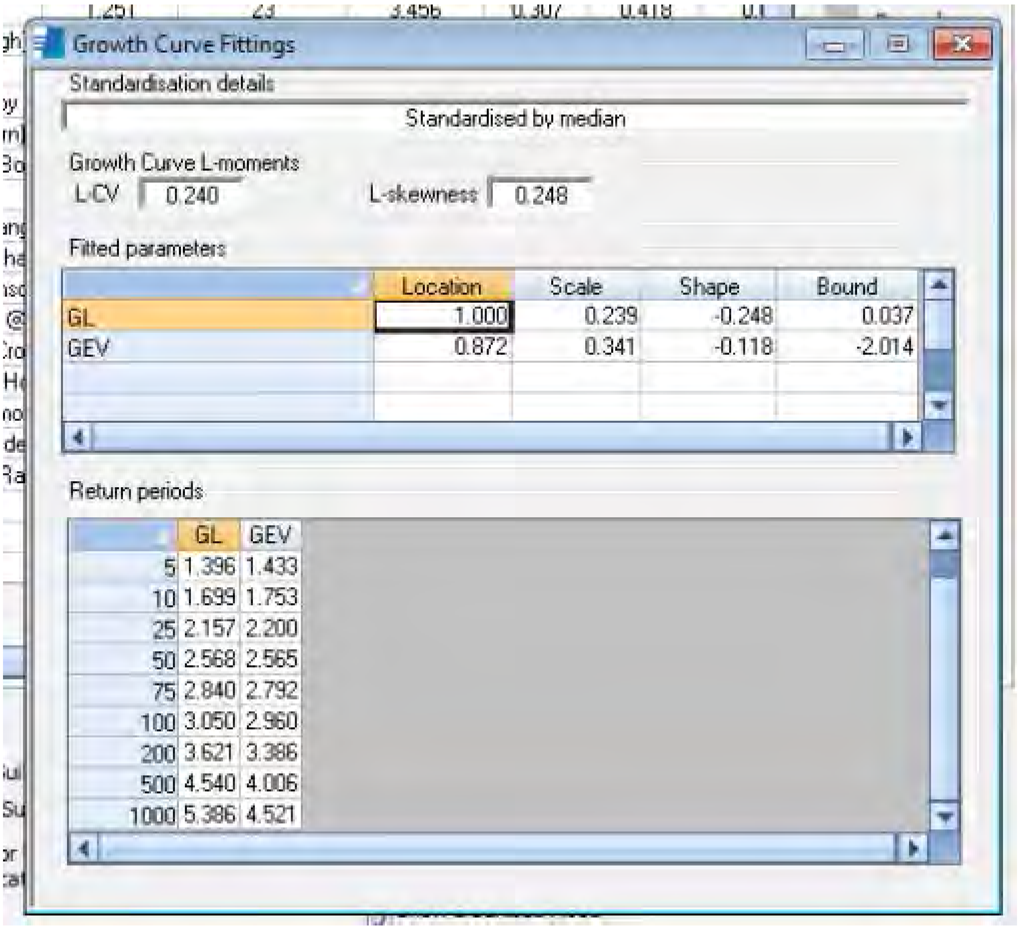
	Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Disco
1	27051 (Crimple @ Burn Bridge)	0.948	44	4.539	0.223	0.156	0.
2	45816 (Haddeo @ Upton)	1.251	23	3.456	0.307	0.418	0.
3	28033 (Dove @ Hollinsclough)	1.535	37	4.200	0.237	0.418	0.
4	25019 (Leven @ Easby)	1.720	38	5.333	0.338	0.391	1.
5	26802 (Gypsey Race @ Kirby Gi	1.752	17	0.116	0.274	0.240	0.
6	76011 (Coal Burn @ Coalburn)	1.754	39	1.840	0.164	0.316	0.
7	49005 (Bollingey Stream @ Bolir	1.942	6	6.511	0.265	0.063	2.
8	49006 (Camel @ Camelford)	1.997	10	11.350	0.120	-0.269	3.
9	25011 (Langdon Beck @ Langd	2.060	28	15.878	0.238	0.318	0.
10	47022 (Tory Brook @ Newnham	2.076	23	7.123	0.262	0.115	0.
11	27010 (Hodge Beck @ Bransda	2.119	41	9.420	0.224	0.293	0.
12	44008 (South Winterbourne @ V	2.219	37	0.448	0.416	0.326	2.
13	71003 (Croasdale Beck @ Croas	2.281	37	10.900	0.212	0.323	0.
14	25003 (Trout Beck @ Moor Hou	2.340	43	15.164	0.170	0.288	0.
15	22003 (Usway Burn @ Shillmoor	2.364	13	16.170	0.282	0.311	0.
16	206006 (Annalong @ Recorder)	2.380	48	15.330	0.189	0.052	1.
17	203046 (Rathmore Burn @ Rath	2.410	34	10.788	0.146	0.136	0.
18							
19	Total		518				
20	Weighted means				0.240	0.248	




Heterogeneity measure de...
Number of simulations
500
Edit No. Simulations
L-CV / L-skewness distance
Observed average 0.1305
Simulated mean of average 0.0940
Simulated S.D. of average 0.0167
Standardised test value H2 2.1833
The pooling group is heterogeneous and a review of the pooling group is desirable.
Standard deviation of L-CV
Observed 0.0724
Simulated mean 0.0371
Simulated S.D. 0.0076
Standardised test value H1 4.6668
Strongly Heterogeneous
Save
Cancel

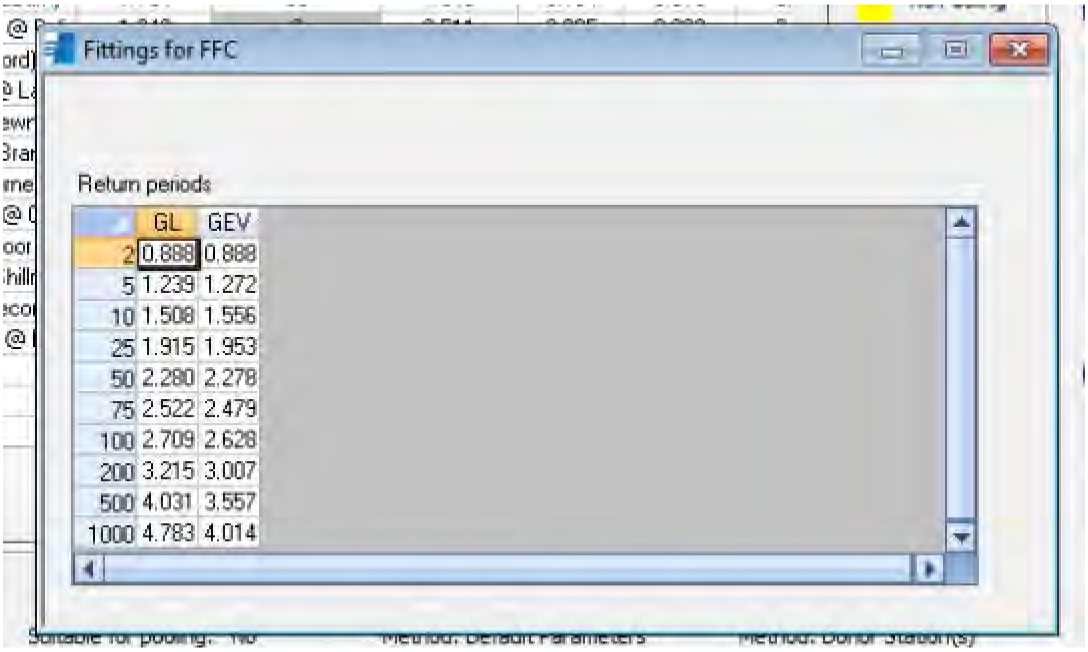

QMED Rural Estimation
Method
Donor Adjustment
Flow Variability
Target Info
QMED Catchment Descriptors: 0.616
Donor Adjusted F.S.E.: 1.372
QMED Donor Adjusted: 0.887
No. Donors: 6
Show
All Sites
Only sites suitable for QMED
URBEXT 2000 < 0.0300
Apply
Station | Distance | URBEXT | Use QMED Obs Deurbanised | QMED Obs | QMED Deurbanised | QMED CDs | Centroid X | Centroid Y | Area
1 | 999200 (gb 352100 238000 (so | | 0.001 | | | | | 351349 | 235319 | 4.561
2 | 55029 (Monnow @ Grosmont) | 16.82 | 0.003 | | 155.954 | 155.314 | 60.199 | 334941 | 231599 | 355.010
3 | 54017 (Leadon @ Wedderburn | 19.36 | 0.010 | | 50.244 | 49.587 | 23.677 | 370614 | 233392 | 287.410
4 | 55018 (Frome @ Yarkhill) | 21.28 | 0.009 | | 22.023 | 21.771 | 14.449 | 364133 | 252327 | 143.820
5 | 55023 (Wye @ Redbrook) | 28.29 | 0.007 | | 491.785 | 487.356 | 570.312 | 326243 | 248368 | 4016.250
6 | 56012 (Grwyne @ Millbrook) | 28.91 | 0.001 | | 22.740 | 22.700 | 20.436 | 324467 | 224693 | 82.800
7 | 55013 (Arrow @ Titley Mill) | 33.76 | 0.005 | | 27.435 | 27.273 | 28.206 | 323593 | 254543 | 125.900
8 | 55021 (Lugg @ Butts Bridge) | 33.95 | 0.004 | | 45.768 | 45.536 | 46.078 | 334075 | 264541 | 365.890
9 | 55025 (Llynfi @ Three Cocks) | 38.74 | 0.004 | | 54.650 | 54.334 | 24.441 | 312746 | 232033 | 131.620
10 | 55014 (Lugg @ Byton) | 39.97 | 0.001 | | 27.587 | 27.552 | 37.434 | 324893 | 265277 | 202.550
11 | 54029 (Teme @ Knightsford Brid | 44.03 | 0.006 | | 171.314 | 169.739 | 135.882 | 346634 | 279097 | 1483.650
Site of Interest
Selected Donor
OK
Cancel
Apply





	Location	Scale	Shape	Bound
GL	1.000	0.239	-0.248	0.037
GEV	0.872	0.341	-0.118	-2.014

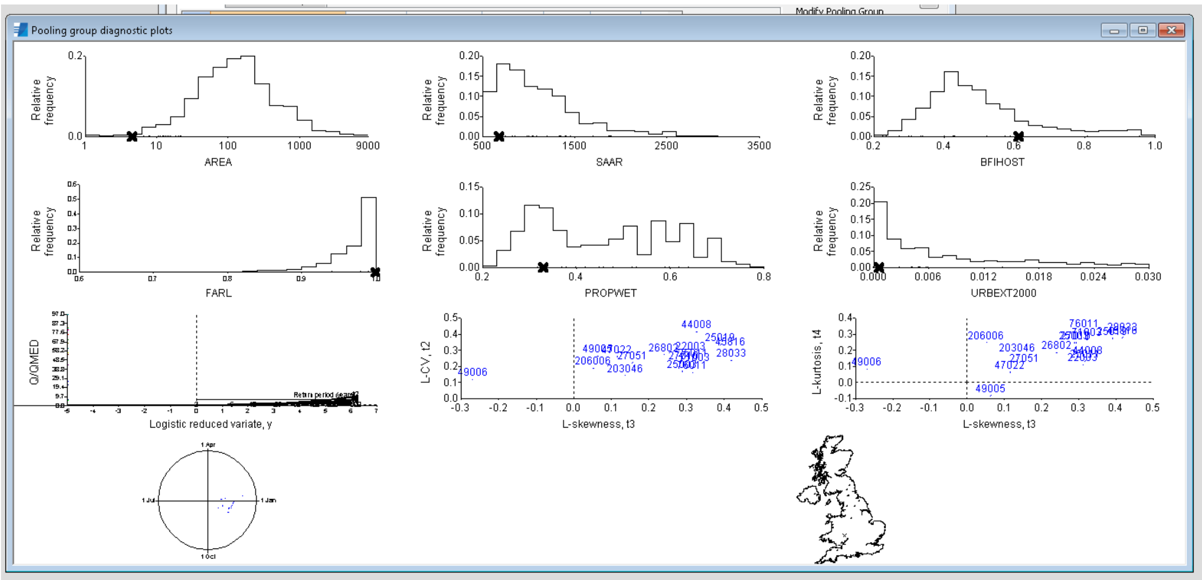
	GL	GEV
5	1.396	1.433
10	1.699	1.753
25	2.157	2.200
50	2.568	2.565
75	2.840	2.792
100	3.050	2.960
200	3.621	3.386
500	4.540	4.006
1000	5.386	4.521

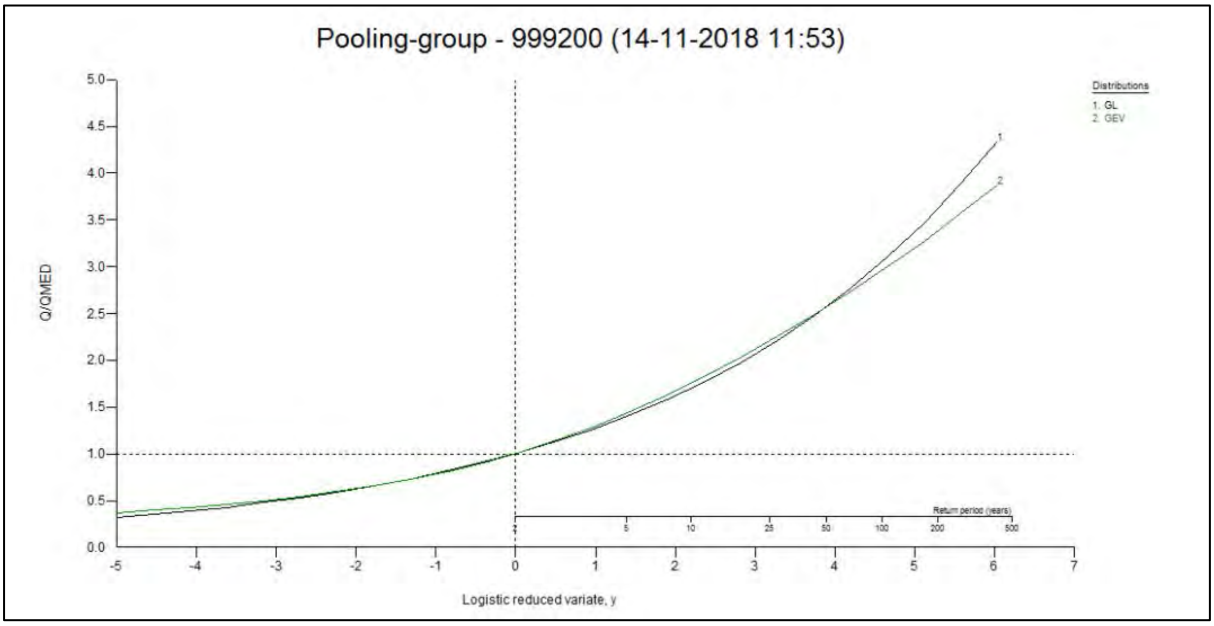


Fittings for FFC

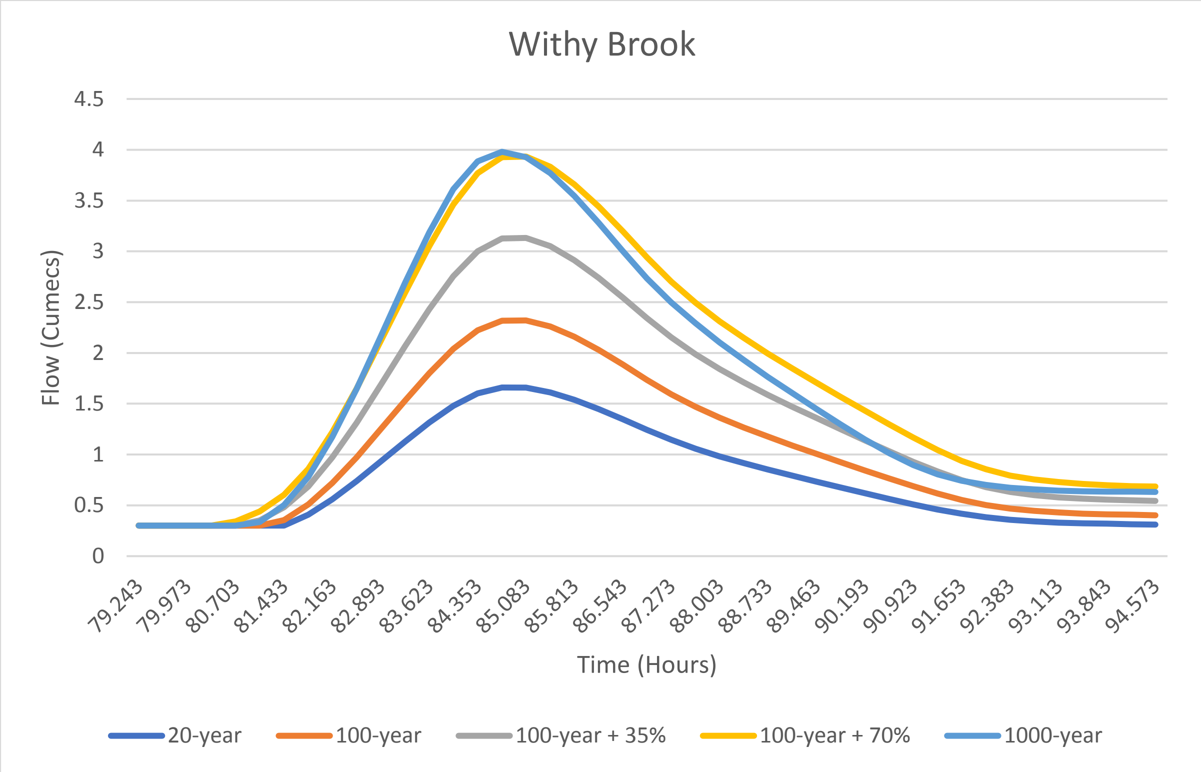
Return periods

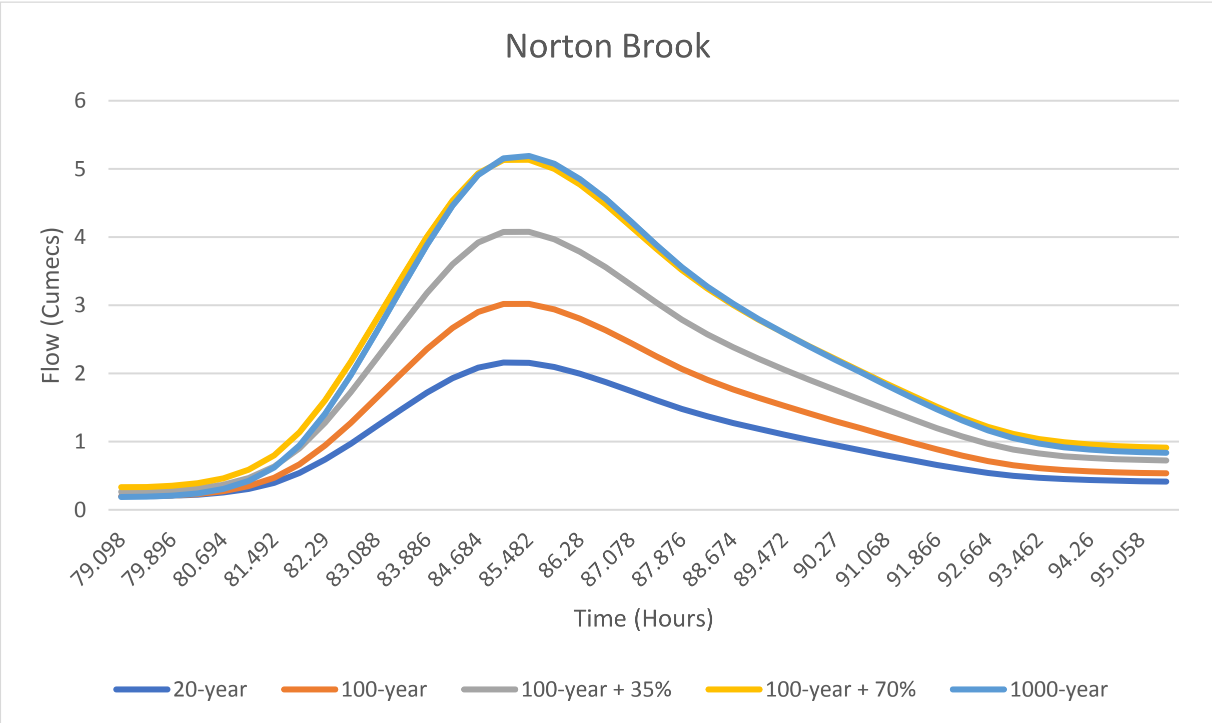
	GL	GEV
2	0.888	0.888
5	1.239	1.272
10	1.508	1.556
25	1.915	1.953
50	2.280	2.278
75	2.522	2.479
100	2.709	2.628
200	3.215	3.007
500	4.031	3.557
1000	4.783	4.014

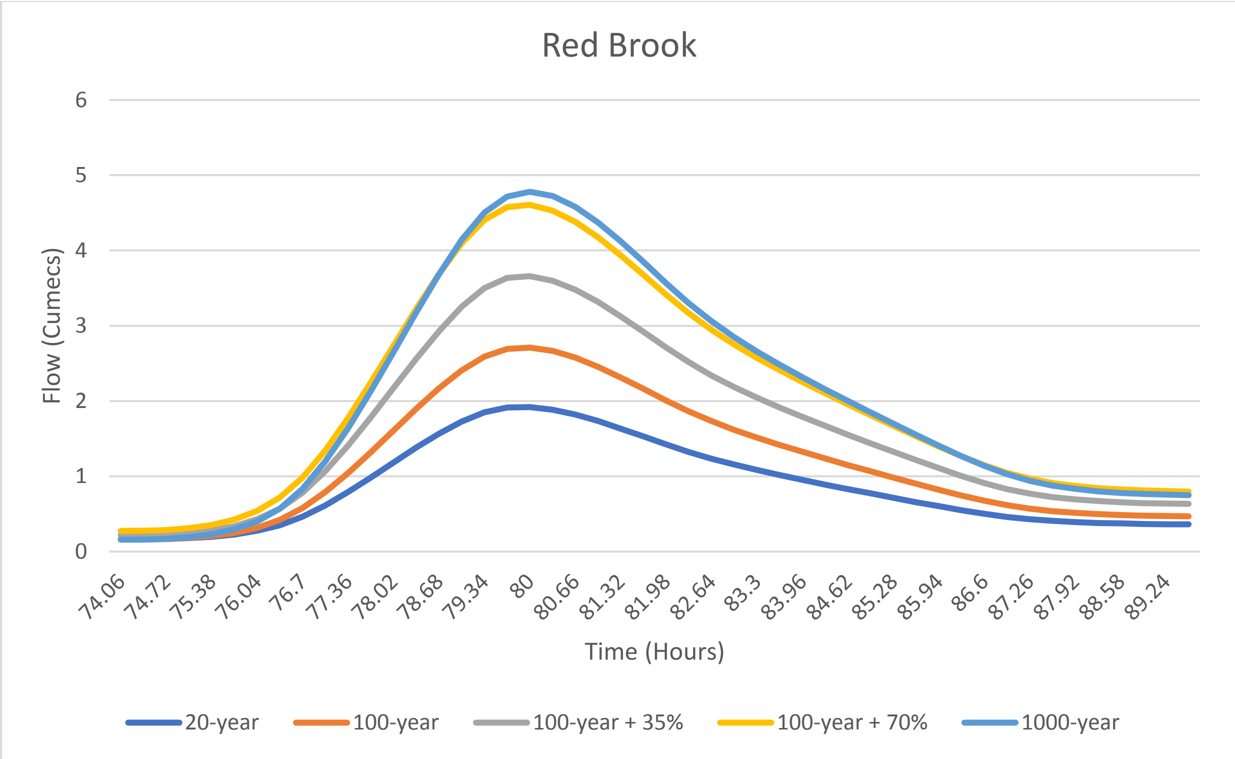


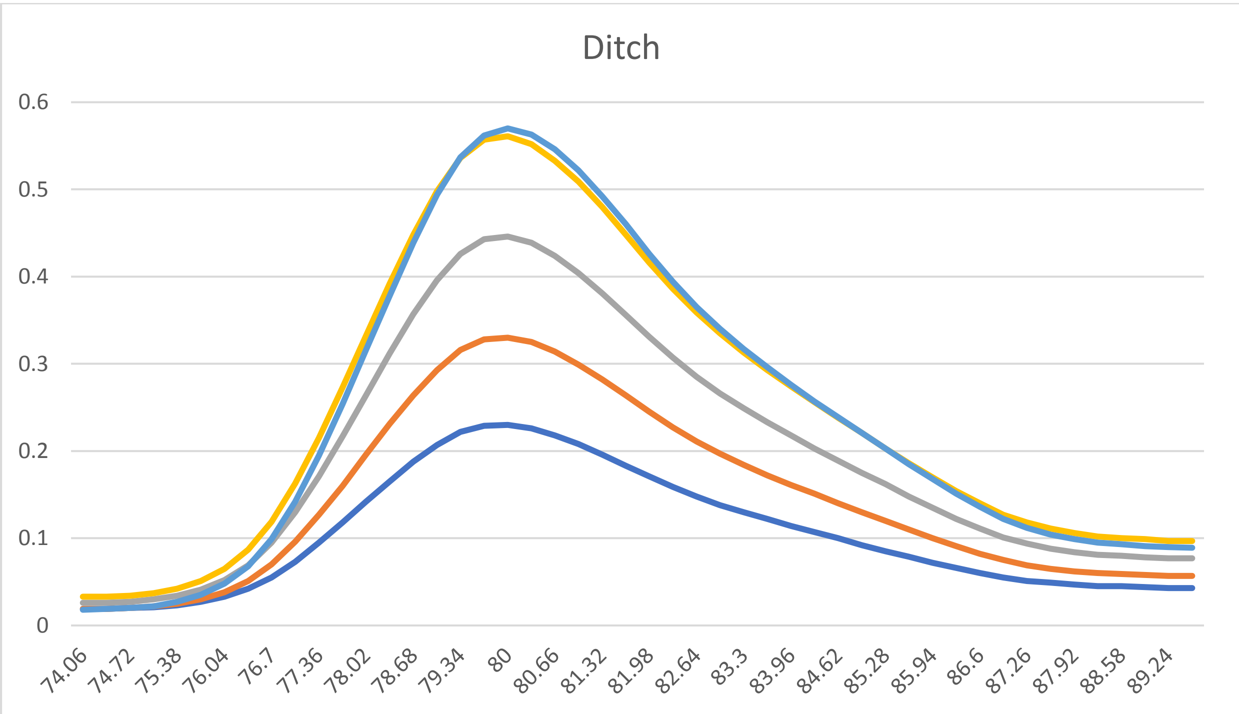

Pooling-group - 999200 (14-11-2018 11:53)
Q/QMED
Logistic reduced variate, y
Return period (years)
Distributions
1. GL
2. GEV

APPENDIX 2: Hydrograph Plots

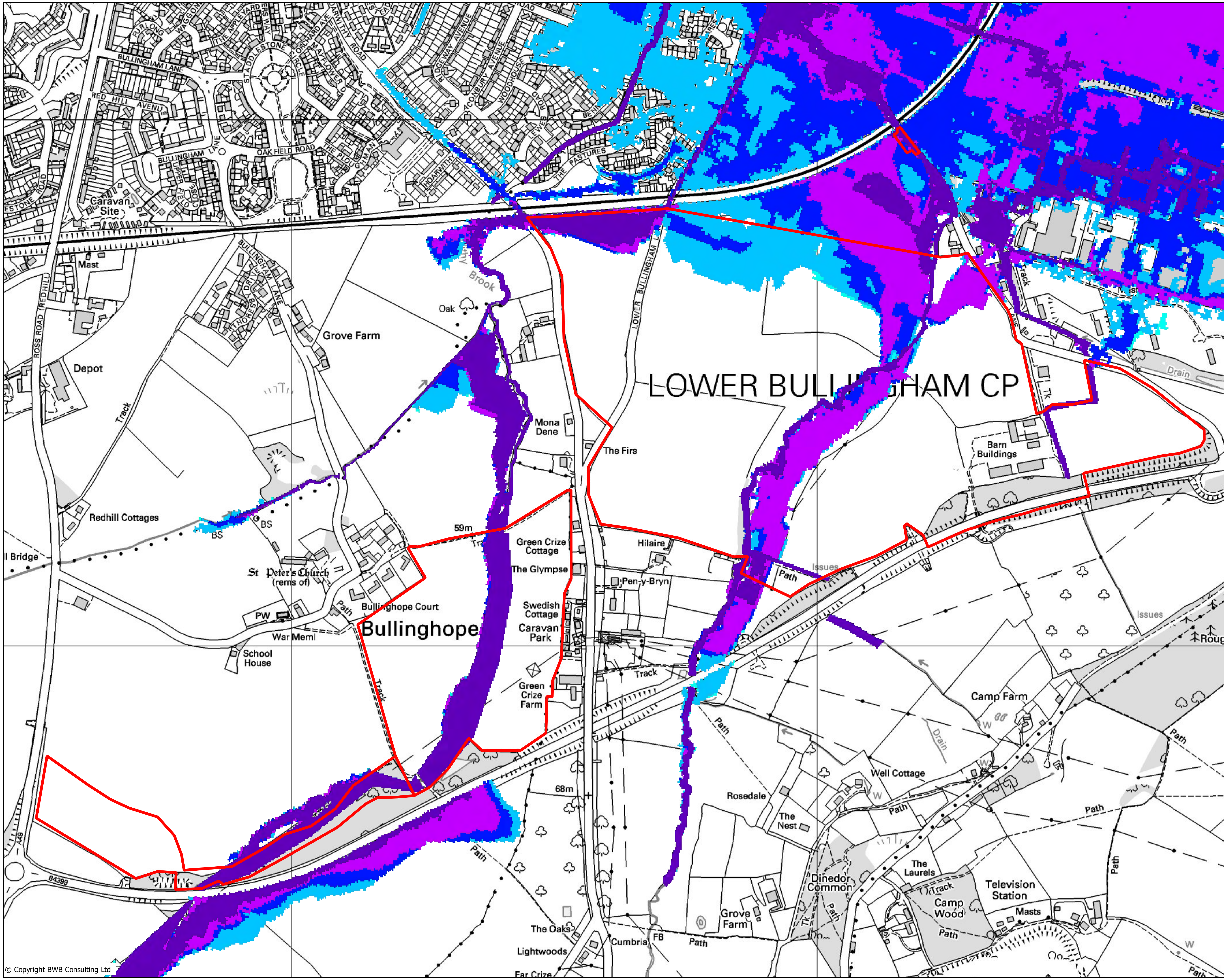

Withy Brook
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Flow (Cumecs)
79.243
79.973
80.703
81.433
82.163
82.893
83.623
84.353
85.083
85.813
86.543
87.273
88.003
88.733
89.463
90.193
90.923
91.653
92.383
93.113
93.843
94.573
Time (Hours)
20-year
100-year
100-year + 35%
100-year + 70%
1000-year


Norton Brook
6
5
4
3
2
1
0
Flow (Cumecs)
79.098
79.896
80.694
81.492
82.29
83.088
83.886
84.684
85.482
86.28
87.078
87.876
88.674
89.472
90.27
91.068
91.866
92.664
93.462
94.26
95.058
Time (Hours)
20-year
100-year
100-year + 35%
100-year + 70%
1000-year


Red Brook
Flow (Cumecs)
0
1
2
3
4
5
6
74.06
74.72
75.38
76.04
76.7
77.36
78.02
78.68
79.34
80
80.66
81.32
81.98
82.64
83.3
83.96
84.62
85.28
85.94
86.6
87.26
87.92
88.58
89.24
Time (Hours)
20-year
100-year
100-year + 35%
100-year + 70%
1000-year


Ditch
0
0.1
0.2
0.3
0.4
0.5
0.6
74.06
74.72
75.38
76.04
76.7
77.36
78.02
78.68
79.34
80
80.66
81.32
81.98
82.64
83.3
83.96
84.62
85.28
85.94
86.6
87.26
87.92
88.58
89.24

APPENDIX 3: Baseline Floodplain Maps – River Wye, Red Brook, Withy Brook & Norton Brook



Notes

1. Do not scale this drawing. All dimensions must be checked/ verified on site. If in doubt ask.

2. This drawing is to be read in conjunction with all relevant architects, engineers and specialists drawings and specifications.

3. All dimensions in millimetres unless noted otherwise. All levels in metres unless noted otherwise.

4. Any discrepancies noted on site are to be reported to the engineer immediately.

Key

Illustrative Site Boundary

Floodplain Extent
- 1 in 20-Year
- 1 in 100-Year
- 1 in 100-Year+35%
- 1 in 100-Year+70%
- 1 in 1000-Year

Rev	Date	Details of issues/ revision	Drw	Rev
P5	08.10.19	GENERAL UPDATE	RG	RG
P4	28.11.18	GENERAL UPDATE	LT	RG
P3	29.10.18	GENERAL UPDATE	LT	RG
P2	14.05.18	GENERAL UPDATE	RG	RG
P1	06.02.18	PRELIMINARY ISSUE	LT	RG

Issues & Revisions

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- ☐ Leeds | 0113 233 8000
- ☐ London | 0207 407 2879
- ☐ Manchester | 0161 233 4260
- ☐ Nottingham | 0115 924 1100

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Client

BLOOR HOMES

Project Title

LOWER BULLINGHAM HEREFORD

Drawing Title

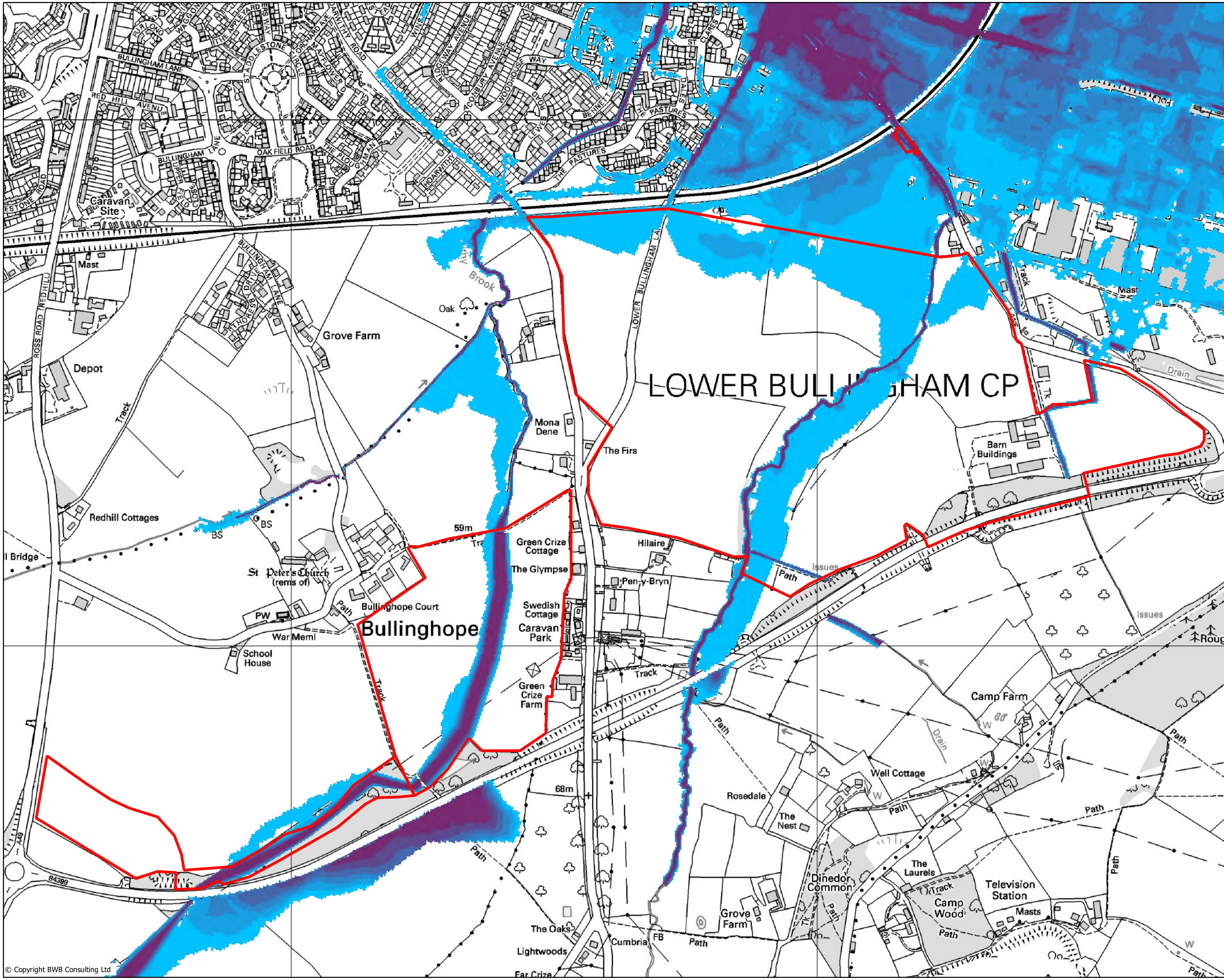
RIVER WYE, RED BROOK, WITHY BROOK & NORTON BROOK FLUVIAL FLOODPLAIN EXTENTS

Drawn:	L Towle	Reviewed:	R Green
BWB Ref:	BMW 2135	Date: 28.11.18	Scale@A3: NTS

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
BULL-BWB-ZZ-XX-DR-YE-0101	S2	P5



Notes

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3. All dimensions in millimetres unless noted otherwise. All levels in metres unless noted otherwise.

4. Any discrepancies noted on site are to be reported to the engineer immediately.

Key

Illustrative Site Boundary

Peak Flood Depths

- <= 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.25
- > 1.25

Rev	Date	Details of issues/ revision	Drw	Rev
P5	08.10.19	GENERAL UPDATE	RG	RG
P4	28.11.18	GENERAL UPDATE	LT	RG
P3	29.10.18	GENERAL UPDATE	LT	RG
P2	14.05.18	GENERAL UPDATE	RG	RG
P1	06.02.18	PRELIMINARY ISSUE	LT	RG

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Client

BLOOR HOMES

Project Title

LOWER BULLINGHAM HEREFORD

Drawing Title

RIVER WYE, RED BROOK, WITHY BROOK & NORTON BROOK FLUVIAL FLOOD DEPTHS: 1 in 1000-YEAR

Drawn:	L Towle	Reviewed:	R Green
BWB Ref: BMW 2135	Date: 28.11.18	Scale@A3:	NTS

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
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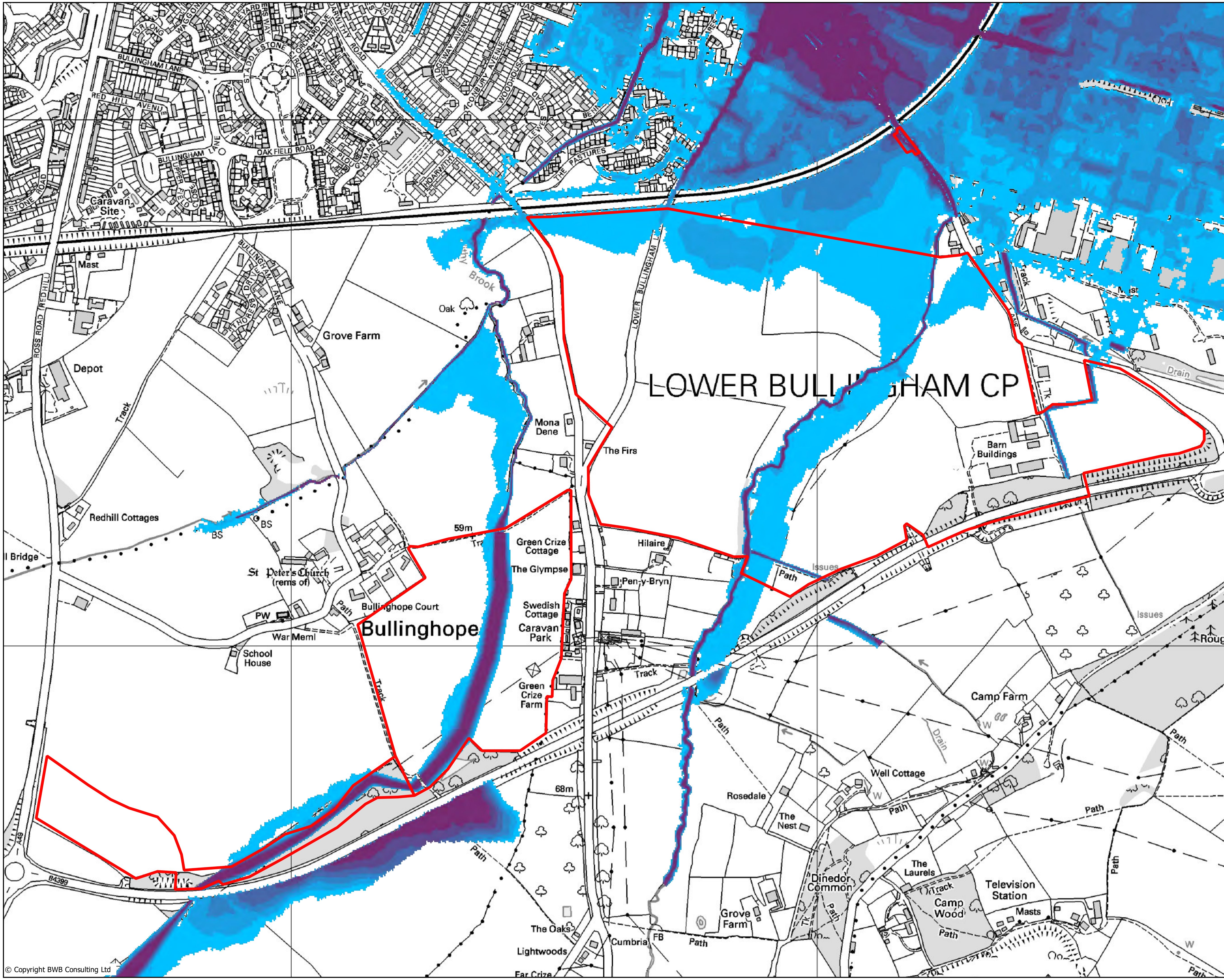

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4. Any discrepancies noted on site are to be reported to the engineer immediately.

Key

Illustrative Site Boundary

Peak Flood Depths

- <= 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.25
- > 1.25

Rev	Date	Details of issues/ revision	Drw	Rev
P5	08.10.19	GENERAL UPDATE	RG	RG
P4	28.11.18	GENERAL UPDATE	LT	RG
P3	29.10.18	GENERAL UPDATE	LT	RG
P2	14.05.18	GENERAL UPDATE	RG	RG
P1	06.02.18	PRELIMINARY ISSUE	LT	RG

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Client

BLOOR HOMES

Project Title

LOWER BULLINGHAM HEREFORD

Drawing Title

RIVER WYE, RED BROOK, WITHY BROOK & NORTON BROOK FLUVIAL FLOOD DEPTHS: 1 in 100-YR+70%

Drawn:	L Towle		Reviewed:	R Green	
BWB Ref:	BMW 2135	Date:	28.11.18	Scale@A3:	NTS

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
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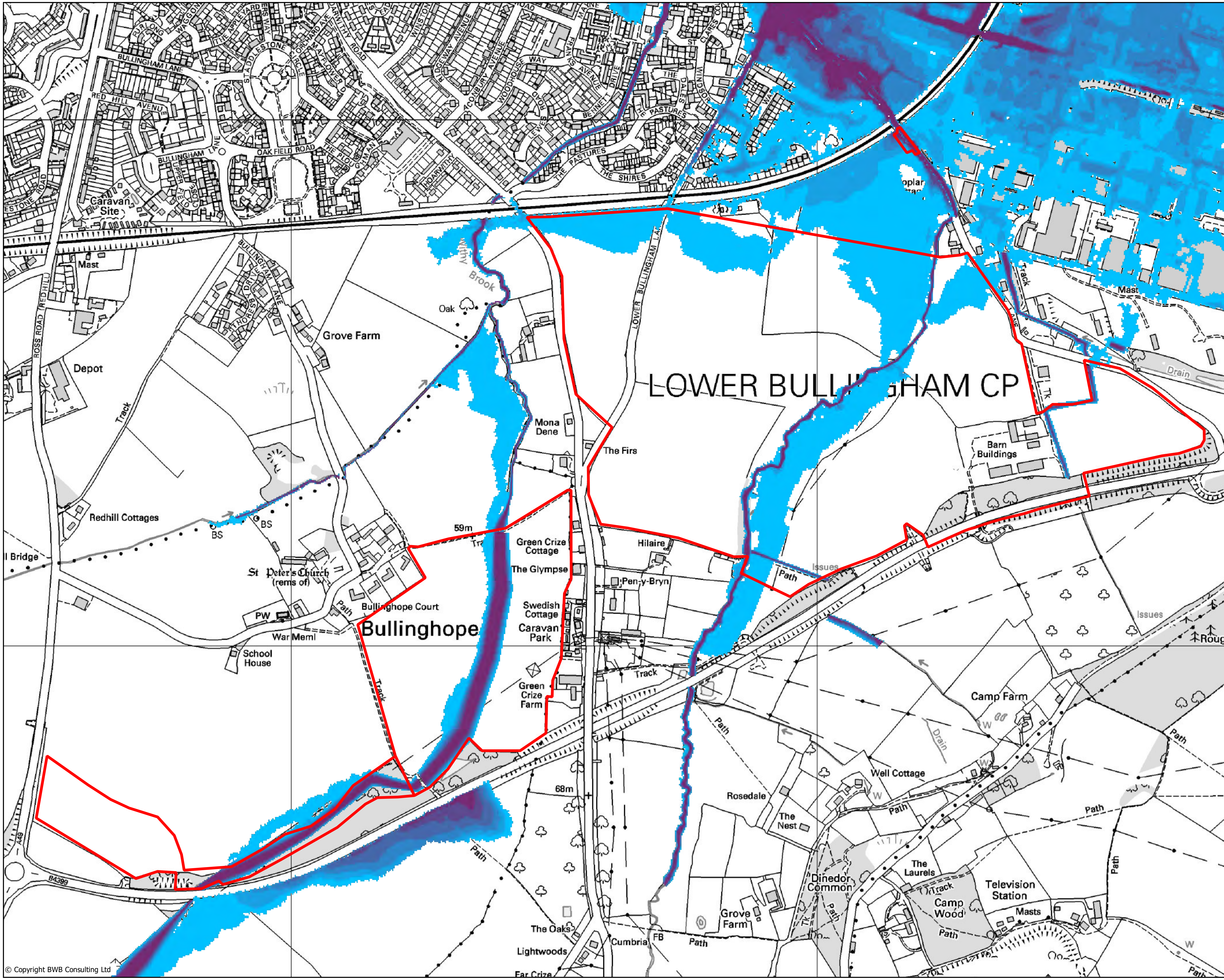

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3. All dimensions in millimetres unless noted otherwise. All levels in metres unless noted otherwise.
4. Any discrepancies noted on site are to be reported to the engineer immediately.

Key

Illustrative Site Boundary

Peak Flood Depths

- <= 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.25
- > 1.25

Rev	Date	Details of issues/ revision	Drw	Rev
P5	08.10.19	GENERAL UPDATE	RG	RG
P4	28.11.18	GENERAL UPDATE	LT	RG
P3	29.10.18	GENERAL UPDATE	LT	RG
P2	14.05.18	GENERAL UPDATE	RG	RG
P1	06.02.18	PRELIMINARY ISSUE	LT	RG

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BLOOR HOMES

Project Title

LOWER BULLINGHAM HEREFORD

Drawing Title

RIVER WYE, RED BROOK, WITHY BROOK & NORTON BROOK FLUVIAL FLOOD DEPTHS: 1 in 100-YR+35%

Drawn:	L Towle	Reviewed:	R Green		
BWB Ref:	BMW 2135	Date:	28.11.18	Scale@A3:	NTS

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
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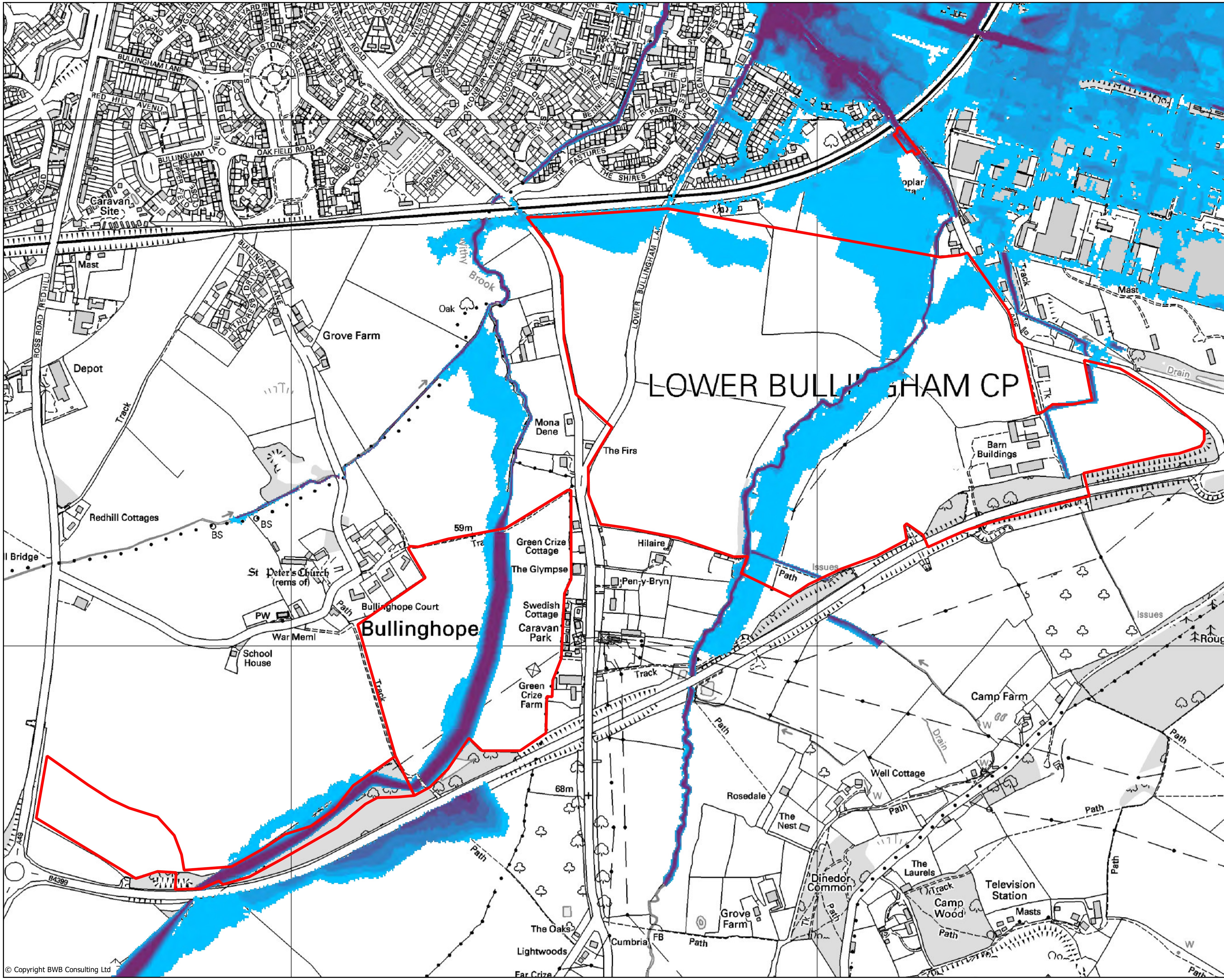

Notes

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3. All dimensions in millimetres unless noted otherwise. All levels in metres unless noted otherwise.

4. Any discrepancies noted on site are to be reported to the engineer immediately.

Key

Illustrative Site Boundary

Peak Flood Depths

- <= 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.25
- > 1.25

Rev	Date	Details of issues/ revision	Drw	Rev
P5	08.10.19	GENERAL UPDATE	RG	RG
P4	28.11.18	GENERAL UPDATE	LT	RG
P3	29.10.18	GENERAL UPDATE	LT	RG
P2	14.05.18	GENERAL UPDATE	RG	RG
P1	06.02.18	PRELIMINARY ISSUE	LT	RG

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BLOOR HOMES

Project Title

LOWER BULLINGHAM HEREFORD

Drawing Title

RIVER WYE, RED BROOK, WITHY BROOK & NORTON BROOK FLUVIAL FLOOD DEPTHS: 1 in 100-YR+25%

Drawn:	L Towle		Reviewed:	R Green	
BWB Ref:	BMW 2135	Date:	28.11.18	Scale@A3:	NTS

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
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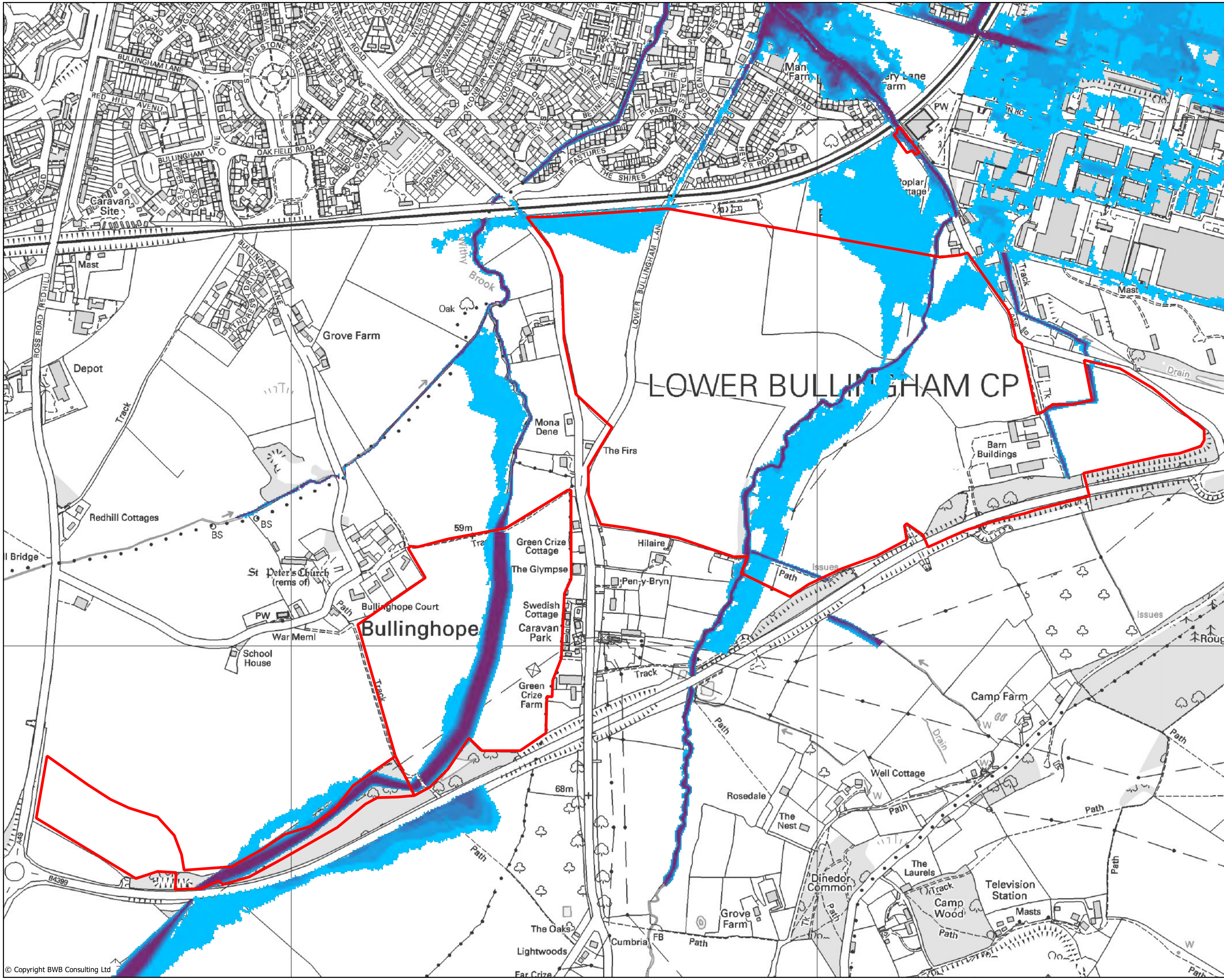

Notes

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3. All dimensions in millimetres unless noted otherwise. All levels in metres unless noted otherwise.

4. Any discrepancies noted on site are to be reported to the engineer immediately.

Key

Illustrative Site Boundary

Peak Flood Depths
- <= 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.25
- > 1.25

Rev	Date	Details of issues/ revision	Drw	Rev
P5	08.10.19	GENERAL UPDATE	RG	RG
P4	28.11.18	GENERAL UPDATE	LT	RG
P3	29.10.18	GENERAL UPDATE	LT	RG
P2	14.05.18	GENERAL UPDATE	RG	RG
P1	06.02.18	PRELIMINARY ISSUE	LT	RG

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BLOOR HOMES

Project Title

LOWER BULLINGHAM HEREFORD

Drawing Title

RIVER WYE, RED BROOK, WITHY BROOK & NORTON BROOK FLUVIAL FLOOD DEPTHS: 1 in 100-YEAR

Drawn:	L Towle	Reviewed:	R Green
BWB Ref:	BMW 2135	Date: 28.11.18	Scale@A3: NTS

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
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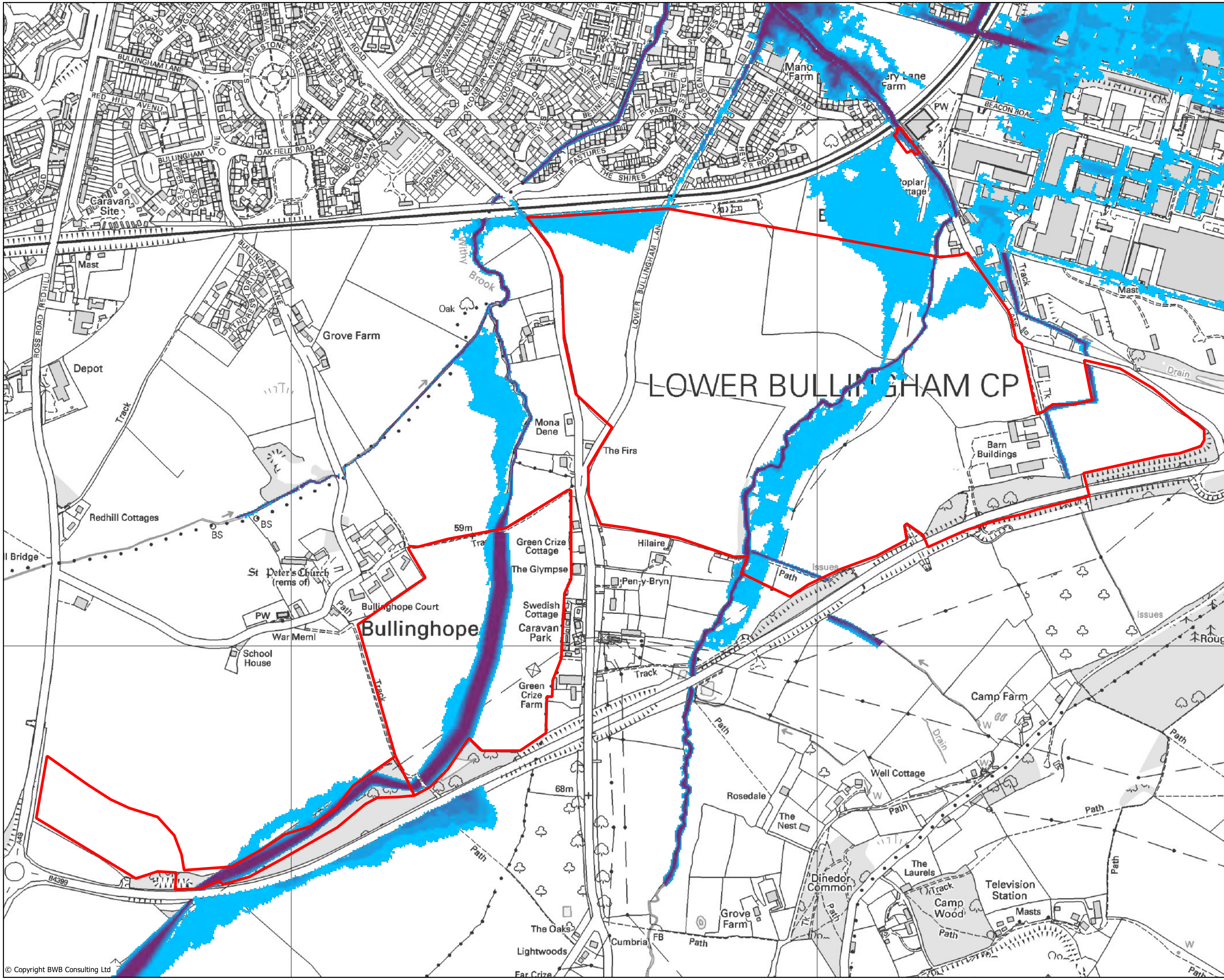

Notes

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3. All dimensions in millimetres unless noted otherwise. All levels in metres unless noted otherwise.

4. Any discrepancies noted on site are to be reported to the engineer immediately.

Key

Illustrative Site Boundary

Peak Flood Depths

- <= 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.25
- > 1.25

Rev	Date	Details of issues/ revision	Drw	Rev
P5	08.10.19	GENERAL UPDATE	RG	RG
P4	28.11.18	GENERAL UPDATE	LT	RG
P3	29.10.18	GENERAL UPDATE	LT	RG
P2	14.05.18	GENERAL UPDATE	RG	RG
P1	06.02.18	PRELIMINARY ISSUE	LT	RG

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BLOOR HOMES

Project Title

LOWER BULLINGHAM HEREFORD

Drawing Title

RIVER WYE, RED BROOK, WITHY BROOK & NORTON BROOK FLUVIAL FLOOD DEPTHS: 1 in 75-YEAR

Drawn:	L Towle	Reviewed:	R Green
BWB Ref:	BMW 2135	Date:	28.11.18
Scale@A3:	NTS		

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
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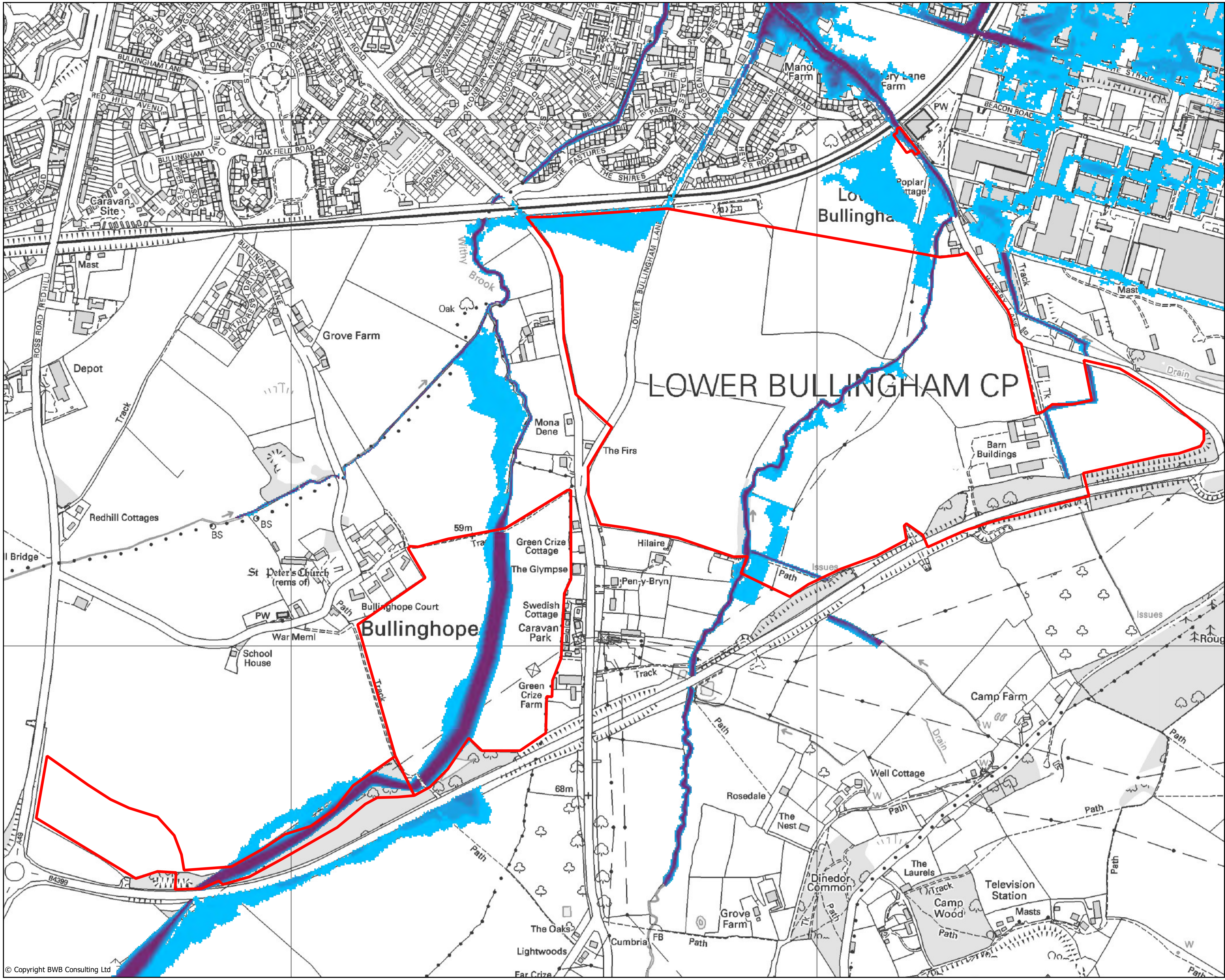

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3. All dimensions in millimetres unless noted otherwise. All levels in metres unless noted otherwise.
4. Any discrepancies noted on site are to be reported to the engineer immediately.

Key

Illustrative Site Boundary

Peak Flood Depths
- <= 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.25
- > 1.25

Rev	Date	Details of issues/ revision	Drw	Rev
P5	08.10.19	GENERAL UPDATE	RG	RG
P4	28.11.18	GENERAL UPDATE	LT	RG
P3	29.10.18	GENERAL UPDATE	LT	RG
P2	14.05.18	GENERAL UPDATE	RG	RG
P1	06.02.18	PRELIMINARY ISSUE	LT	RG

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Client

BLOOR HOMES

Project Title

LOWER BULLINGHAM HEREFORD

Drawing Title

RIVER WYE, RED BROOK, WITHY BROOK & NORTON BROOK FLUVIAL FLOOD DEPTHS: 1 in 50-YEAR

Drawn:	L Towle	Reviewed:	R Green
BWB Ref: BMW 2135	Date: 28.11.18	Scale@A3:	NTS

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
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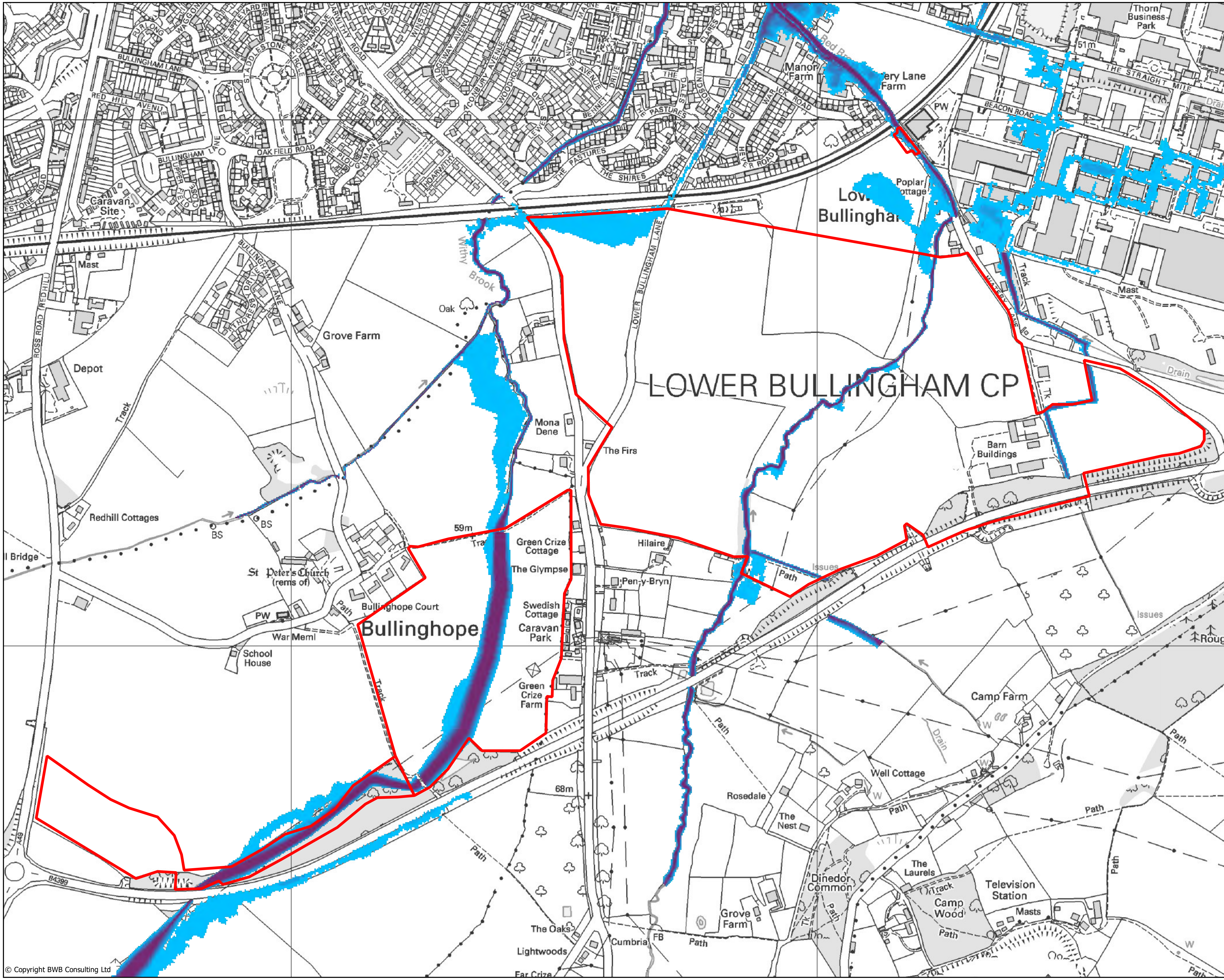

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Key

Illustrative Site Boundary

Peak Flood Depths

- <= 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.25
- > 1.25

Rev	Date	Details of issues/ revision	Drw	Rev
P5	08.10.19	GENERAL UPDATE	RG	RG
P4	28.11.18	GENERAL UPDATE	LT	RG
P3	29.10.18	GENERAL UPDATE	LT	RG
P2	14.05.18	GENERAL UPDATE	RG	RG
P1	06.02.18	PRELIMINARY ISSUE	LT	RG

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BLOOR HOMES

Project Title

LOWER BULLINGHAM HEREFORD

Drawing Title

RIVER WYE, RED BROOK, WITHY BROOK & NORTON BROOK FLUVIAL FLOOD DEPTHS: 1 in 20-YEAR

Drawn:	L Towle	Reviewed:	R Green
BWB Ref:	BMW 2135	Date: 28.11.18	Scale@A3: NTS

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
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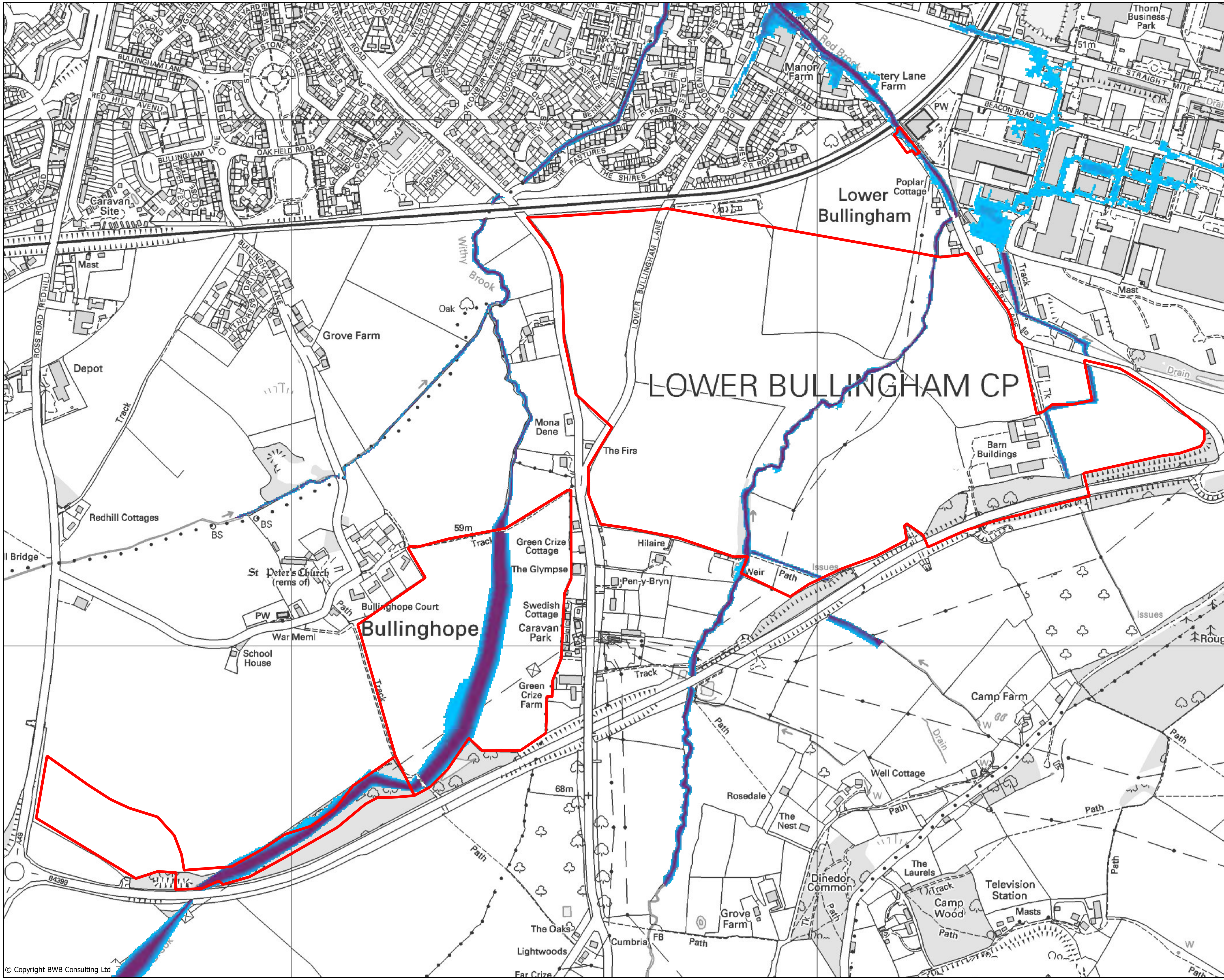

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Key

Illustrative Site Boundary

Peak Flood Depths
- <= 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.25
- > 1.25

Rev	Date	Details of issues/ revision	Drw	Rev
P5	08.10.19	GENERAL UPDATE	RG	RG
P4	28.11.18	GENERAL UPDATE	LT	RG
P3	29.10.18	GENERAL UPDATE	LT	RG
P2	14.05.18	GENERAL UPDATE	RG	RG
P1	06.02.18	PRELIMINARY ISSUE	LT	RG

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BLOOR HOMES

Project Title

LOWER BULLINGHAM HEREFORD

Drawing Title

RIVER WYE, RED BROOK, WITHY BROOK & NORTON BROOK FLUVIAL FLOOD DEPTHS: 1 in 5-YEAR

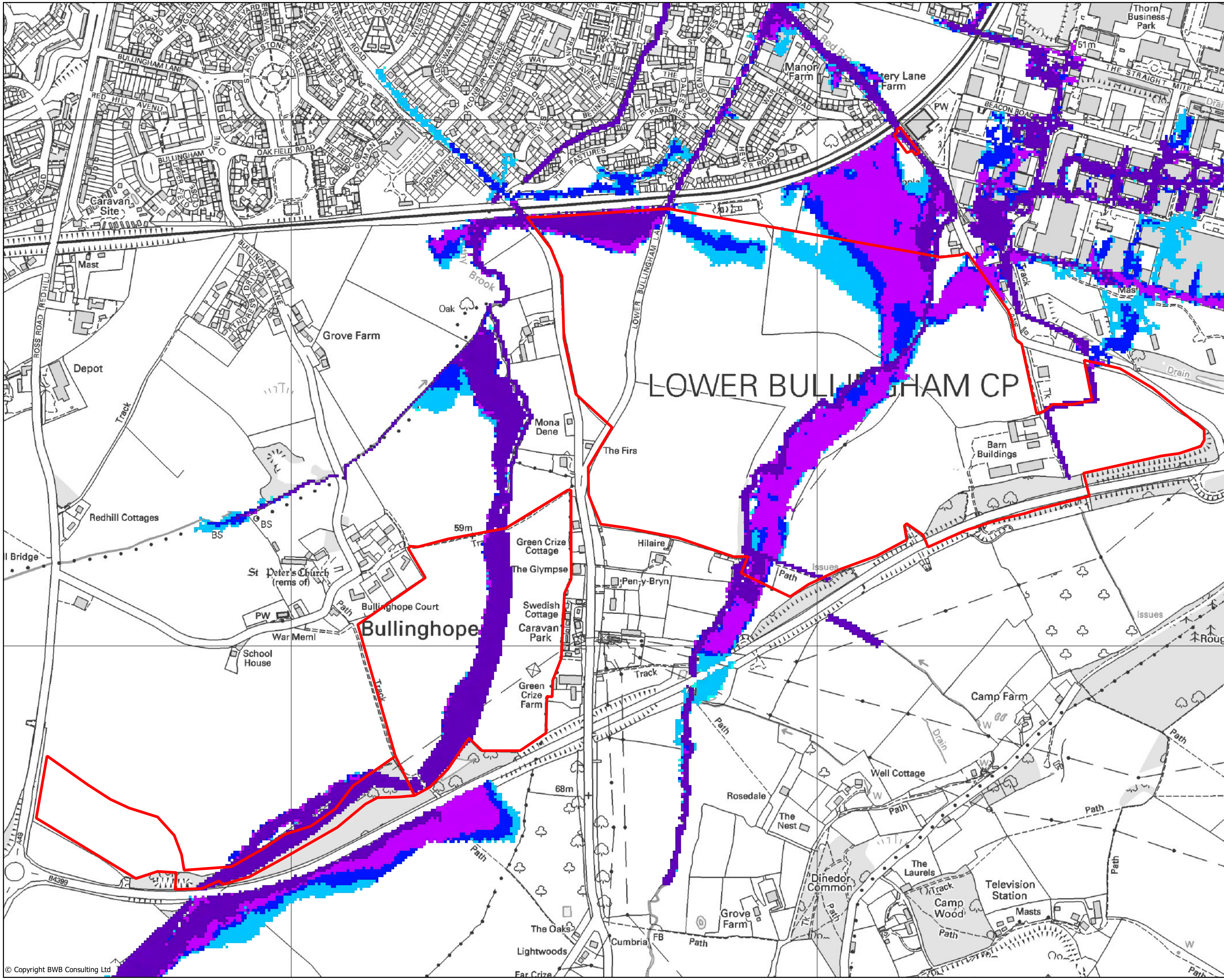
Drawn:	L Towle	Reviewed:	R Green
BWB Ref: BMW 2135	Date: 28.11.18	Scale@A3: NTS	

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
BULL-BWB-ZZ-XX-DR-YE-0110	S2	P5

APPENDIX 4: Baseline Floodplain Maps – Red Brook, Withy Brook & Norton Brook (No River Wye)



Notes

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4. Any discrepancies noted on site are to be reported to the engineer immediately.

Key

Illustrative Site Boundary

Floodplain Extent
- 1 in 20-Year
- 1 in 100-Year
- 1 in 100-Year+35%
- 1 in 100-Year+70%
- 1 in 1000-Year

Rev	Date	Details of issues/ revision	Drw	Rev
P5	08.10.19	GENERAL UPDATE	RG	RG
P4	28.11.18	GENERAL UPDATE	LT	RG
P3	29.10.18	GENERAL UPDATE	LT	RG
P2	14.05.18	GENERAL UPDATE	RG	RG
P1	06.02.18	PRELIMINARY ISSUE	LT	RG

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BLOOR HOMES

Project Title

LOWER BULLINGHAM HEREFORD

Drawing Title

RED BROOK, WITHY BROOK & NORTON BROOK FLOODPLAIN EXTENTS

Drawn:	L Towle	Reviewed:	R Green
BWB Ref:	BMW 2135	Date: 28.11.18	Scale@A3: NTS

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
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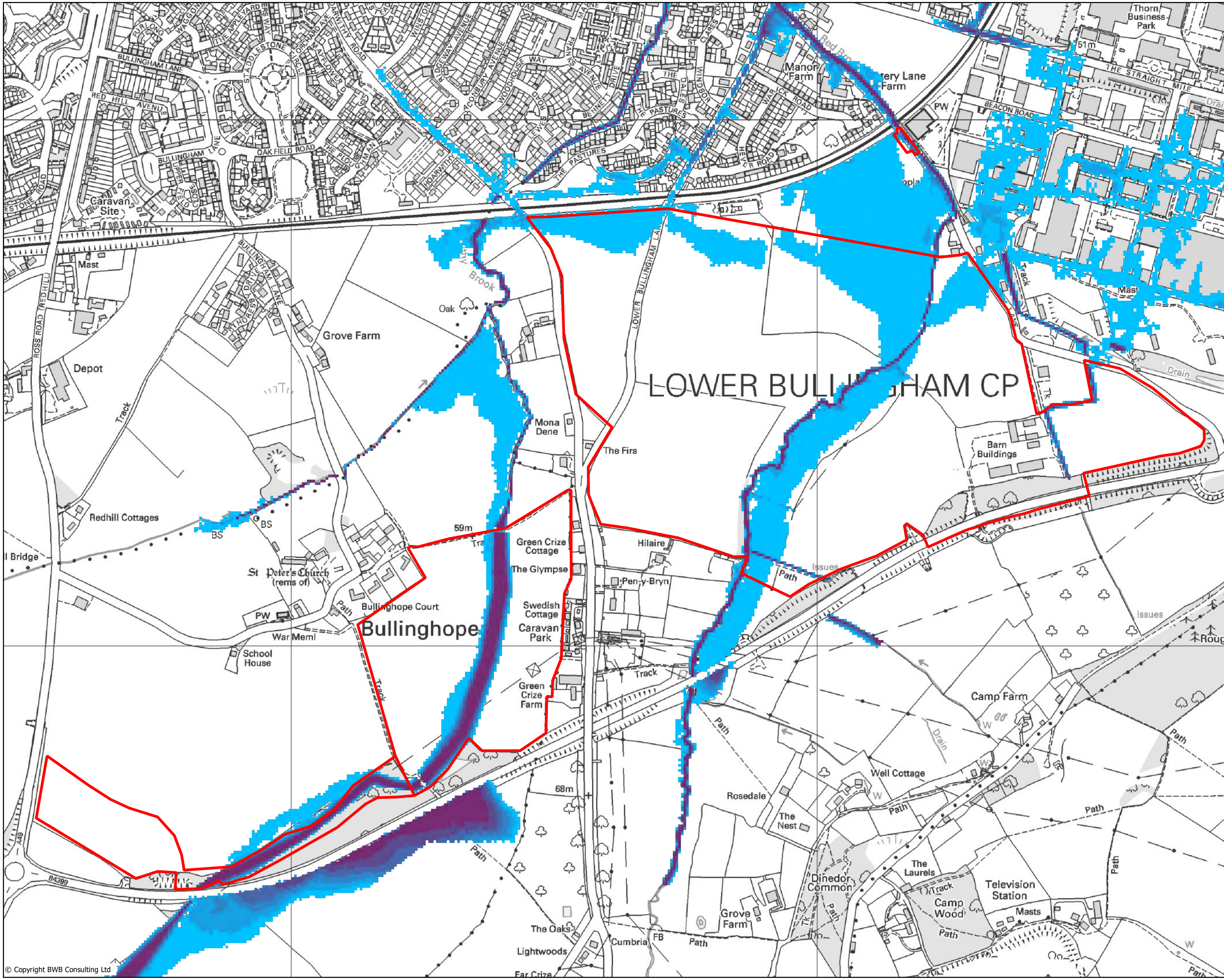

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4. Any discrepancies noted on site are to be reported to the engineer immediately.

Key

Illustrative Site Boundary

Peak Flood Depths

- <= 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.25
- > 1.25

Rev	Date	Details of issues/ revision	Drw	Rev
P5	08.10.19	GENERAL UPDATE	RG	RG
P4	28.11.18	GENERAL UPDATE	LT	RG
P3	29.10.18	GENERAL UPDATE	LT	RG
P2	14.05.18	GENERAL UPDATE	RG	RG
P1	06.02.18	PRELIMINARY ISSUE	LT	RG

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Client

BLOOR HOMES

Project Title

LOWER BULLINGHAM HEREFORD

Drawing Title

RED BROOK, WITHY BROOK & NORTON BROOK FLOOD DEPTHS: 1 in 1000-YEAR

Drawn:	L Towle	Reviewed:	R Green
BWB Ref:	BMW 2135	Date:	28.11.18
Scale@A3:	NTS		

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
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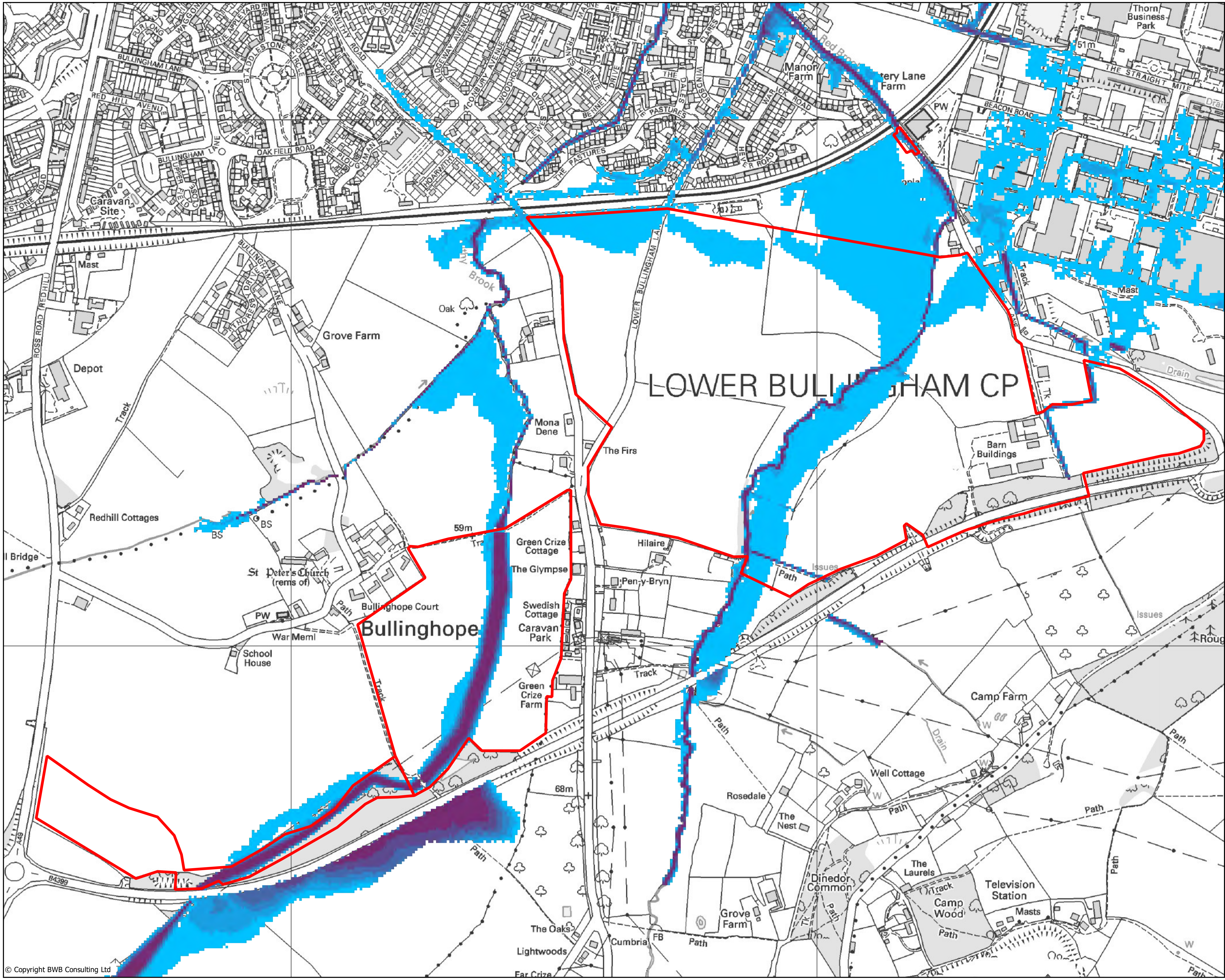

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4. Any discrepancies noted on site are to be reported to the engineer immediately.

Key

Illustrative Site Boundary

Peak Flood Depths

- <= 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.25
- > 1.25

Rev	Date	Details of issues/ revision	Drw	Rev
P5	08.10.19	GENERAL UPDATE	RG	RG
P4	28.11.18	GENERAL UPDATE	LT	RG
P3	29.10.18	GENERAL UPDATE	LT	RG
P2	14.05.18	GENERAL UPDATE	RG	RG
P1	06.02.18	PRELIMINARY ISSUE	LT	RG

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Client

BLOOR HOMES

Project Title

LOWER BULLINGHAM HEREFORD

Drawing Title

RED BROOK, WITHY BROOK & NORTON BROOK FLOOD DEPTHS: 1 in 100-YEAR+70%

Drawn:	L Towle	Reviewed:	R Green
BWB Ref:	BMW 2135	Date:	28.11.18
Scale@A3:	NTS		

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
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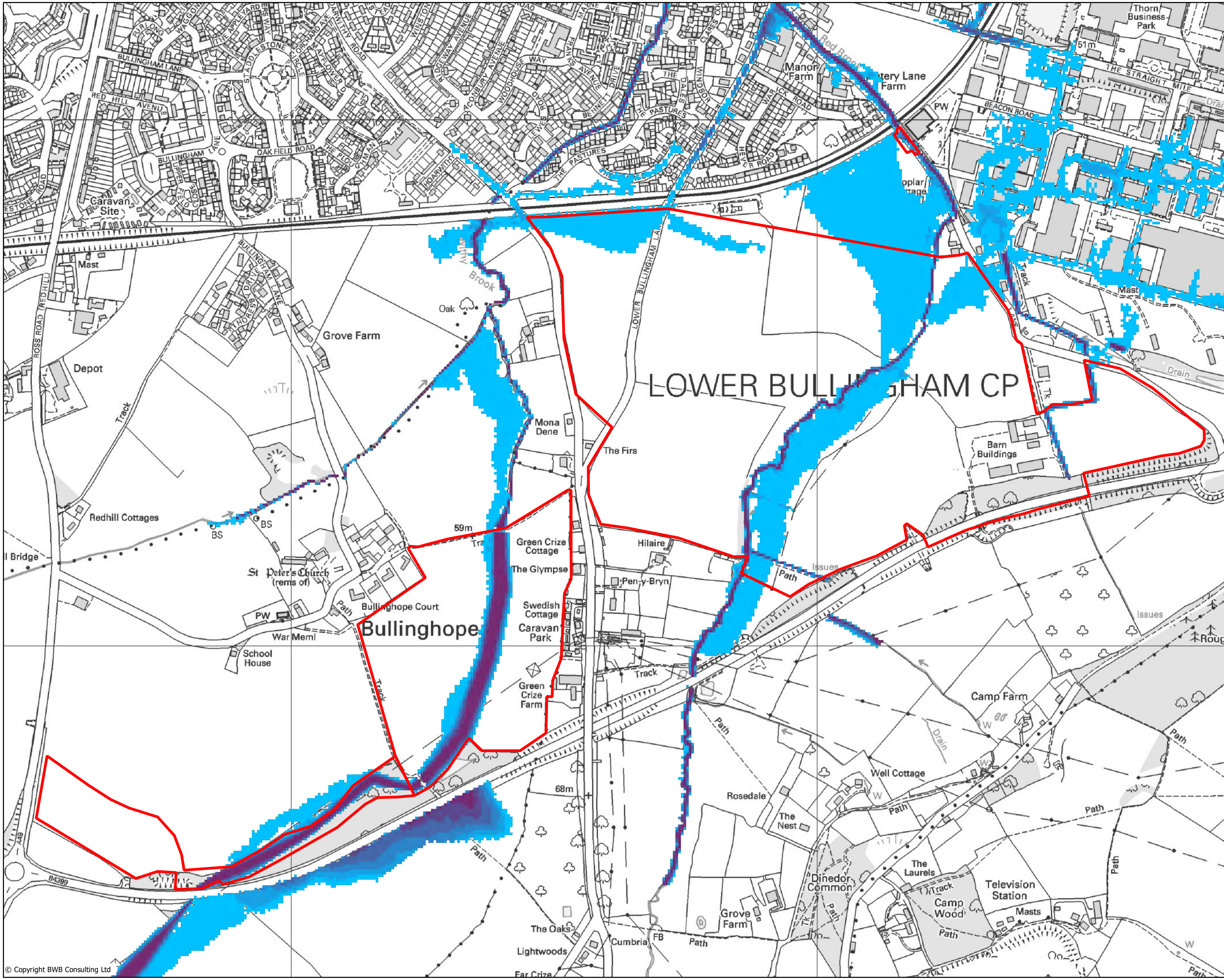

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4. Any discrepancies noted on site are to be reported to the engineer immediately.

Key

Illustrative Site Boundary

Peak Flood Depths

- <= 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.25
- > 1.25

Rev	Date	Details of issues/ revision	Drw	Rev
P5	08.10.19	GENERAL UPDATE	RG	RG
P4	28.11.18	GENERAL UPDATE	LT	RG
P3	29.10.18	GENERAL UPDATE	LT	RG
P2	14.05.18	GENERAL UPDATE	RG	RG
P1	06.02.18	PRELIMINARY ISSUE	LT	RG

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Client

BLOOR HOMES

Project Title

LOWER BULLINGHAM HEREFORD

Drawing Title

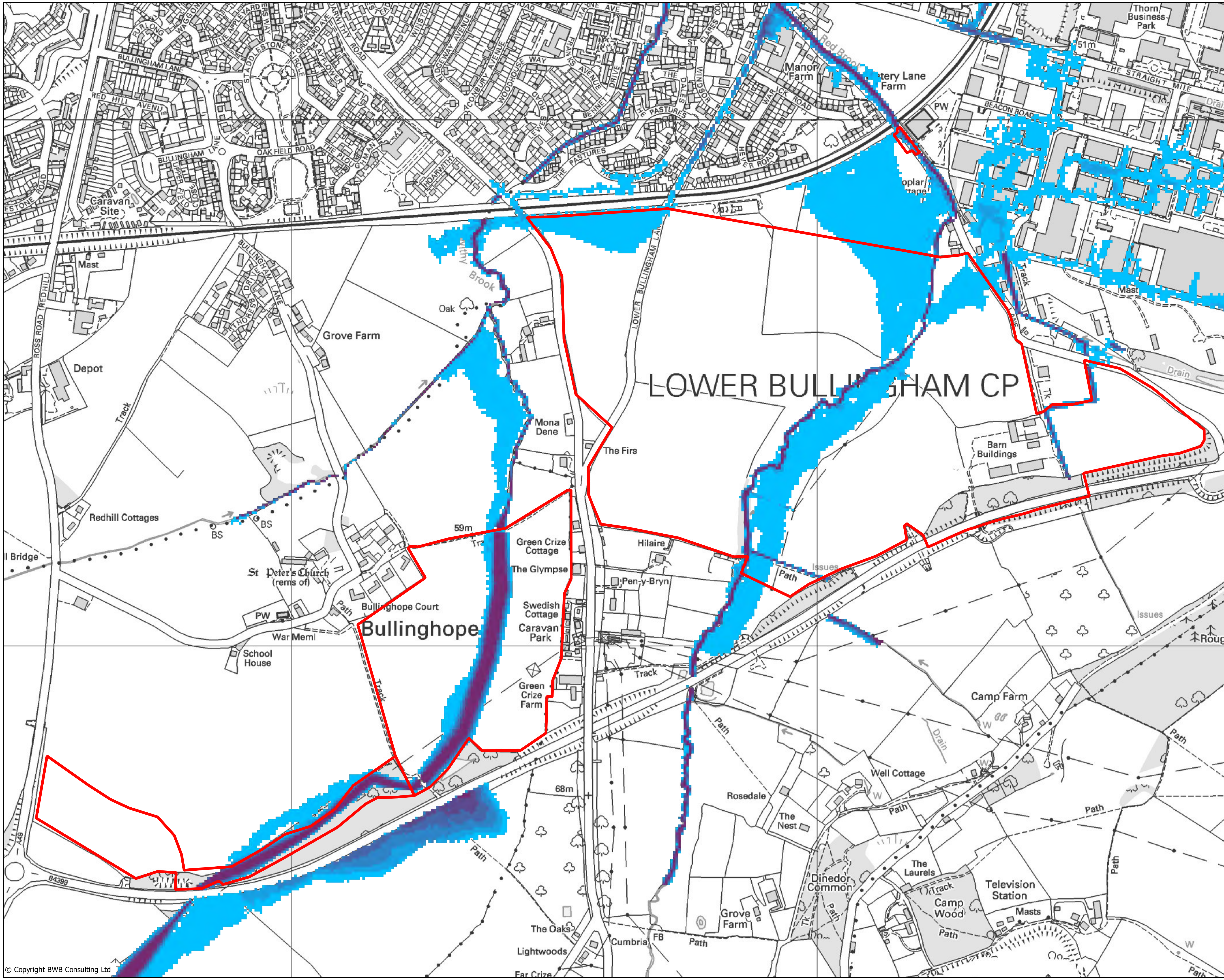
RED BROOK, WITHY BROOK & NORTON BROOK FLOOD DEPTHS: 1 in 100-YEAR+35%

Drawn:	L Towle	Reviewed:	R Green
BWB Ref:	BMW 2135	Date:	28.11.18	Scale@A3:	NTS

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
BULL-BWB-ZZ-XX-DR-YE-0204	S2	P5



Notes

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2. This drawing is to be read in conjunction with all relevant architects, engineers and specialists drawings and specifications.

3. All dimensions in millimetres unless noted otherwise. All levels in metres unless noted otherwise.

4. Any discrepancies noted on site are to be reported to the engineer immediately.

Key

Illustrative Site Boundary

Peak Flood Depths
- <= 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.25
- > 1.25

Rev	Date	Details of issues/ revision	Drw	Rev
P5	08.10.19	GENERAL UPDATE	RG	RG
P4	28.11.18	GENERAL UPDATE	LT	RG
P3	29.10.18	GENERAL UPDATE	LT	RG
P2	14.05.18	GENERAL UPDATE	RG	RG
P1	06.02.18	PRELIMINARY ISSUE	LT	RG

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Client

BLOOR HOMES

Project Title

LOWER BULLINGHAM HEREFORD

Drawing Title

RED BROOK, WITHY BROOK & NORTON BROOK FLOOD DEPTHS: 1 in 100-YEAR+25%

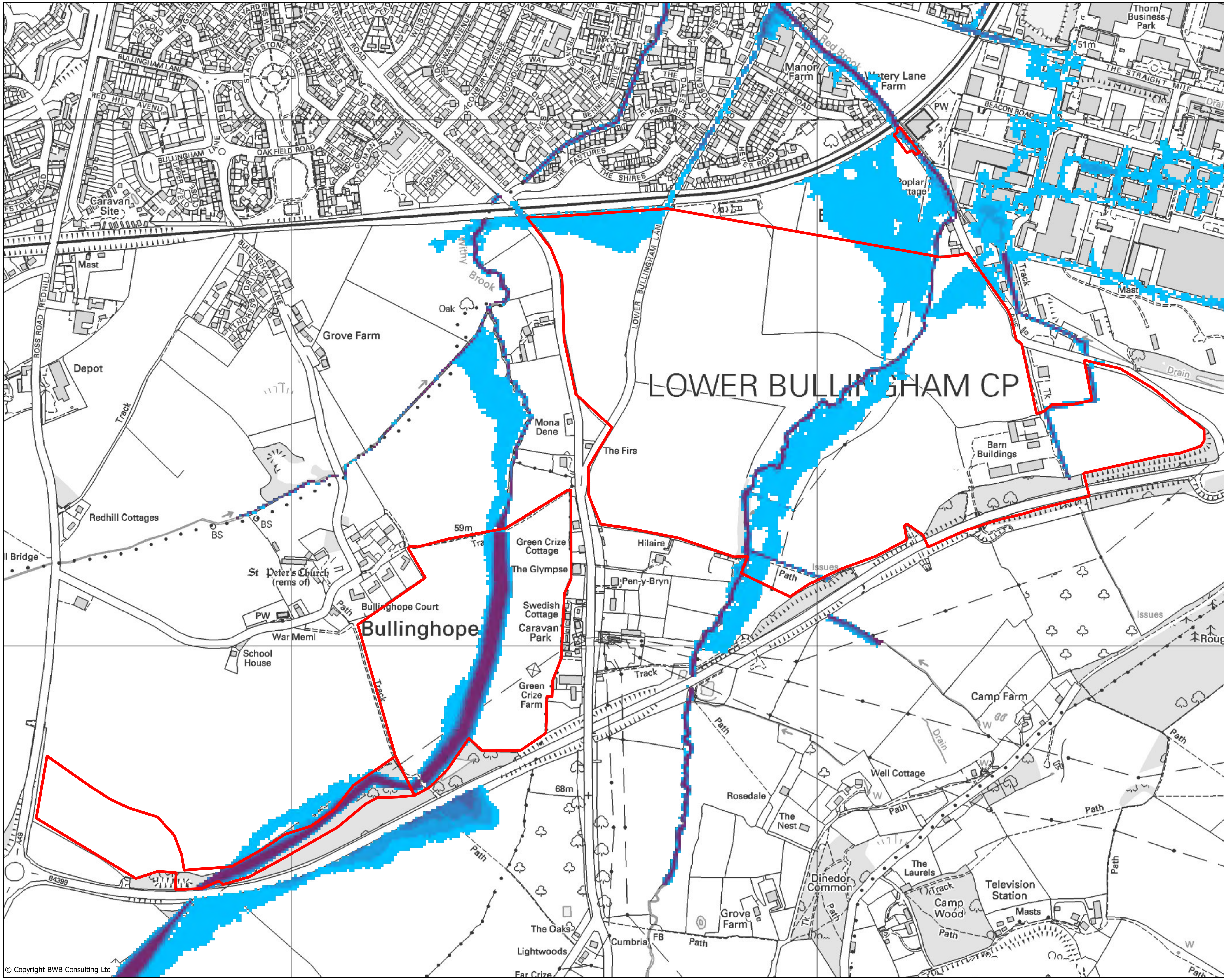
Drawn:	L Towle	Reviewed:	R Green

BWB Ref:	BMW 2135	Date:	28.11.18	Scale@A3:	NTS

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
BULL-BWB-ZZ-XX-DR-YE-0205	S2	P5



Notes

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3. All dimensions in millimetres unless noted otherwise. All levels in metres unless noted otherwise.

4. Any discrepancies noted on site are to be reported to the engineer immediately.

Key

Illustrative Site Boundary

Peak Flood Depths

- <= 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.25
- > 1.25

Rev	Date	Details of issues/ revision	Drw	Rev
P5	08.10.19	GENERAL UPDATE	RG	RG
P4	28.11.18	GENERAL UPDATE	LT	RG
P3	29.10.18	GENERAL UPDATE	LT	RG
P2	14.05.18	GENERAL UPDATE	RG	RG
P1	06.02.18	PRELIMINARY ISSUE	LT	RG

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BLOOR HOMES

Project Title

LOWER BULLINGHAM HEREFORD

Drawing Title

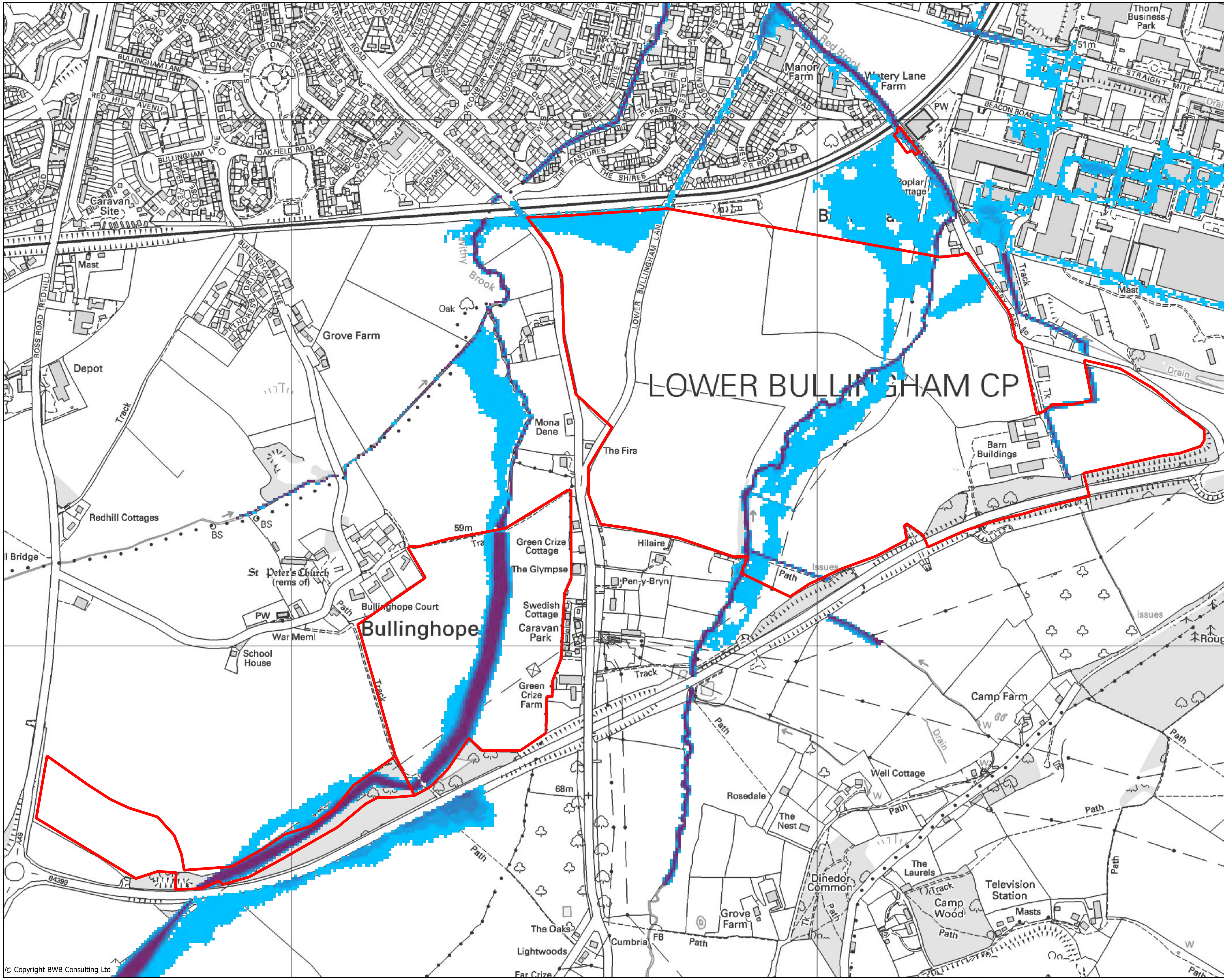
RED BROOK, WITHY BROOK & NORTON BROOK FLOOD DEPTHS: 1 in 100-YEAR

Drawn:	L Towle	Reviewed:	R Green
BWB Ref:	BMW 2135	Date:	28.11.18	Scale@A3:	NTS

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
BULL-BWB-ZZ-XX-DR-YE-0206	S2	P5



Notes

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2. This drawing is to be read in conjunction with all relevant architects, engineers and specialists drawings and specifications.

3. All dimensions in millimetres unless noted otherwise. All levels in metres unless noted otherwise.

4. Any discrepancies noted on site are to be reported to the engineer immediately.

Key

Illustrative Site Boundary

Peak Flood Depths
- <= 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.25
- > 1.25

Rev	Date	Details of issues/ revision	Drw	Rev
P5	08.10.19	GENERAL UPDATE	RG	RG
P4	28.11.18	GENERAL UPDATE	LT	RG
P3	29.10.18	GENERAL UPDATE	LT	RG
P2	14.05.18	GENERAL UPDATE	RG	RG
P1	06.02.18	PRELIMINARY ISSUE	LT	RG

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BLOOR HOMES

Project Title

LOWER BULLINGHAM HEREFORD

Drawing Title

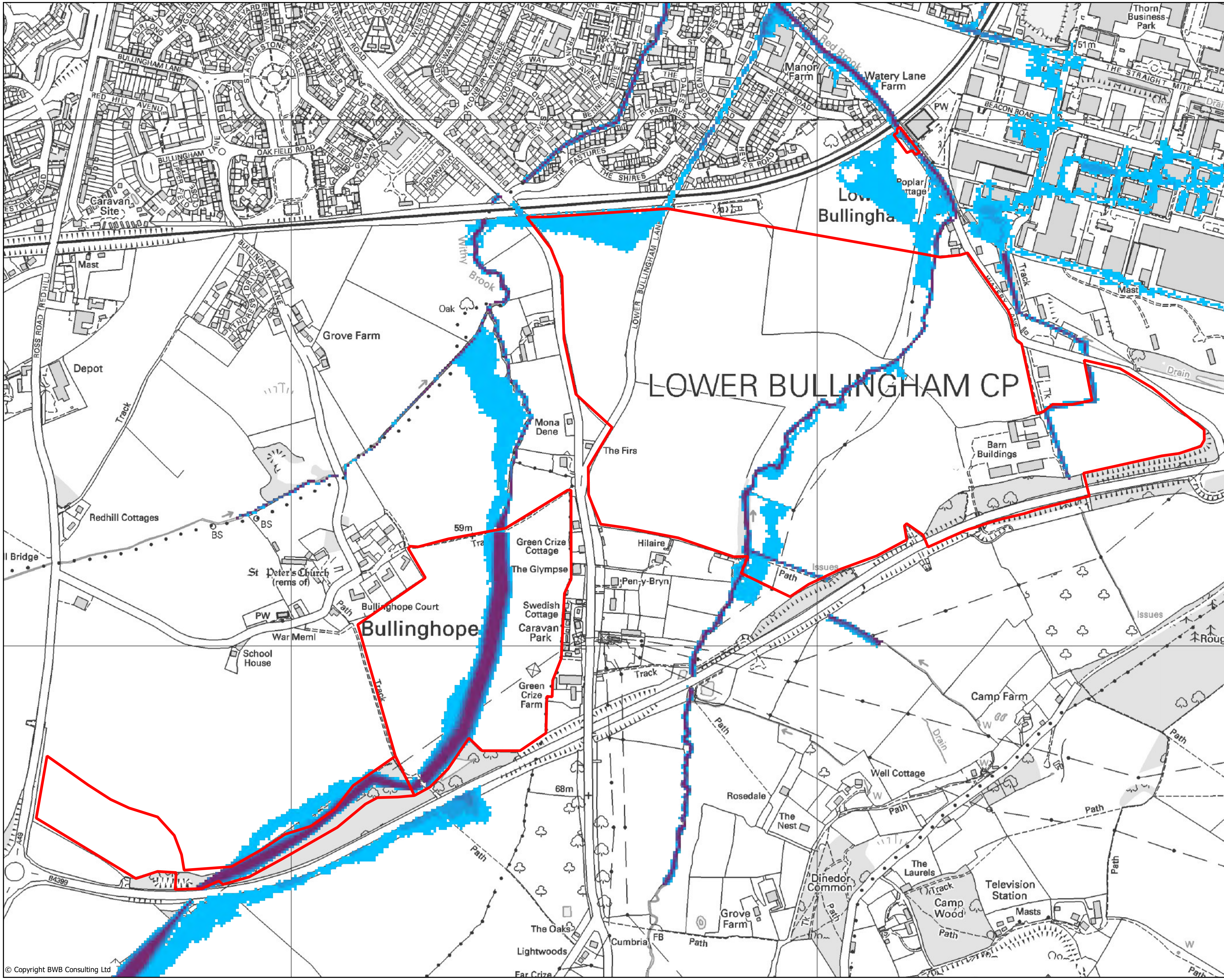
RED BROOK, WITHY BROOK & NORTON BROOK FLOOD DEPTHS: 1 in 75-YEAR

Drawn:	L Towle	Reviewed:	R Green
BWB Ref: BMW 2135	Date: 28.11.18	Scale@A3:	NTS

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
BULL-BWB-ZZ-XX-DR-YE-0207	S2	P5



Notes

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2. This drawing is to be read in conjunction with all relevant architects, engineers and specialists drawings and specifications.

3. All dimensions in millimetres unless noted otherwise. All levels in metres unless noted otherwise.

4. Any discrepancies noted on site are to be reported to the engineer immediately.

Key

Illustrative Site Boundary

Peak Flood Depths
- <= 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.25
- > 1.25

Rev	Date	Details of issues/ revision	Drw	Rev
P5	08.10.19	GENERAL UPDATE	RG	RG
P4	28.11.18	GENERAL UPDATE	LT	RG
P3	29.10.18	GENERAL UPDATE	LT	RG
P2	14.05.18	GENERAL UPDATE	RG	RG
P1	06.02.18	PRELIMINARY ISSUE	LT	RG

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BLOOR HOMES

Project Title

LOWER BULLINGHAM HEREFORD

Drawing Title

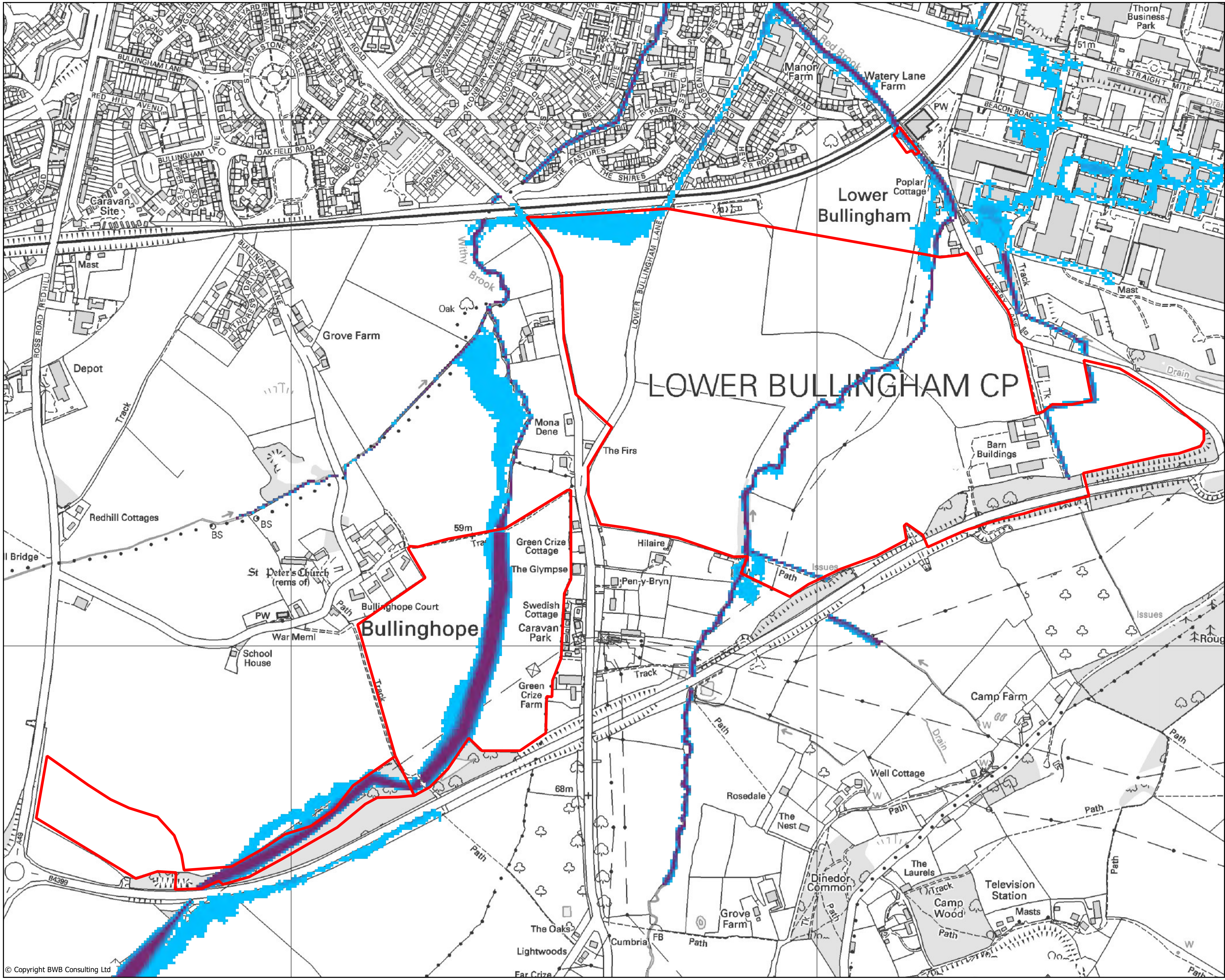
RED BROOK, WITHY BROOK & NORTON BROOK FLOOD DEPTHS: 1 in 50-YEAR

Drawn:	L Towle	Reviewed:	R Green
BWB Ref:	BMW 2135	Date: 28.11.18	Scale@A3: NTS

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
BULL-BWB-ZZ-XX-DR-YE-0208	S2	P5



Notes

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2. This drawing is to be read in conjunction with all relevant architects, engineers and specialists drawings and specifications.

3. All dimensions in millimetres unless noted otherwise. All levels in metres unless noted otherwise.

4. Any discrepancies noted on site are to be reported to the engineer immediately.

Key

Illustrative Site Boundary

Peak Flood Depths

- <= 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.25
- > 1.25

Rev	Date	Details of issues/ revision	Drw	Rev
P5	08.10.19	GENERAL UPDATE	RG	RG
P4	28.11.18	GENERAL UPDATE	LT	RG
P3	29.10.18	GENERAL UPDATE	LT	RG
P2	14.05.18	GENERAL UPDATE	RG	RG
P1	06.02.18	PRELIMINARY ISSUE	LT	RG

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BLOOR HOMES

Project Title

LOWER BULLINGHAM HEREFORD

Drawing Title

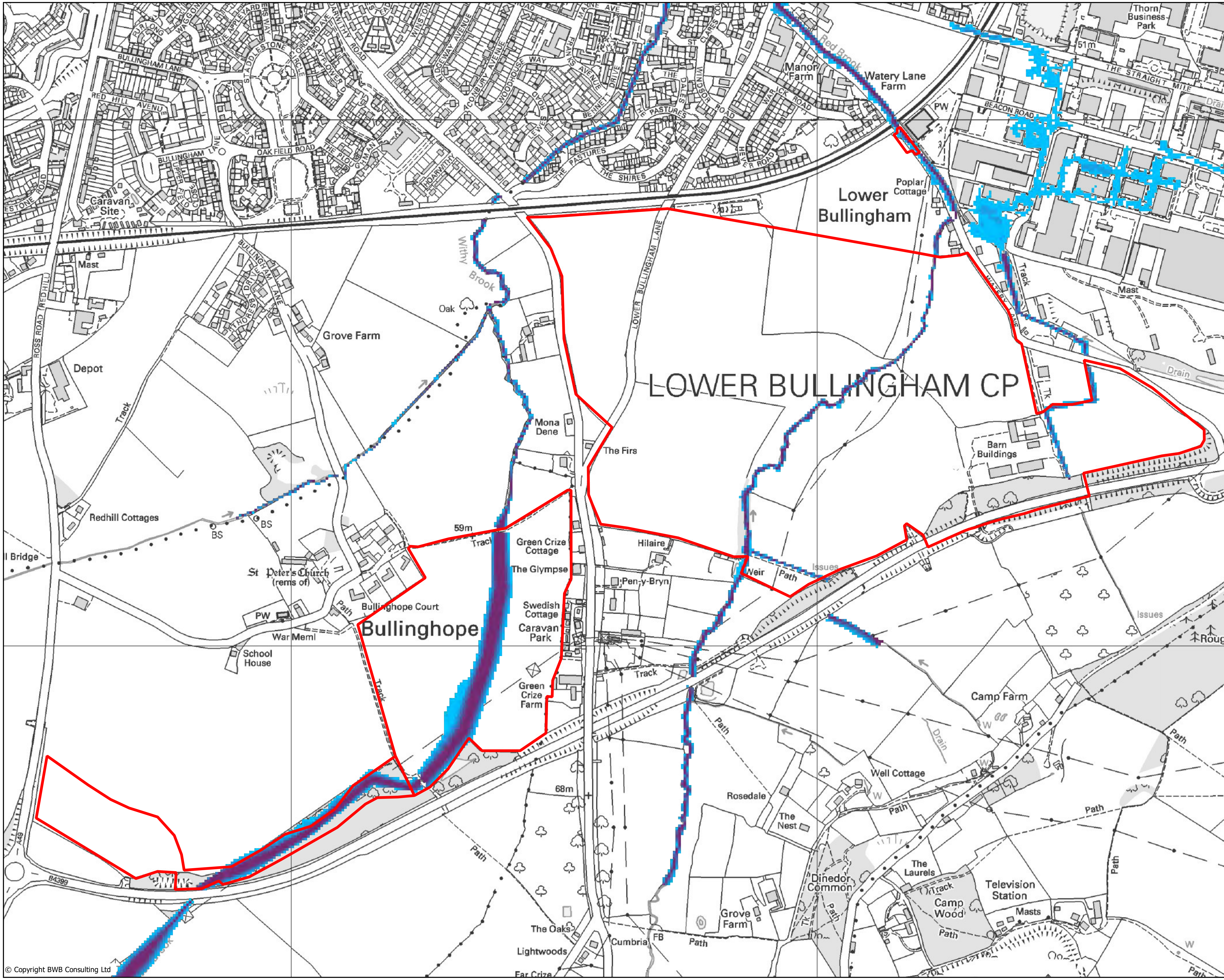
RED BROOK, WITHY BROOK & NORTON BROOK FLOOD DEPTHS: 1 in 20-YEAR

Drawn:	L Towle	Reviewed:	R Green
BWB Ref: BMW 2135	Date: 28.11.18	Scale@A3:	NTS

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
BULL-BWB-ZZ-XX-DR-YE-0209	S2	P5



Notes

1. Do not scale this drawing. All dimensions must be checked/ verified on site. If in doubt ask.
2. This drawing is to be read in conjunction with all relevant architects, engineers and specialists drawings and specifications.
3. All dimensions in millimetres unless noted otherwise. All levels in metres unless noted otherwise.
4. Any discrepancies noted on site are to be reported to the engineer immediately.

Key

Illustrative Site Boundary

Peak Flood Depths
- <= 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.25
- > 1.25

Rev	Date	Details of issues/ revision	Drw	Rev
P5	08.10.19	GENERAL UPDATE	RG	RG
P4	28.11.18	GENERAL UPDATE	LT	RG
P3	29.10.18	GENERAL UPDATE	LT	RG
P2	14.05.18	GENERAL UPDATE	RG	RG
P1	06.02.18	PRELIMINARY ISSUE	LT	RG

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BLOOR HOMES

Project Title

LOWER BULLINGHAM HEREFORD

Drawing Title

RED BROOK, WITHY BROOK & NORTON BROOK FLOOD DEPTHS: 1 in 5-YEAR

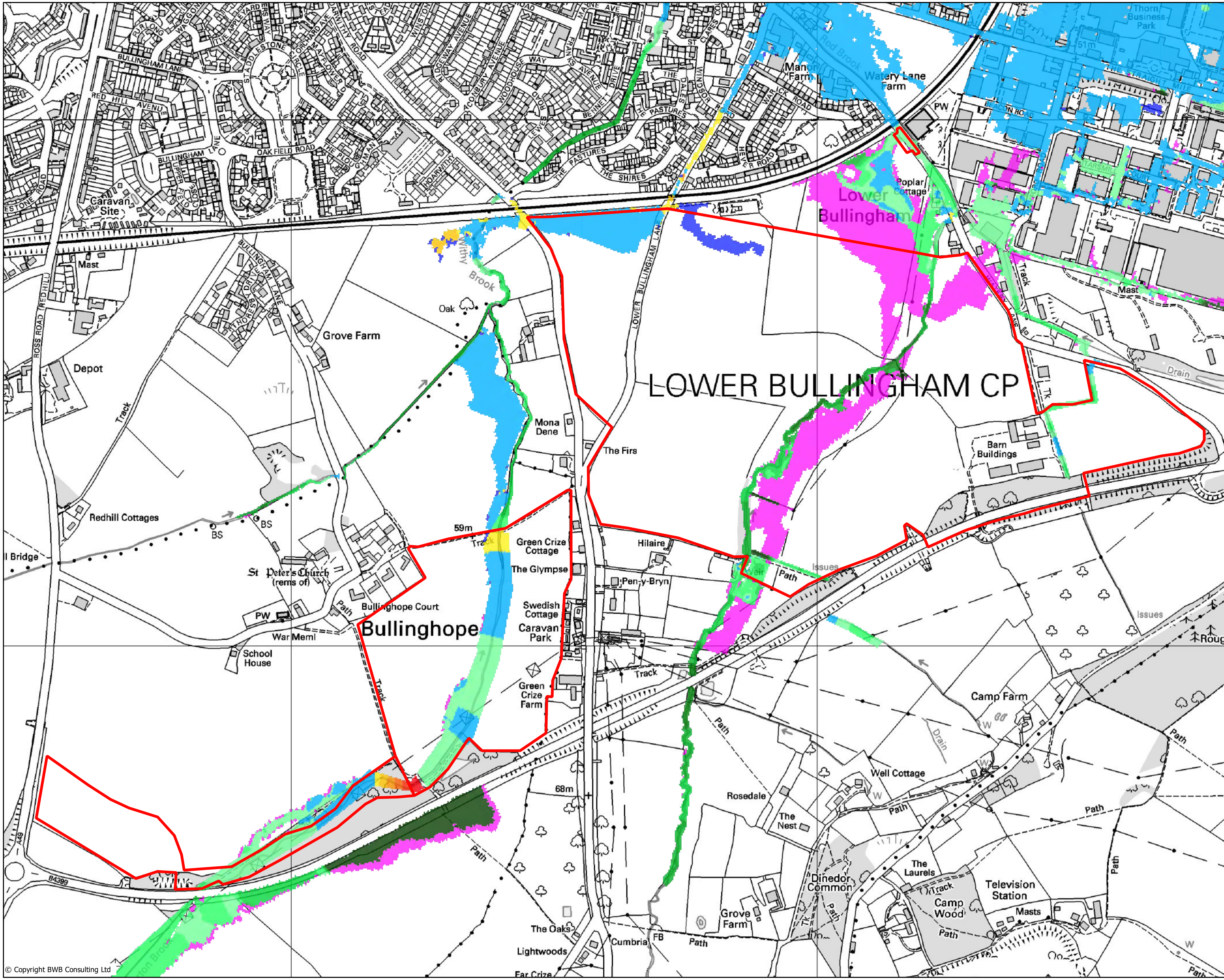
Drawn:	L Towle	Reviewed:	R Green
BWB Ref: BMW 2135	Date: 28.11.18	Scale@A3: NTS	

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
BULL-BWB-ZZ-XX-DR-YE-0210	S2	P5

APPENDIX 5: Sensitivity Tests



Notes

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2. This drawing is to be read in conjunction with all relevant architects, engineers and specialists drawings and specifications.
3. All dimensions in millimetres unless noted otherwise. All levels in metres unless noted otherwise.
4. Any discrepancies noted on site are to be reported to the engineer immediately.

Key

Illustrative Site Boundary

Change in Peak Flood Level (m)
- <= -0.125
- -0.125 - -0.100
- -0.100 - -0.075
- -0.075 - -0.050
- -0.050 - -0.025
- -0.025 - -0.01
- -0.01 - 0.01 (No Change)
- 0.01 - 0.025
- 0.025 - 0.050
- 0.050 - 0.075
- 0.075 - 0.100
- 0.100 - 0.125
- > 0.125

Change in Floodplain Extent
- Former Wet Areas Now Dry
- Former Dry Areas Now Wet

Rev	Date	Details of issues/ revision	Drw	Rev
P5	08.10.19	GENERAL UPDATE	RG	RG
P4	28.11.18	GENERAL UPDATE	LT	RG
P3	29.10.18	GENERAL UPDATE	LT	RG
P2	14.05.18	GENERAL UPDATE	RG	RG
P1	06.02.18	PRELIMINARY ISSUE	LT	RG

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Client

BLOOR HOMES

Project Title

LOWER BULLINGHAM HEREFORD

Drawing Title

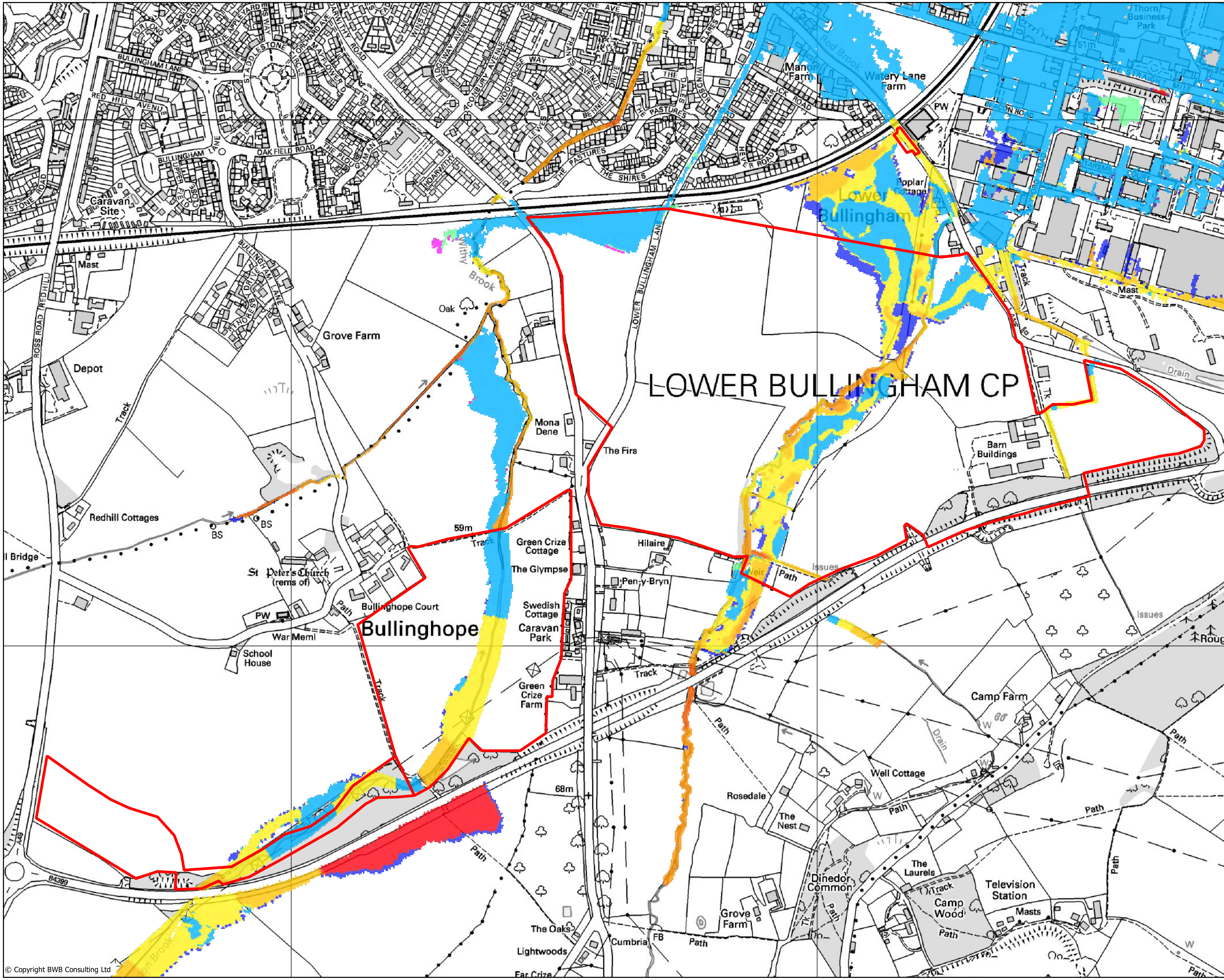
SENSITIVITY TESTS: 1 in 100-YEAR: ROUGHNESS-20%

Drawn:	L Towle	Reviewed:	R Green		
BWB Ref:	BMW 2135	Date:	28.11.18	Scale@A3:	NTS

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
BULL-BWB-ZZ-XX-DR-YE-0111	S2	P5



Notes

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4. Any discrepancies noted on site are to be reported to the engineer immediately.

Key

- Illustrative Site Boundary

Change in Peak Flood Level (m)

- <= -0.125
- -0.125 - -0.100
- -0.100 - -0.075
- -0.075 - -0.050
- -0.050 - -0.025
- -0.025 - -0.01
- -0.01 - 0.01 (No Change)
- 0.01 - 0.025
- 0.025 - 0.050
- 0.050 - 0.075
- 0.075 - 0.100
- 0.100 - 0.125
- > 0.125

Change in Floodplain Extent

- Former Wet Areas Now Dry
- Former Dry Areas Now Wet

Rev	Date	Details of issues/ revision	Drw	Rev
P5	08.10.19	GENERAL UPDATE	RG	RG
P4	28.11.18	GENERAL UPDATE	LT	RG
P3	29.10.18	GENERAL UPDATE	LT	RG
P2	14.05.18	GENERAL UPDATE	RG	RG
P1	06.02.18	PRELIMINARY ISSUE	LT	RG

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Client

BLOOR HOMES

Project Title

LOWER BULLINGHAM HEREFORD

Drawing Title

SENSITIVITY TESTS: 1 in 100-YEAR: ROUGHNESS+20%

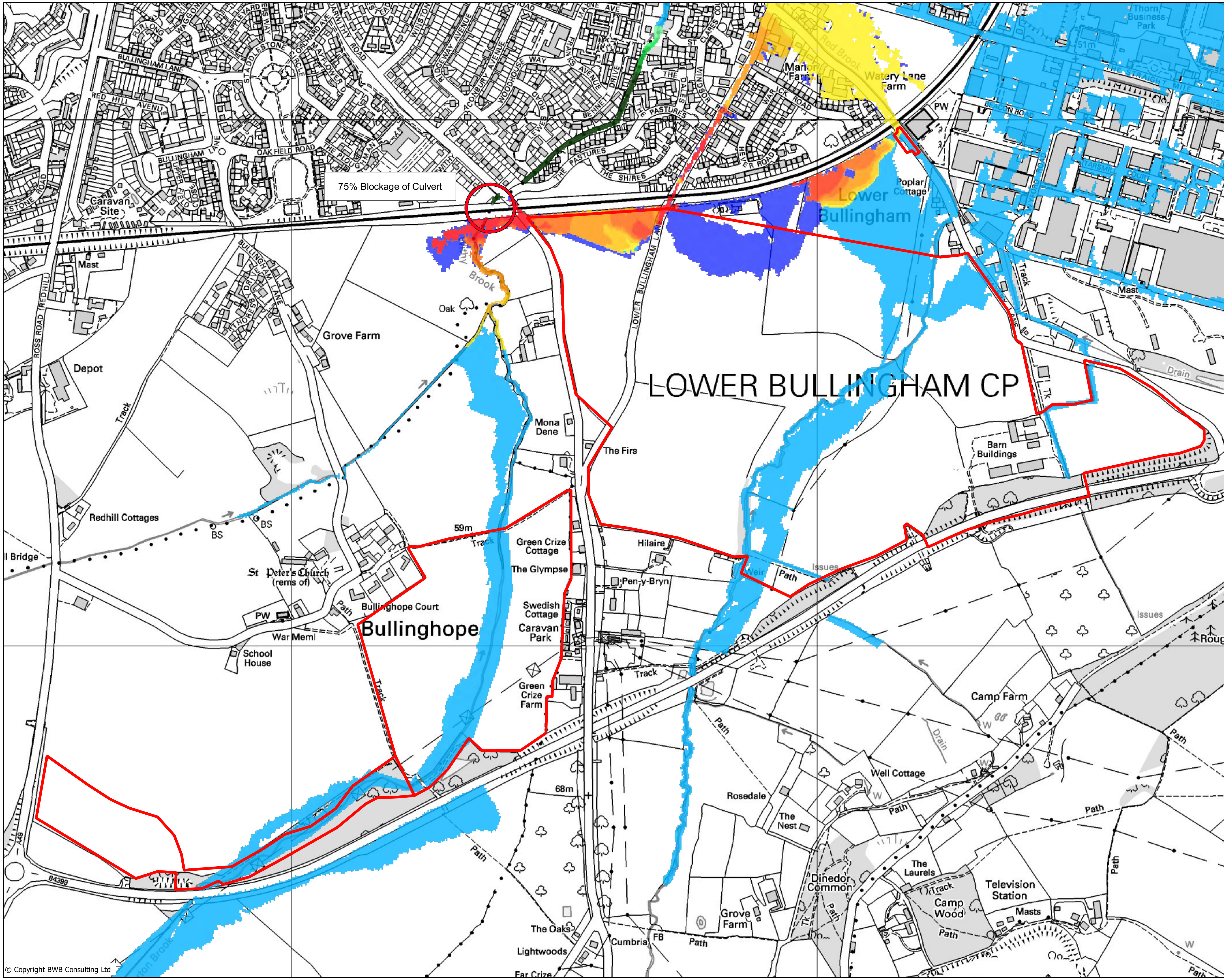
Drawn:	L Towle	Reviewed:	R Green

BWB Ref:	BMW 2135	Date:	28.11.18	Scale@A3:	NTS

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
BULL-BWB-ZZ-XX-DR-YE-0112	S2	P5



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3. All dimensions in millimetres unless noted otherwise. All levels in metres unless noted otherwise.

4. Any discrepancies noted on site are to be reported to the engineer immediately.

Key

Illustrative Site Boundary

Change in Peak Flood Level (m)
- <= -0.125
- -0.125 - -0.100
- -0.100 - -0.075
- -0.075 - -0.050
- -0.050 - -0.025
- -0.025 - -0.01
- -0.01 - 0.01 (No Change)
- 0.01 - 0.025
- 0.025 - 0.050
- 0.050 - 0.075
- 0.075 - 0.100
- 0.100 - 0.125
- > 0.125

Change in Floodplain Extent
- Former Wet Areas Now Dry
- Former Dry Areas Now Wet

Rev	Date	Details of issues/ revision	Drw	Rev
P5	08.10.19	GENERAL UPDATE	RG	RG
P4	28.11.18	GENERAL UPDATE	LT	RG
P3	29.10.18	GENERAL UPDATE	LT	RG
P2	14.05.18	GENERAL UPDATE	RG	RG
P1	06.02.18	PRELIMINARY ISSUE	LT	RG

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BLOOR HOMES

Project Title

LOWER BULLINGHAM HEREFORD

Drawing Title

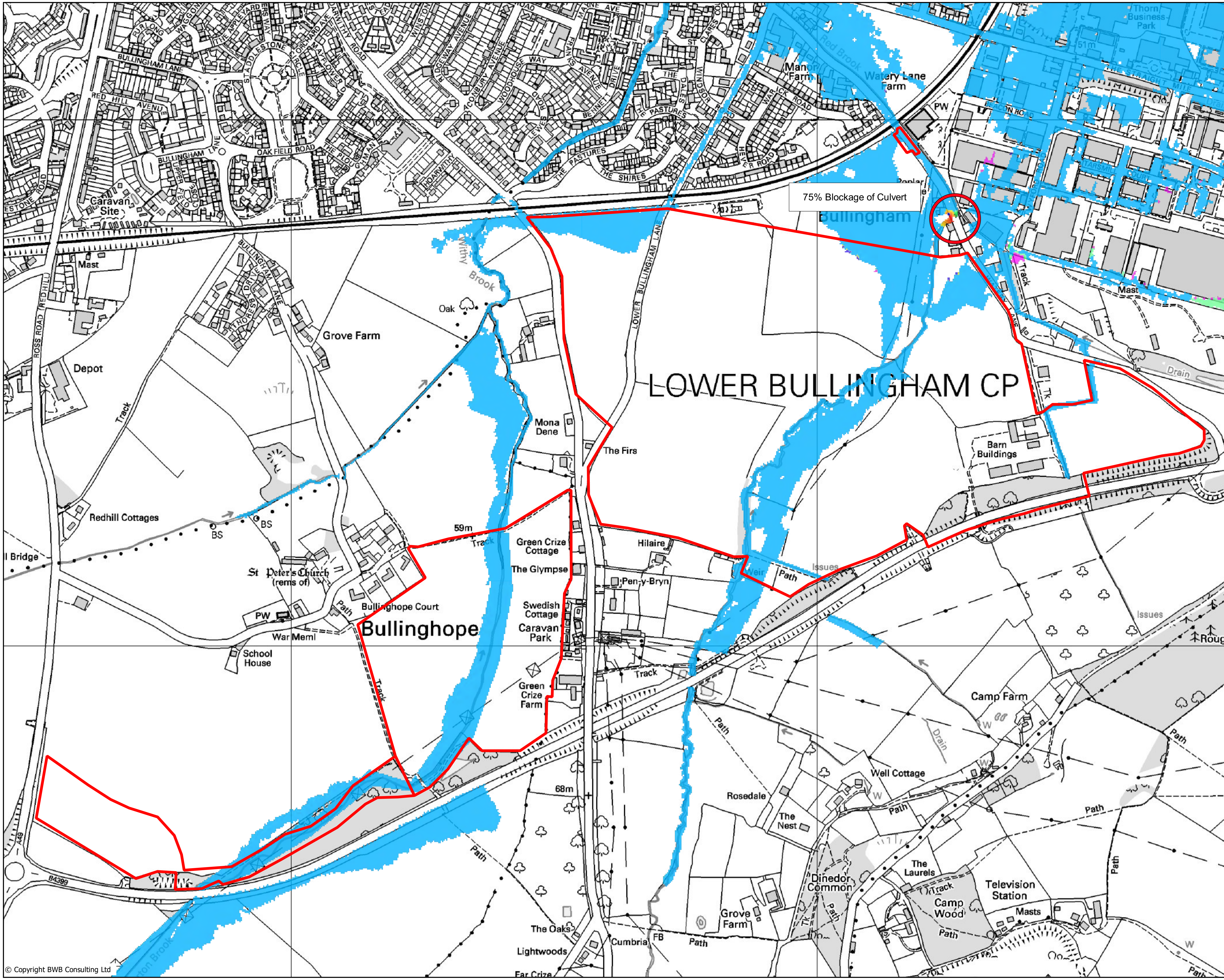
SENSITIVITY TESTS: 1 in 100-YEAR: BLOCKAGE 1

Drawn:	L Towle	Reviewed:	R Green
BWB Ref:	BMW 2135	Date:	28.11.18	Scale@A3:	NTS

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
BULL-BWB-ZZ-XX-DR-YE-0113	S2	P5



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4. Any discrepancies noted on site are to be reported to the engineer immediately.

Key

- Illustrative Site Boundary

Change in Peak Flood Level (m)

- <= -0.125
- -0.125 - -0.100
- -0.100 - -0.075
- -0.075 - -0.050
- -0.050 - -0.025
- -0.025 - -0.01
- -0.01 - 0.01 (No Change)
- 0.01 - 0.025
- 0.025 - 0.050
- 0.050 - 0.075
- 0.075 - 0.100
- 0.100 - 0.125
- > 0.125

Change in Floodplain Extent

- Former Wet Areas Now Dry
- Former Dry Areas Now Wet

Rev	Date	Details of issues/ revision	Drw	Rev
P5	08.10.19	GENERAL UPDATE	RG	RG
P4	28.11.18	GENERAL UPDATE	LT	RG
P3	29.10.18	GENERAL UPDATE	LT	RG
P2	14.05.18	GENERAL UPDATE	RG	RG
P1	06.02.18	PRELIMINARY ISSUE	LT	RG

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BLOOR HOMES

Project Title

LOWER BULLINGHAM HEREFORD

Drawing Title

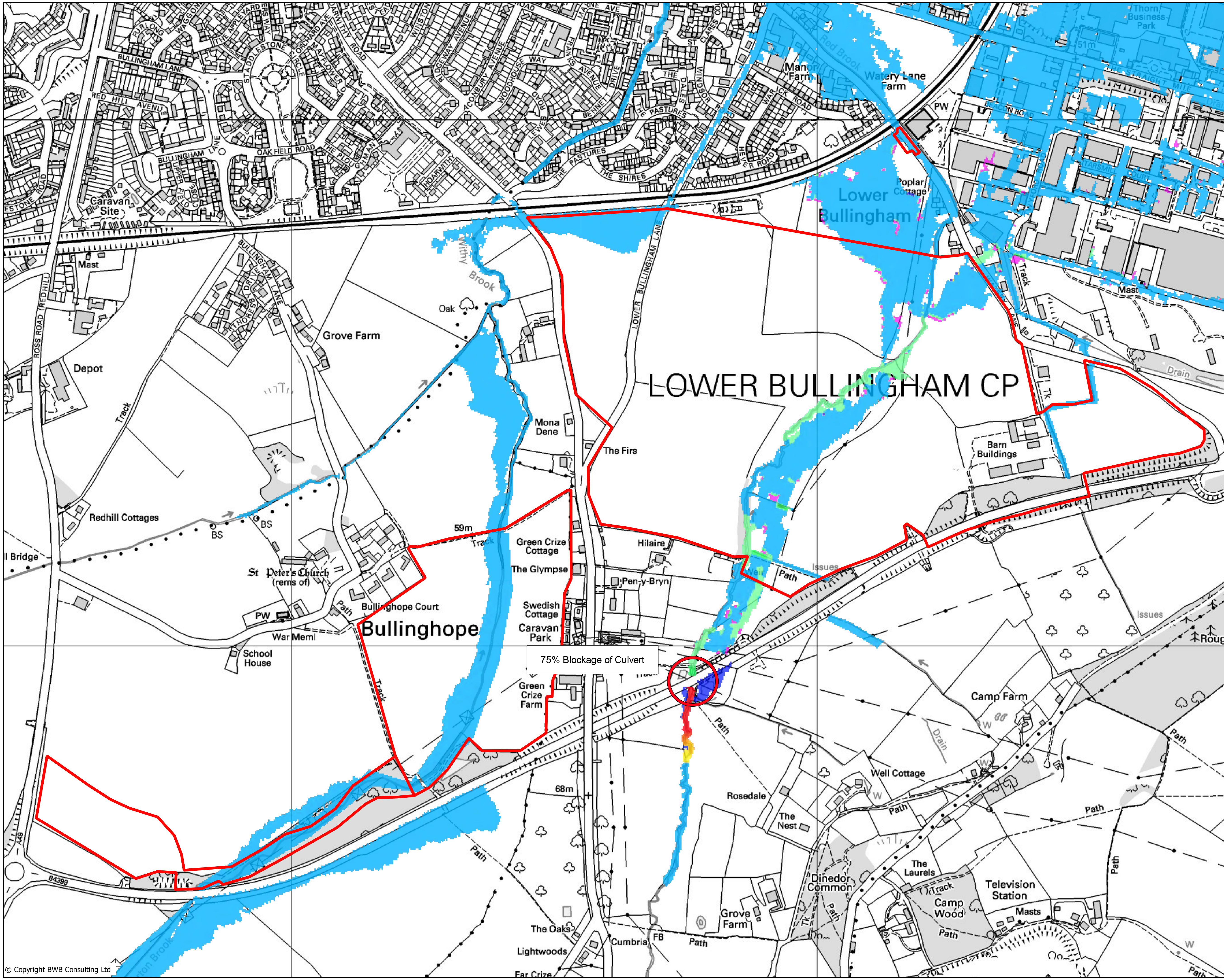
SENSITIVITY TESTS: 1 in 100-YEAR: BLOCKAGE 2

Drawn:	L Towle	Reviewed:	R Green
BWB Ref:	BMW 2135	Date: 28.11.18	Scale@A3: NTS

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
BULL-BWB-ZZ-XX-DR-YE-0114	S2	P5



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3. All dimensions in millimetres unless noted otherwise. All levels in metres unless noted otherwise.

4. Any discrepancies noted on site are to be reported to the engineer immediately.

Key

- Illustrative Site Boundary

Change in Peak Flood Level (m)

- <= -0.125
- -0.125 - -0.100
- -0.100 - -0.075
- -0.075 - -0.050
- -0.050 - -0.025
- -0.025 - -0.01
- -0.01 - 0.01 (No Change)
- 0.01 - 0.025
- 0.025 - 0.050
- 0.050 - 0.075
- 0.075 - 0.100
- 0.100 - 0.125
- > 0.125

Change in Floodplain Extent

- Former Wet Areas Now Dry
- Former Dry Areas Now Wet

Rev	Date	Details of issues/ revision	Drw	Rev
P5	08.10.19	GENERAL UPDATE	RG	RG
P4	28.11.18	GENERAL UPDATE	LT	RG
P3	29.10.18	GENERAL UPDATE	LT	RG
P2	14.05.18	GENERAL UPDATE	RG	RG
P1	06.02.18	PRELIMINARY ISSUE	LT	RG

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Client

BLOOR HOMES

Project Title

LOWER BULLINGHAM HEREFORD

Drawing Title

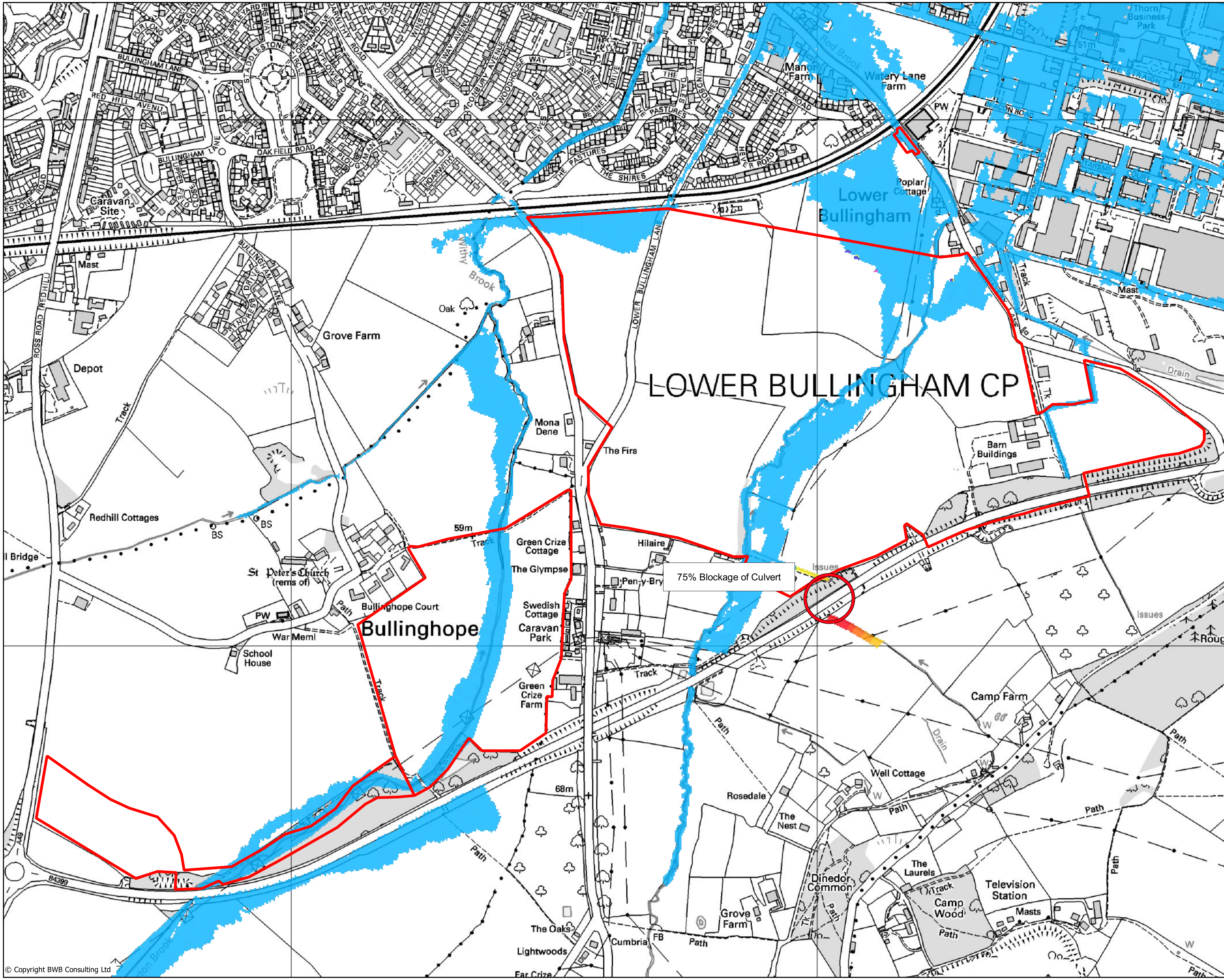
SENSITIVITY TESTS: 1 in 100-YEAR: BLOCKAGE 3

Drawn:	L Towle	Reviewed:	R Green
BWB Ref:	BMW 2135	Date:	28.11.18
Scale@A3:	NTS		

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
BULL-BWB-ZZ-XX-DR-YE-0115	S2	P5



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3. All dimensions in millimetres unless noted otherwise. All levels in metres unless noted otherwise.

4. Any discrepancies noted on site are to be reported to the engineer immediately.

Key

Illustrative Site Boundary

Change in Peak Flood Level (m)

- <= -0.125
- -0.125 - -0.100
- -0.100 - -0.075
- -0.075 - -0.050
- -0.050 - -0.025
- -0.025 - -0.01
- -0.01 - 0.01 (No Change)
- 0.01 - 0.025
- 0.025 - 0.050
- 0.050 - 0.075
- 0.075 - 0.100
- 0.100 - 0.125
- > 0.125

Change in Floodplain Extent

- Former Wet Areas Now Dry
- Former Dry Areas Now Wet

Rev	Date	Details of issues/ revision	Drw	Rev
P5	08.10.19	GENERAL UPDATE	RG	RG
P4	28.11.18	GENERAL UPDATE	LT	RG
P3	29.10.18	GENERAL UPDATE	LT	RG
P2	14.05.18	GENERAL UPDATE	RG	RG
P1	06.02.18	PRELIMINARY ISSUE	LT	RG

Issues & Revisions

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BLOOR HOMES

Project Title

LOWER BULLINGHAM HEREFORD

Drawing Title

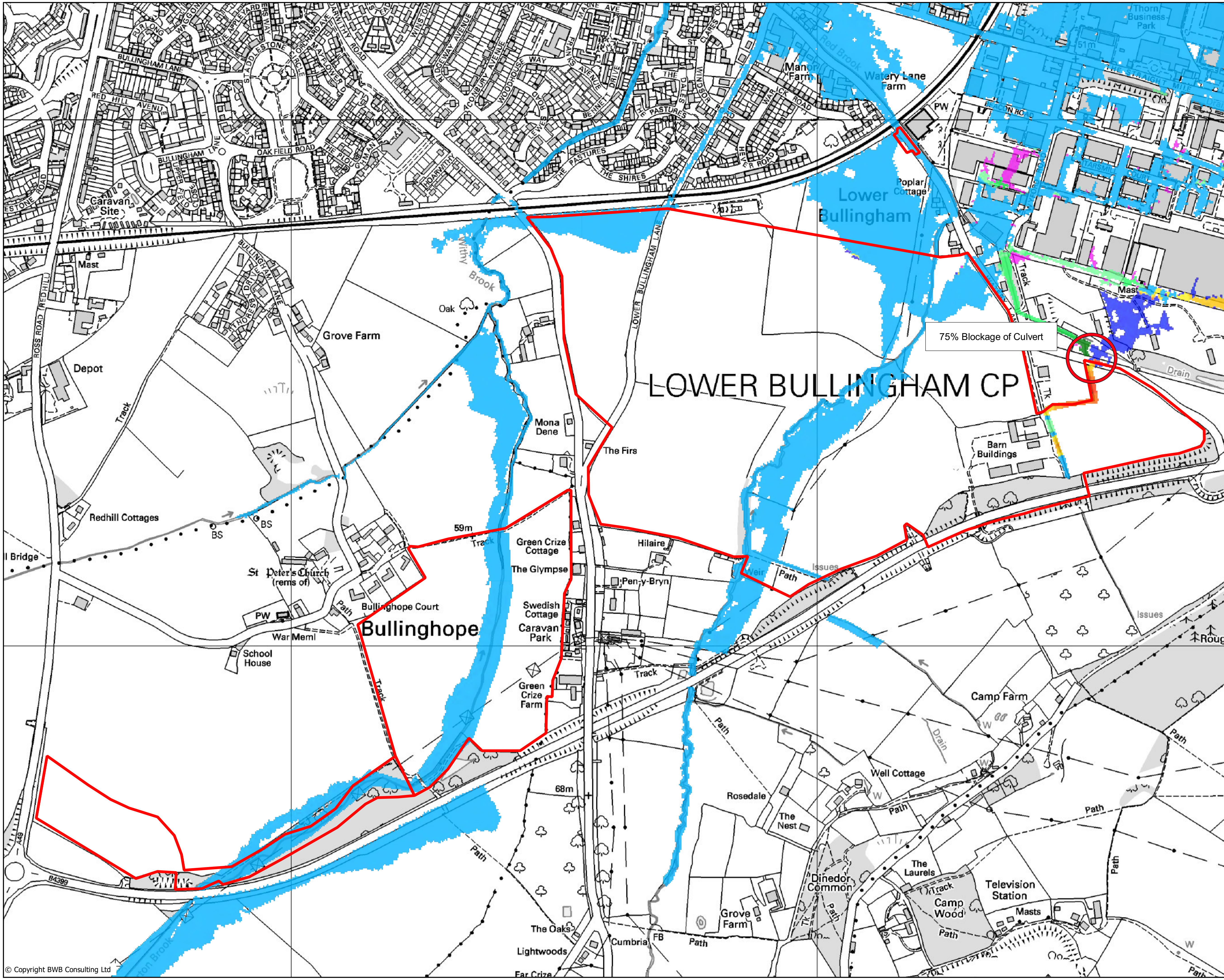
SENSITIVITY TESTS: 1 in 100-YEAR: BLOCKAGE 4

Drawn:	L Towle	Reviewed:	R Green
BWB Ref:	BMW 2135	Date:	28.11.18
Scale@A3:	NTS		

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
BULL-BWB-ZZ-XX-DR-YE-0116	S2	P5



Notes

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2. This drawing is to be read in conjunction with all relevant architects, engineers and specialists drawings and specifications.

3. All dimensions in millimetres unless noted otherwise. All levels in metres unless noted otherwise.

4. Any discrepancies noted on site are to be reported to the engineer immediately.

Key

- Illustrative Site Boundary
- Change in Peak Flood Level (m)
  - <= -0.125
  - -0.125 - -0.100
  - -0.100 - -0.075
  - -0.075 - -0.050
  - -0.050 - -0.025
  - -0.025 - -0.01
  - -0.01 - 0.01 (No Change)
  - 0.01 - 0.025
  - 0.025 - 0.050
  - 0.050 - 0.075
  - 0.075 - 0.100
  - 0.100 - 0.125
  - > 0.125
- Change in Floodplain Extent
  - Former Wet Areas Now Dry
  - Former Dry Areas Now Wet

Rev	Date	Details of issues/ revision	Drw	Rev
P5	08.10.19	GENERAL UPDATE	RG	RG
P4	28.11.18	GENERAL UPDATE	LT	RG
P3	29.10.18	GENERAL UPDATE	LT	RG
P2	14.05.18	GENERAL UPDATE	RG	RG
P1	06.02.18	PRELIMINARY ISSUE	LT	RG

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BLOOR HOMES

Project Title

LOWER BULLINGHAM HEREFORD

Drawing Title

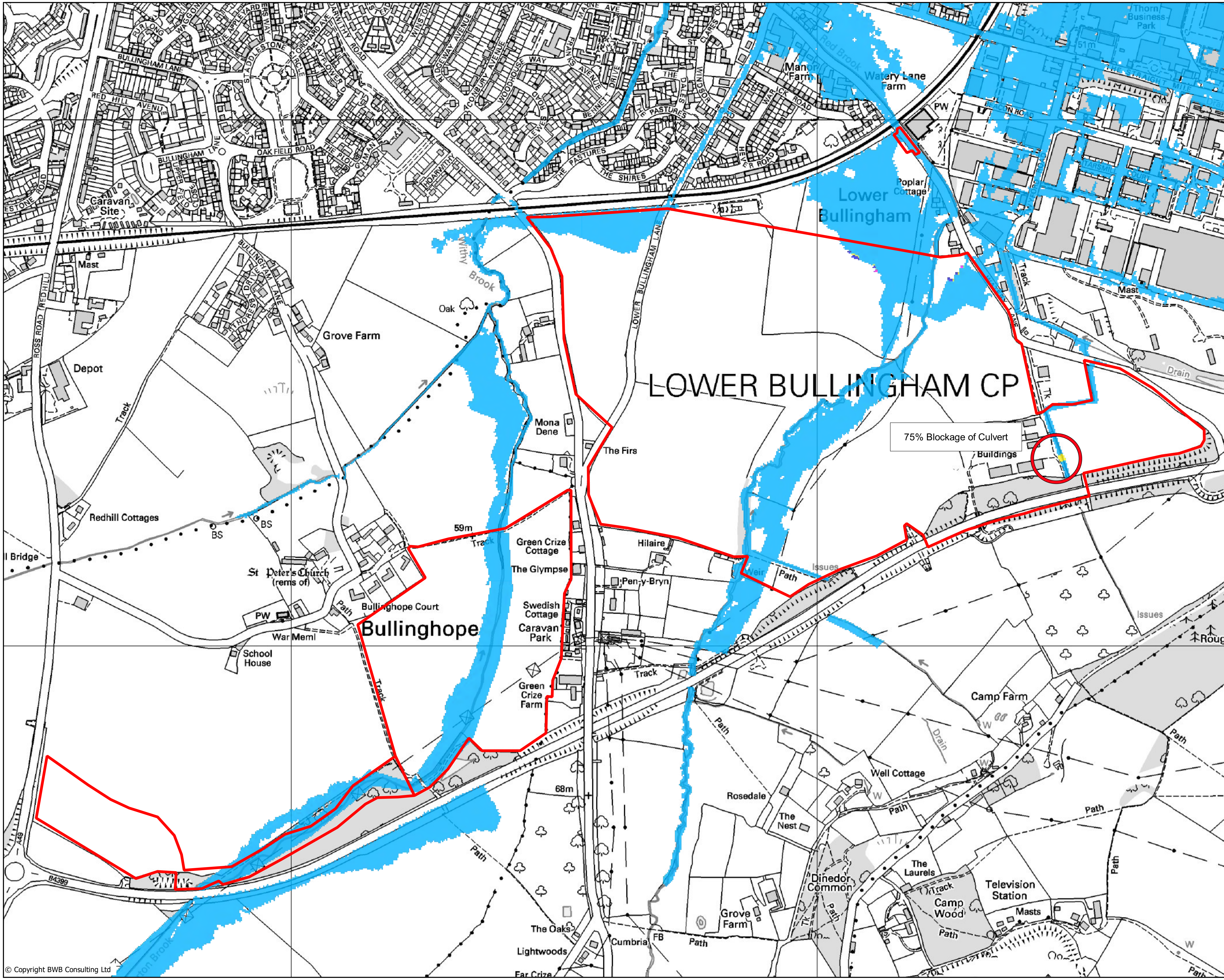
SENSITIVITY TESTS: 1 in 100-YEAR: BLOCKAGE 5

Drawn:	L Towle	Reviewed:	R Green
BWB Ref: BMW 2135	Date: 28.11.18	Scale@A3: NTS	

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
BULL-BWB-ZZ-XX-DR-YE-0117	S2	P5



Notes

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2. This drawing is to be read in conjunction with all relevant architects, engineers and specialists drawings and specifications.
3. All dimensions in millimetres unless noted otherwise. All levels in metres unless noted otherwise.
4. Any discrepancies noted on site are to be reported to the engineer immediately.

Key

Illustrative Site Boundary

Change in Peak Flood Level (m)

- <= -0.125
- -0.125 - -0.100
- -0.100 - -0.075
- -0.075 - -0.050
- -0.050 - -0.025
- -0.025 - -0.01
- -0.01 - 0.01 (No Change)
- 0.01 - 0.025
- 0.025 - 0.050
- 0.050 - 0.075
- 0.075 - 0.100
- 0.100 - 0.125
- > 0.125

Change in Floodplain Extent

- Former Wet Areas Now Dry
- Former Dry Areas Now Wet

Rev	Date	Details of issues/ revision	Drw	Rev
P5	08.10.19	GENERAL UPDATE	RG	RG
P4	28.11.18	GENERAL UPDATE	LT	RG
P3	29.10.18	GENERAL UPDATE	LT	RG
P2	14.05.18	GENERAL UPDATE	RG	RG
P1	06.02.18	PRELIMINARY ISSUE	LT	RG

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BLOOR HOMES

Project Title

LOWER BULLINGHAM HEREFORD

Drawing Title

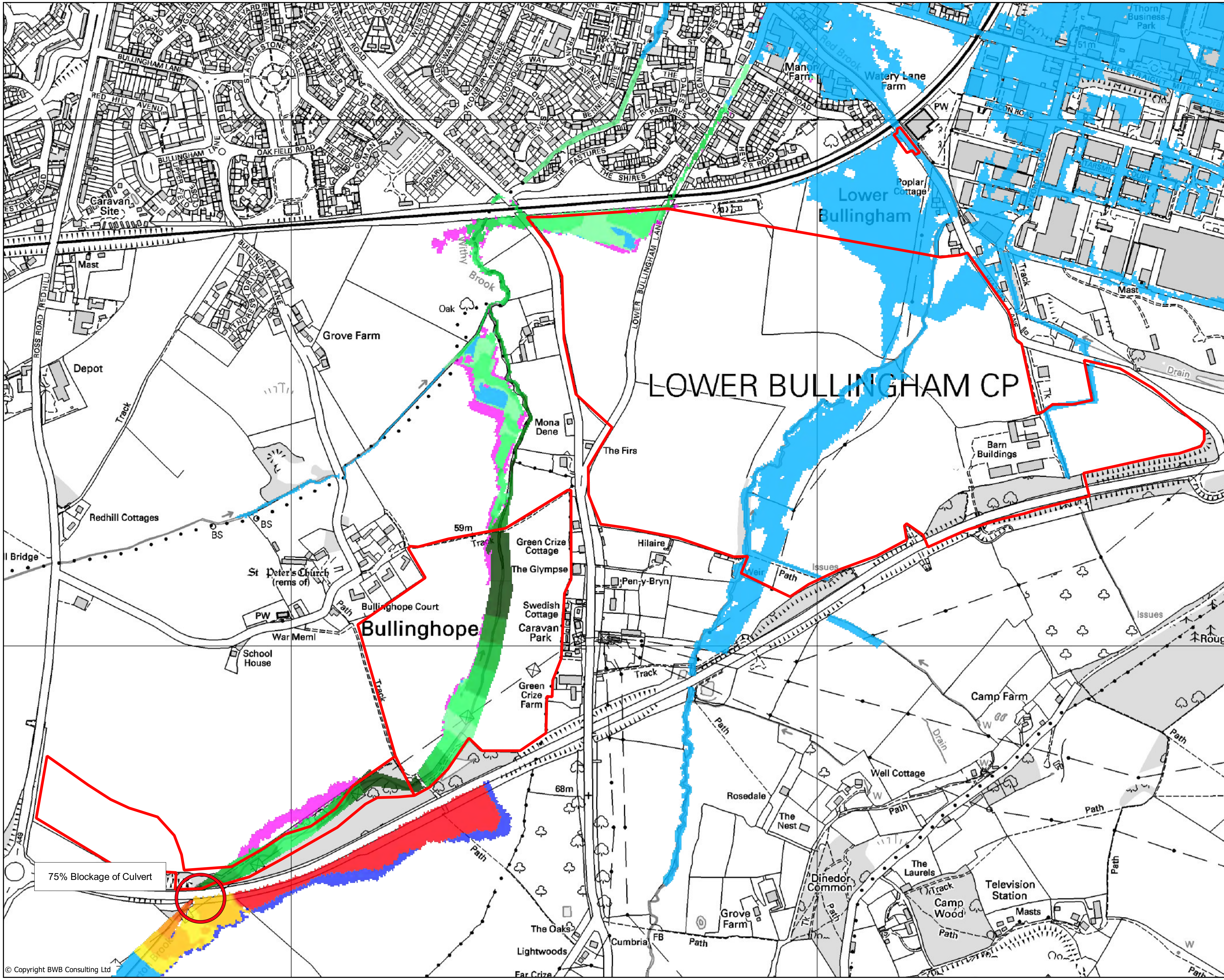
SENSITIVITY TESTS: 1 in 100-YEAR: BLOCKAGE 6

Drawn:	L Towle	Reviewed:	R Green
BWB Ref:	BMW 2135	Date: 28.11.18	Scale@A3: NTS

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
BULL-BWB-ZZ-XX-DR-YE-0118	S2	P5



Notes

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3. All dimensions in millimetres unless noted otherwise. All levels in metres unless noted otherwise.

4. Any discrepancies noted on site are to be reported to the engineer immediately.

Key

Illustrative Site Boundary

Change in Peak Flood Level (m)
- <= -0.125
- -0.125 - -0.100
- -0.100 - -0.075
- -0.075 - -0.050
- -0.050 - -0.025
- -0.025 - -0.01
- -0.01 - 0.01 (No Change)
- 0.01 - 0.025
- 0.025 - 0.050
- 0.050 - 0.075
- 0.075 - 0.100
- 0.100 - 0.125
- > 0.125

Change in Floodplain Extent
- Former Wet Areas Now Dry
- Former Dry Areas Now Wet

Rev	Date	Details of issues/ revision	Drw	Rev
P5	08.10.19	GENERAL UPDATE	RG	RG
P4	28.11.18	GENERAL UPDATE	LT	RG
P3	29.10.18	GENERAL UPDATE	LT	RG
P2	14.05.18	GENERAL UPDATE	RG	RG
P1	06.02.18	PRELIMINARY ISSUE	LT	RG

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BLOOR HOMES

Project Title

LOWER BULLINGHAM HEREFORD

Drawing Title

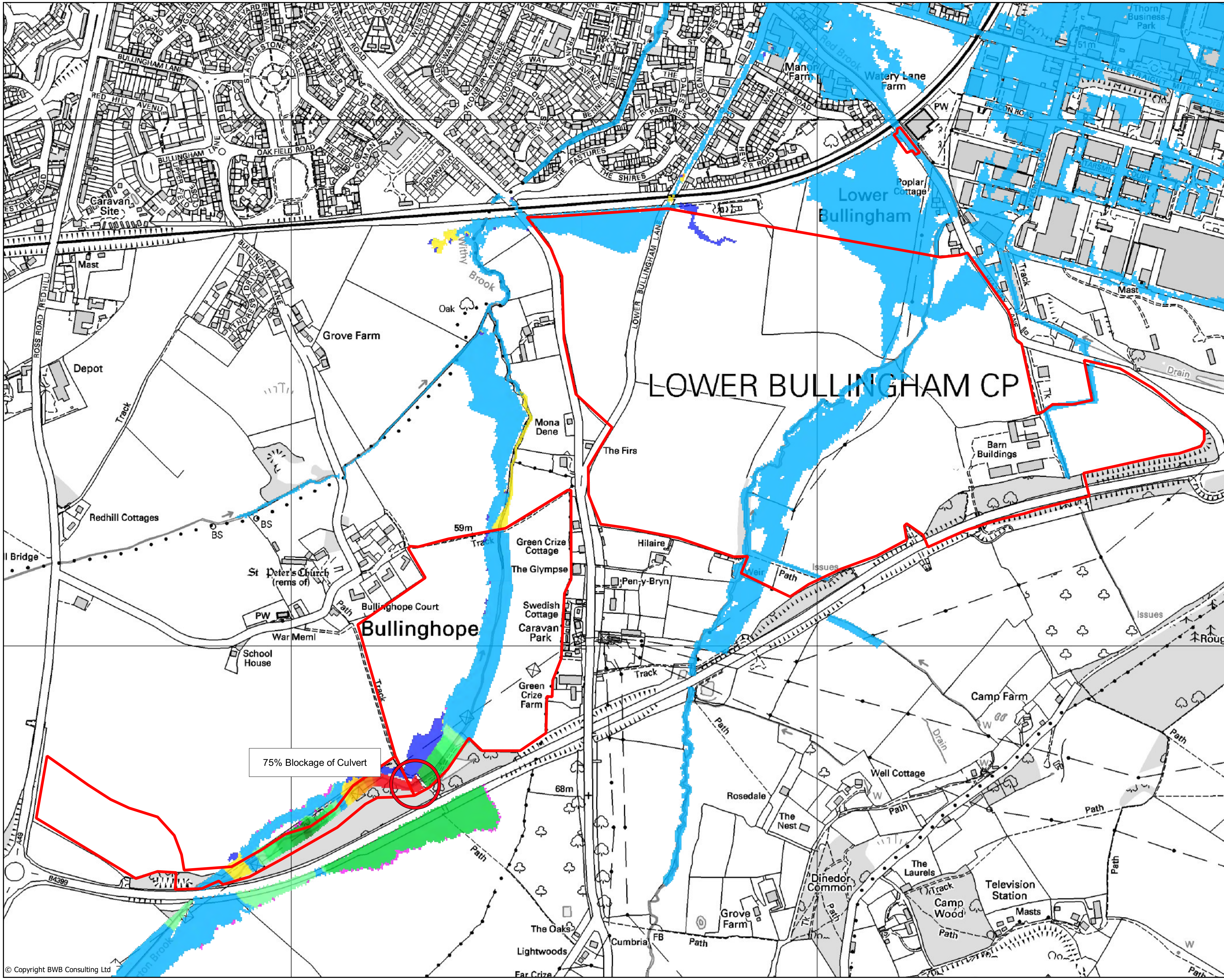
SENSITIVITY TESTS: 1 in 100-YEAR: BLOCKAGE 7

Drawn:	L Towle	Reviewed:	R Green
BWB Ref:	BMW 2135	Date:	28.11.18	Scale@A3:	NTS

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
BULL-BWB-ZZ-XX-DR-YE-0119	S2	P5



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3. All dimensions in millimetres unless noted otherwise. All levels in metres unless noted otherwise.

4. Any discrepancies noted on site are to be reported to the engineer immediately.

Key

Illustrative Site Boundary

Change in Peak Flood Level (m)

- <= -0.125
- -0.125 - -0.100
- -0.100 - -0.075
- -0.075 - -0.050
- -0.050 - -0.025
- -0.025 - -0.01
- -0.01 - 0.01 (No Change)
- 0.01 - 0.025
- 0.025 - 0.050
- 0.050 - 0.075
- 0.075 - 0.100
- 0.100 - 0.125
- > 0.125

Change in Floodplain Extent

- Former Wet Areas Now Dry
- Former Dry Areas Now Wet

P5	08.10.19	GENERAL UPDATE	RG	RG
P4	28.11.18	GENERAL UPDATE	LT	RG
P3	29.10.18	GENERAL UPDATE	LT	RG
P2	14.05.18	GENERAL UPDATE	RG	RG
P1	06.02.18	PRELIMINARY ISSUE	LT	RG
Rev	Date	Details of issues/ revision	Drw	Rev

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BLOOR HOMES

Project Title

LOWER BULLINGHAM HEREFORD

Drawing Title

SENSITIVITY TESTS: 1 in 100-YEAR: BLOCKAGE 8

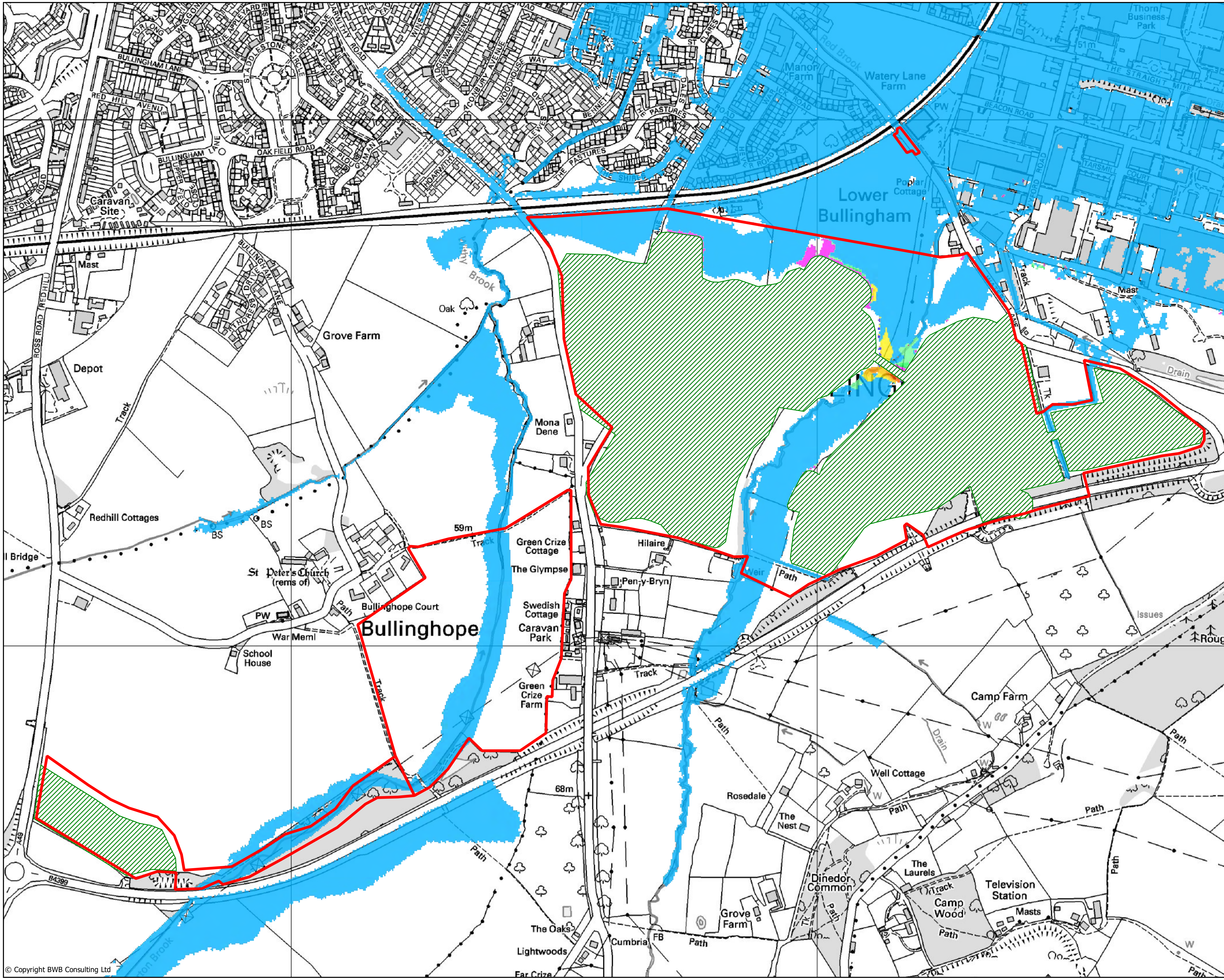
Drawn:	L Towle	Reviewed:	R Green
BWB Ref:	BMW 2135	Date: 28.11.18	Scale@A3: NTS

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
BULL-BWB-ZZ-XX-DR-YE-0120	S2	P5

APPENDIX 6: Post-Development Comparative Analysis



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3. All dimensions in millimetres unless noted otherwise. All levels in metres unless noted otherwise.
4. Any discrepancies noted on site are to be reported to the engineer immediately.

Key

- Illustrative Site Boundary
- Illustrative Development Parcels

Change in Peak Flood Level (m)

- <= -0.125
- -0.125 - -0.100
- -0.100 - -0.075
- -0.075 - -0.050
- -0.050 - -0.025
- -0.025 - -0.01
- -0.01 - 0.01 (No Change)
- 0.01 - 0.025
- 0.025 - 0.050
- 0.050 - 0.075
- 0.075 - 0.100
- 0.100 - 0.125
- > 0.125

Change in Floodplain Extent

- Former Wet Areas Now Dry
- Former Dry Areas Now Wet

Rev	Date	Details of issues/ revision	Drw	Rev
P5	08.10.19	GENERAL UPDATE	RG	RG
P4	28.11.18	GENERAL UPDATE	LT	RG
P3	29.10.18	GENERAL UPDATE	LT	RG
P2	14.05.18	GENERAL UPDATE	RG	RG
P1	06.02.18	PRELIMINARY ISSUE	LT	RG

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BLOOR HOMES

Project Title

LOWER BULLINGHAM HEREFORD

Drawing Title

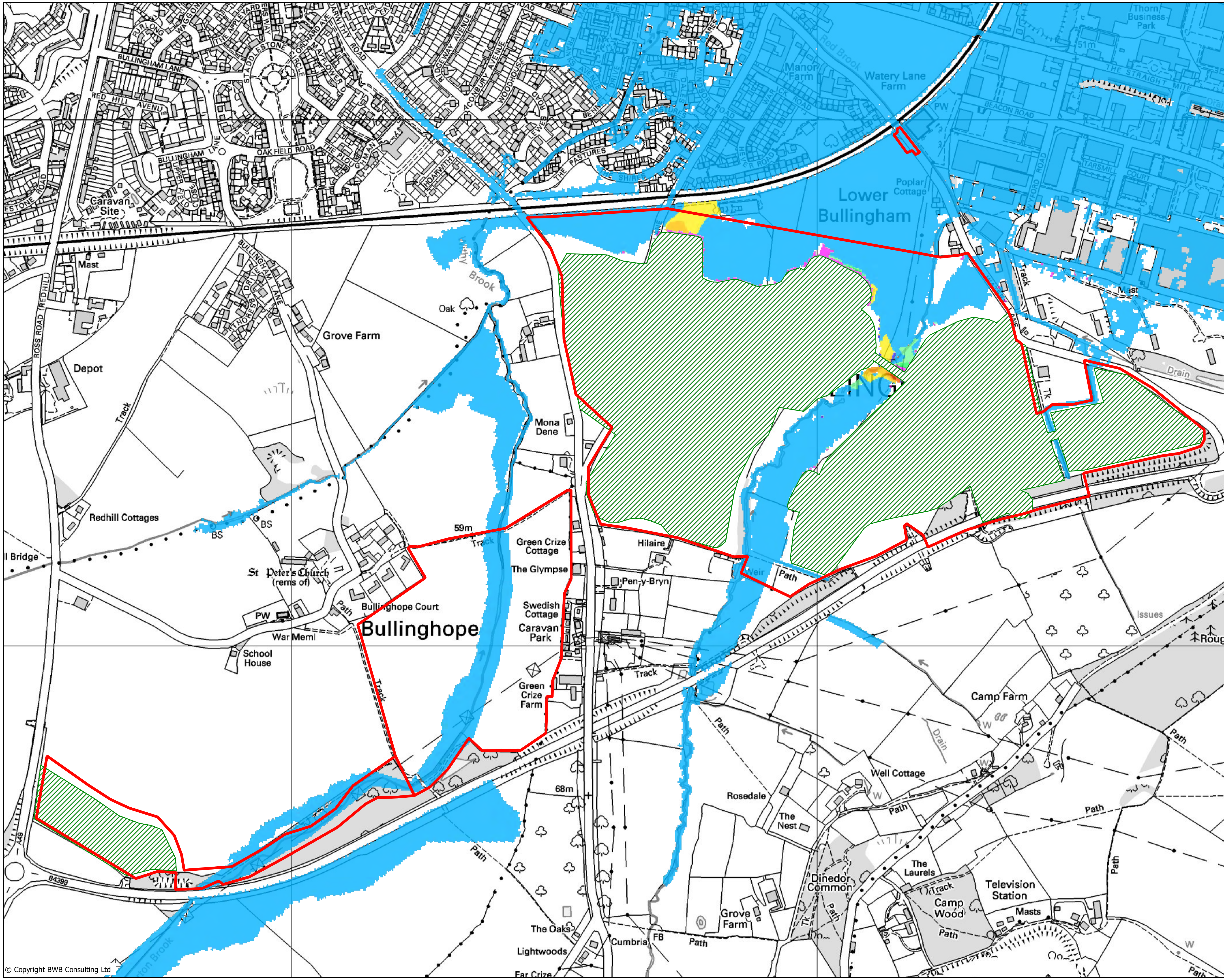
ILLUSTRATIVE DEVELOPMENT ANALYSIS: 1 IN 1000-YEAR

Drawn:	L Towle	Reviewed:	R Green
BWB Ref: BMW 2135	Date: 28.11.18	Scale@A3:	NTS

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
BULL-BWB-ZZ-XX-DR-YE-0129	S2	P5



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3. All dimensions in millimetres unless noted otherwise. All levels in metres unless noted otherwise.

4. Any discrepancies noted on site are to be reported to the engineer immediately.

Key

- Illustrative Site Boundary
- Illustrative Development Parcels

Change in Peak Flood Level (m)

- <= -0.125
- -0.125 - -0.100
- -0.100 - -0.075
- -0.075 - -0.050
- -0.050 - -0.025
- -0.025 - -0.01
- -0.01 - 0.01 (No Change)
- 0.01 - 0.025
- 0.025 - 0.050
- 0.050 - 0.075
- 0.075 - 0.100
- 0.100 - 0.125
- > 0.125

Change in Floodplain Extent

- Former Wet Areas Now Dry
- Former Dry Areas Now Wet

Rev	Date	Details of issues/ revision	Drw	Rev
P5	08.10.19	GENERAL UPDATE	RG	RG
P4	28.11.18	GENERAL UPDATE	LT	RG
P3	29.10.18	GENERAL UPDATE	LT	RG
P2	14.05.18	GENERAL UPDATE	RG	RG
P1	06.02.18	PRELIMINARY ISSUE	LT	RG

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Client

BLOOR HOMES

Project Title

LOWER BULLINGHAM HEREFORD

Drawing Title

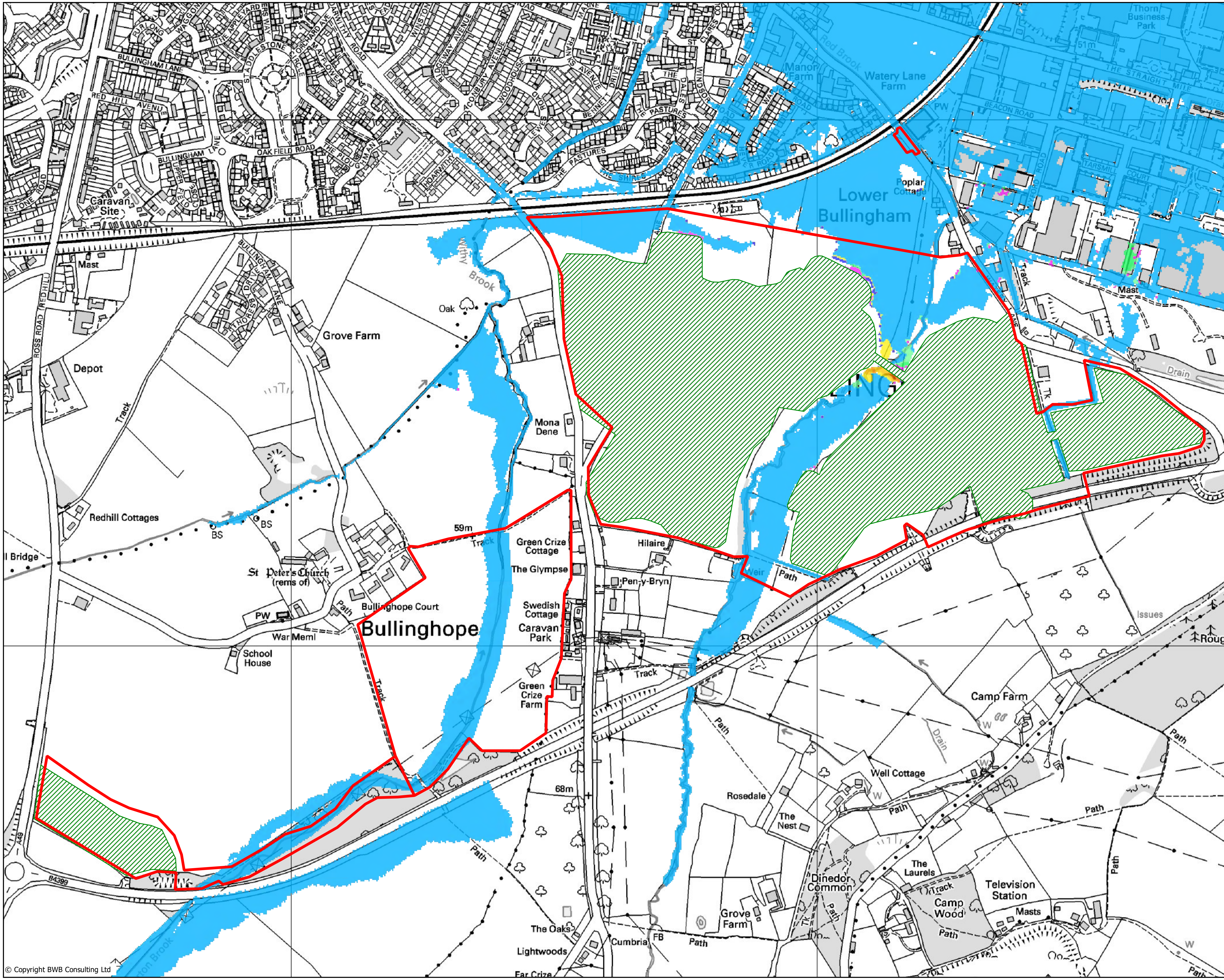
ILLUSTRATIVE DEVELOPMENT ANALYSIS: 1 IN 100-YEAR+70%

Drawn:	L Towle	Reviewed:	R Green
BWB Ref: BMW 2135	Date: 28.11.18	Scale@A3: NTS	

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
BULL-BWB-ZZ-XX-DR-YE-0130	S2	P5



Notes

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3. All dimensions in millimetres unless noted otherwise. All levels in metres unless noted otherwise.

4. Any discrepancies noted on site are to be reported to the engineer immediately.

Key

- Illustrative Site Boundary
- Illustrative Development Parcels

Change in Peak Flood Level (m)

- <= -0.125
- -0.125 - -0.100
- -0.100 - -0.075
- -0.075 - -0.050
- -0.050 - -0.025
- -0.025 - -0.01
- -0.01 - 0.01 (No Change)
- 0.01 - 0.025
- 0.025 - 0.050
- 0.050 - 0.075
- 0.075 - 0.100
- 0.100 - 0.125
- > 0.125

Change in Floodplain Extent

- Former Wet Areas Now Dry
- Former Dry Areas Now Wet

Rev	Date	Details of issues/ revision	Drw	Rev
P5	08.10.19	GENERAL UPDATE	RG	RG
P4	28.11.18	GENERAL UPDATE	LT	RG
P3	29.10.18	GENERAL UPDATE	LT	RG
P2	14.05.18	GENERAL UPDATE	RG	RG
P1	06.02.18	PRELIMINARY ISSUE	LT	RG

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Client

BLOOR HOMES

Project Title

LOWER BULLINGHAM HEREFORD

Drawing Title

ILLUSTRATIVE DEVELOPMENT ANALYSIS: 1 IN 100-YEAR+35%

Drawn:	L Towle	Reviewed:	R Green
BWB Ref:	BMW 2135	Date:	28.11.18
Scale@A3:	NTS		

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
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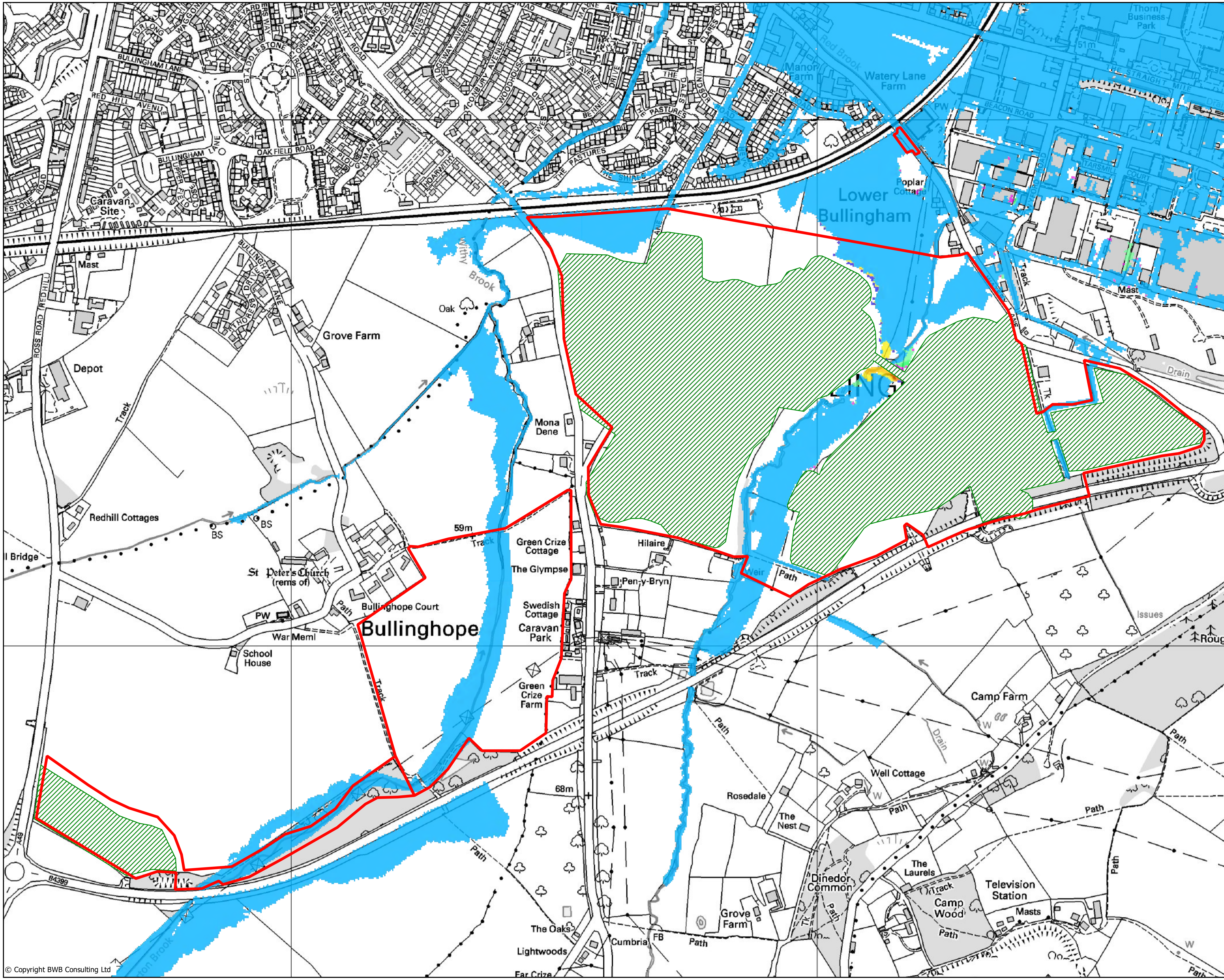

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Key

- Illustrative Site Boundary
- Illustrative Development Parcels

Change in Peak Flood Level (m)

- <= -0.125
- -0.125 - -0.100
- -0.100 - -0.075
- -0.075 - -0.050
- -0.050 - -0.025
- -0.025 - -0.01
- -0.01 - 0.01 (No Change)
- 0.01 - 0.025
- 0.025 - 0.050
- 0.050 - 0.075
- 0.075 - 0.100
- 0.100 - 0.125
- > 0.125

Change in Floodplain Extent

- Former Wet Areas Now Dry
- Former Dry Areas Now Wet

Rev	Date	Details of issues/ revision	Drw	Rev
P5	08.10.19	GENERAL UPDATE	RG	RG
P4	28.11.18	GENERAL UPDATE	LT	RG
P3	29.10.18	GENERAL UPDATE	LT	RG
P2	14.05.18	GENERAL UPDATE	RG	RG
P1	06.02.18	PRELIMINARY ISSUE	LT	RG

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Client

BLOOR HOMES

Project Title

LOWER BULLINGHAM HEREFORD

Drawing Title

ILLUSTRATIVE DEVELOPMENT ANALYSIS: 1 IN 100-YEAR+25%

Drawn:	L Towle	Reviewed:	R Green
BWB Ref:	BMW 2135	Date: 28.11.18	Scale@A3: NTS

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
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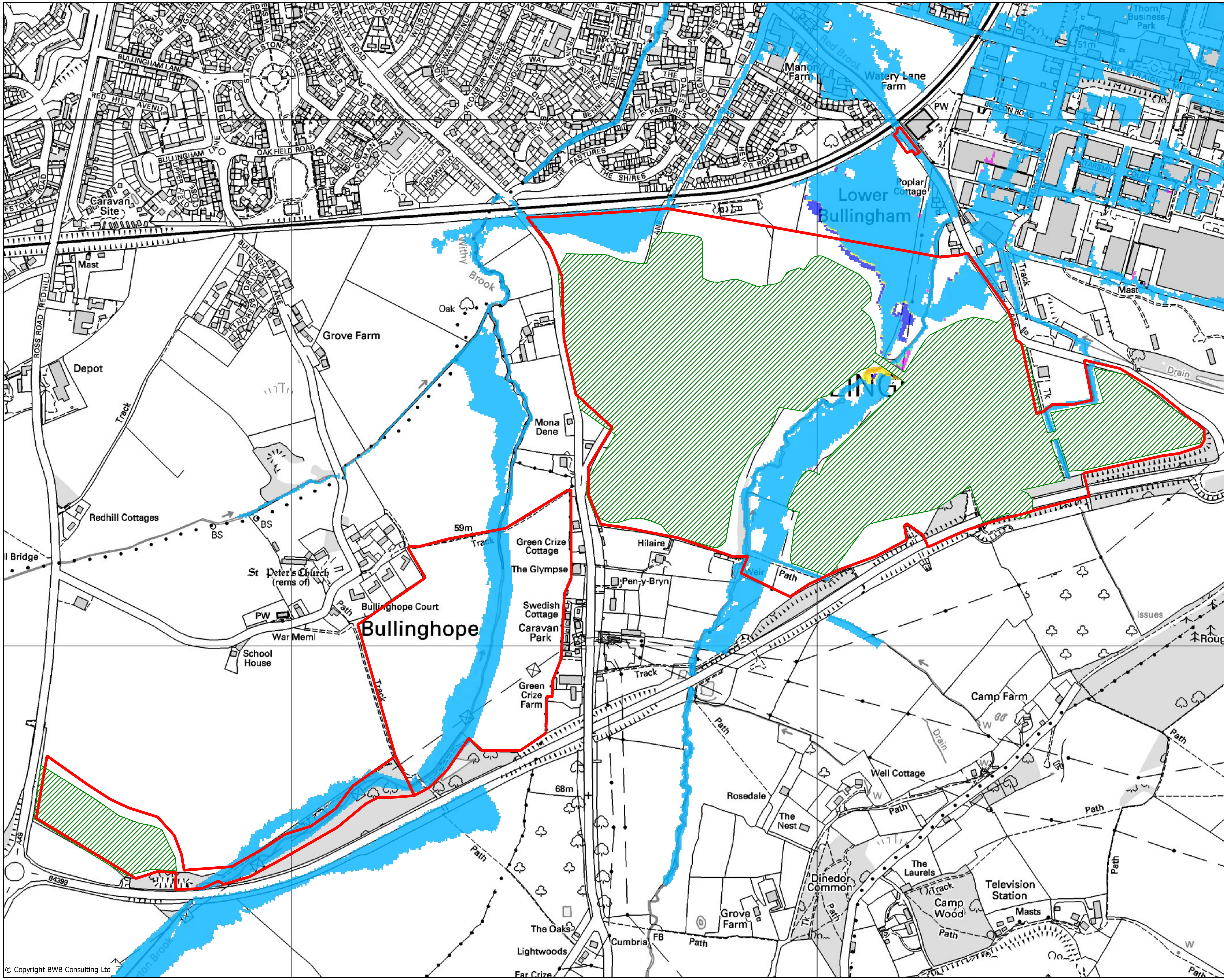

Notes

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Key

- Illustrative Site Boundary
- Illustrative Development Parcels

Change in Peak Flood Level (m)

- <= -0.125
- -0.125 - -0.100
- -0.100 - -0.075
- -0.075 - -0.050
- -0.050 - -0.025
- -0.025 - -0.01
- -0.01 - 0.01 (No Change)
- 0.01 - 0.025
- 0.025 - 0.050
- 0.050 - 0.075
- 0.075 - 0.100
- 0.100 - 0.125
- > 0.125

Change in Floodplain Extent

- Former Wet Areas Now Dry
- Former Dry Areas Now Wet

Rev	Date	Details of issues/ revision	Drw	Rev
P5	08.10.19	GENERAL UPDATE	RG	RG
P4	28.11.18	GENERAL UPDATE	LT	RG
P3	29.10.18	GENERAL UPDATE	LT	RG
P2	14.05.18	GENERAL UPDATE	RG	RG
P1	06.02.18	PRELIMINARY ISSUE	LT	RG

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BLOOR HOMES

Project Title

LOWER BULLINGHAM HEREFORD

Drawing Title

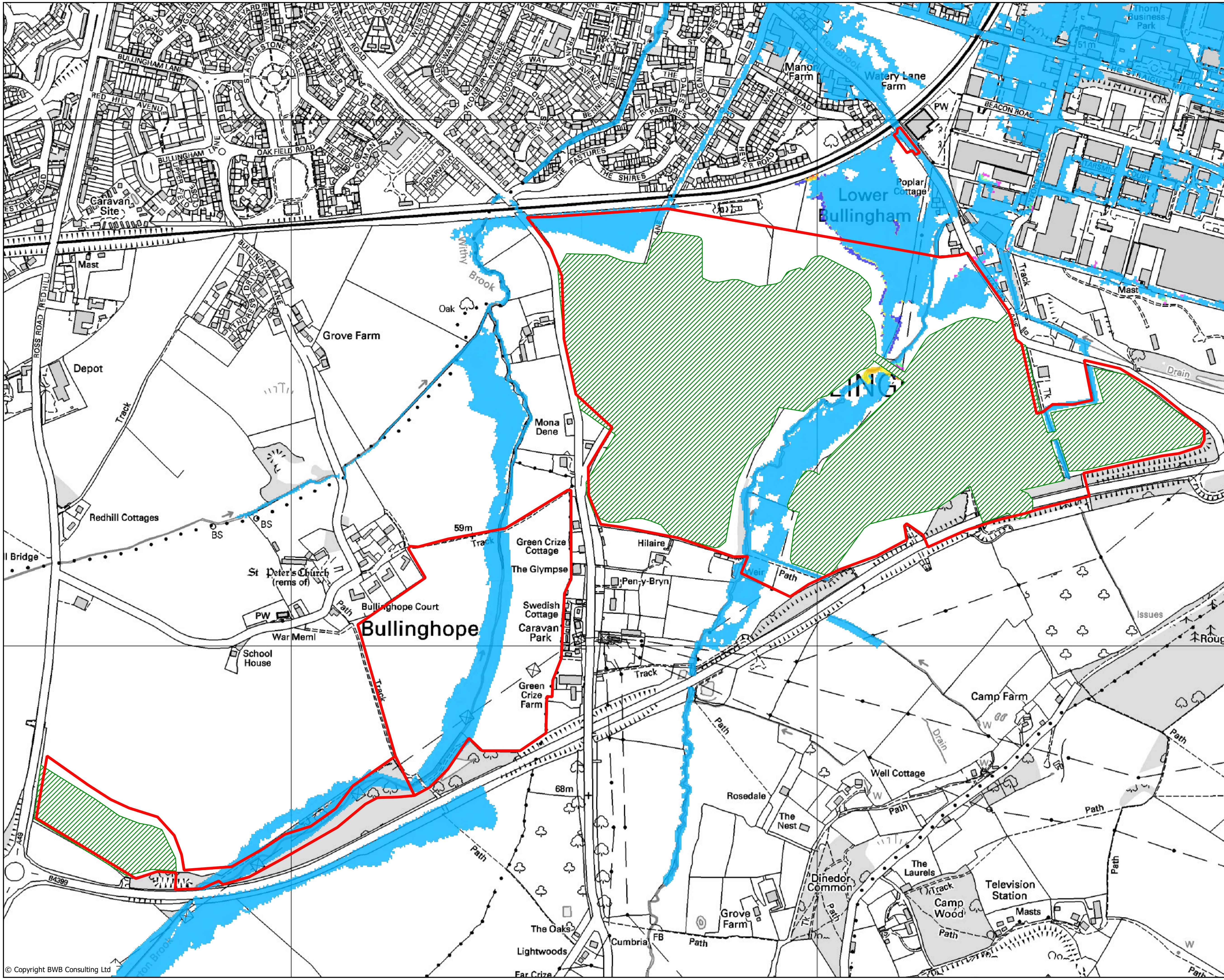
ILLUSTRATIVE DEVELOPMENT ANALYSIS: 1 IN 100-YEAR

Drawn:	L Towle	Reviewed:	R Green		
BWB Ref:	BMW 2135	Date:	28.11.18	Scale@A3:	NTS

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
BULL-BWB-ZZ-XX-DR-YE-0133	S2	P5



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3. All dimensions in millimetres unless noted otherwise. All levels in metres unless noted otherwise.

4. Any discrepancies noted on site are to be reported to the engineer immediately.

Key

Illustrative Site Boundary
Illustrative Development Parcels

Change in Peak Flood Level (m)

- <= -0.125
- -0.125 - -0.100
- -0.100 - -0.075
- -0.075 - -0.050
- -0.050 - -0.025
- -0.025 - -0.01
- -0.01 - 0.01 (No Change)
- 0.01 - 0.025
- 0.025 - 0.050
- 0.050 - 0.075
- 0.075 - 0.100
- 0.100 - 0.125
- > 0.125

Change in Floodplain Extent

- Former Wet Areas Now Dry
- Former Dry Areas Now Wet

Rev	Date	Details of issues/ revision	Drw	Rev
P5	08.10.19	GENERAL UPDATE	RG	RG
P4	28.11.18	GENERAL UPDATE	LT	RG
P3	29.10.18	GENERAL UPDATE	LT	RG
P2	14.05.18	GENERAL UPDATE	RG	RG
P1	06.02.18	PRELIMINARY ISSUE	LT	RG

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BLOOR HOMES

Project Title

LOWER BULLINGHAM HEREFORD

Drawing Title

ILLUSTRATIVE DEVELOPMENT ANALYSIS: 1 IN 75-YEAR

Drawn:	L Towle	Reviewed:	R Green
BWB Ref:	BMW 2135	Date: 28.11.18	Scale@A3: NTS

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
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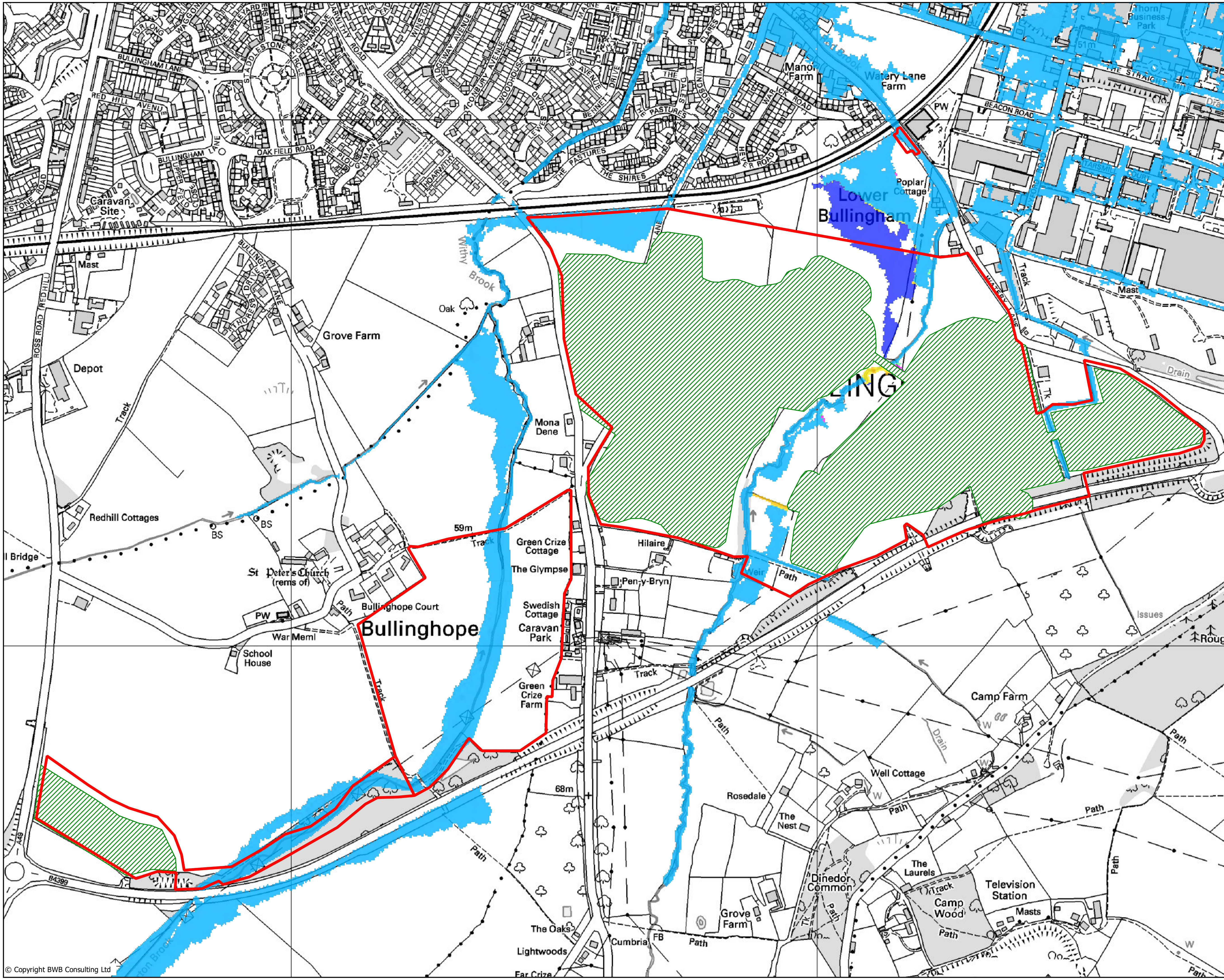

Notes

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3. All dimensions in millimetres unless noted otherwise. All levels in metres unless noted otherwise.

4. Any discrepancies noted on site are to be reported to the engineer immediately.

Key

- Illustrative Site Boundary
- Illustrative Development Parcels

Change in Peak Flood Level (m)

- <= -0.125
- -0.125 - -0.100
- -0.100 - -0.075
- -0.075 - -0.050
- -0.050 - -0.025
- -0.025 - -0.01
- -0.01 - 0.01 (No Change)
- 0.01 - 0.025
- 0.025 - 0.050
- 0.050 - 0.075
- 0.075 - 0.100
- 0.100 - 0.125
- > 0.125

Change in Floodplain Extent

- Former Wet Areas Now Dry
- Former Dry Areas Now Wet

Rev	Date	Details of issues/ revision	Drw	Rev
P5	08.10.19	GENERAL UPDATE	RG	RG
P4	28.11.18	GENERAL UPDATE	LT	RG
P3	29.10.18	GENERAL UPDATE	LT	RG
P2	14.05.18	GENERAL UPDATE	RG	RG
P1	06.02.18	PRELIMINARY ISSUE	LT	RG

Issues & Revisions

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- ☐ Nottingham | 0115 924 1100

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Client

BLOOR HOMES

Project Title

LOWER BULLINGHAM HEREFORD

Drawing Title

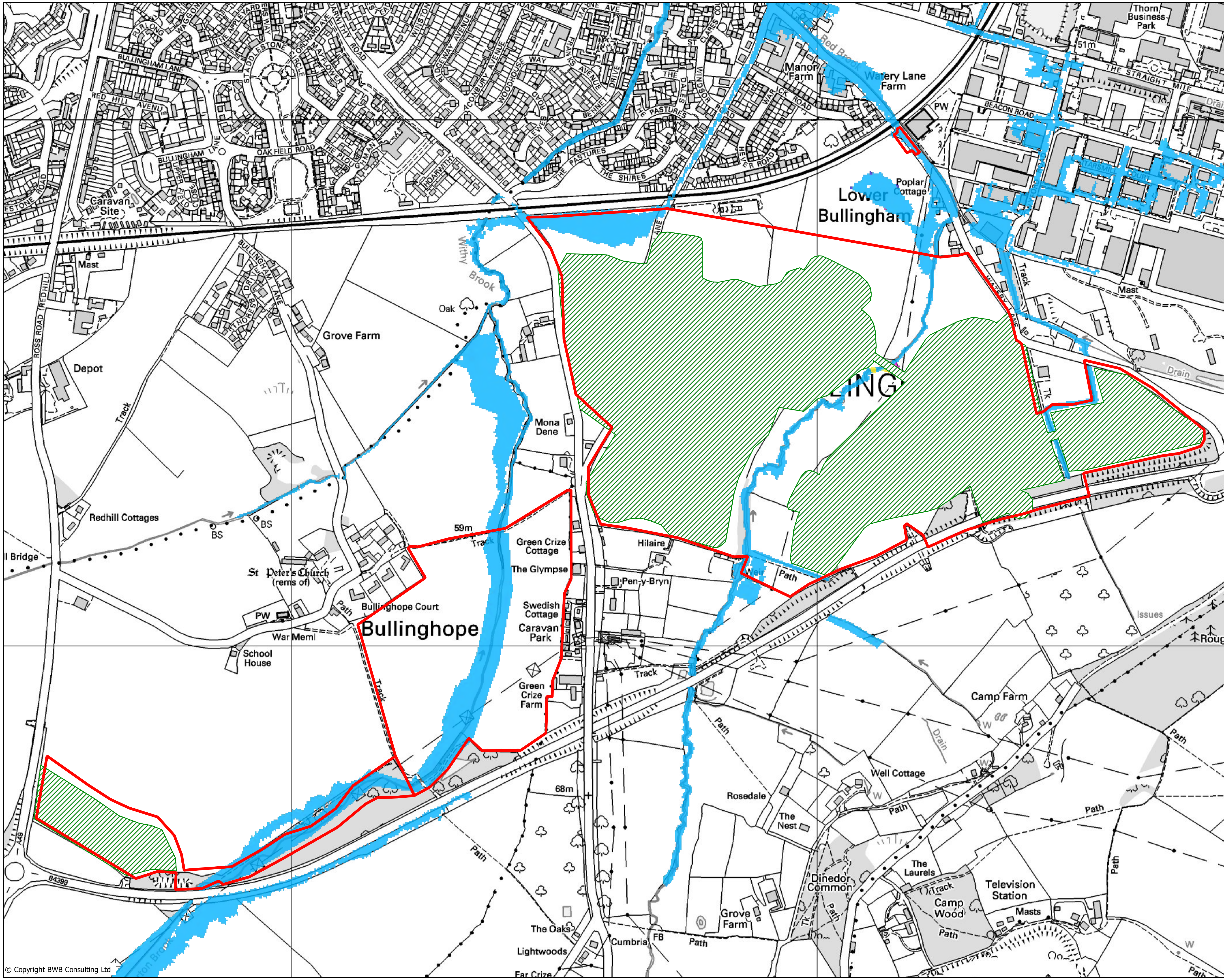
ILLUSTRATIVE DEVELOPMENT ANALYSIS: 1 IN 50-YEAR

Drawn:	L Towle	Reviewed:	R Green
BWB Ref:	BMW 2135	Date: 28.11.18	Scale@A3: NTS

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
BULL-BWB-ZZ-XX-DR-YE-0135	S2	P5



Notes

1. Do not scale this drawing. All dimensions must be checked/ verified on site. If in doubt ask.
2. This drawing is to be read in conjunction with all relevant architects, engineers and specialists drawings and specifications.
3. All dimensions in millimetres unless noted otherwise. All levels in metres unless noted otherwise.
4. Any discrepancies noted on site are to be reported to the engineer immediately.

Key

- Illustrative Site Boundary
- Illustrative Development Parcels

Change in Peak Flood Level (m)

- <= -0.125
- -0.125 - -0.100
- -0.100 - -0.075
- -0.075 - -0.050
- -0.050 - -0.025
- -0.025 - -0.01
- -0.01 - 0.01 (No Change)
- 0.01 - 0.025
- 0.025 - 0.050
- 0.050 - 0.075
- 0.075 - 0.100
- 0.100 - 0.125
- > 0.125

Change in Floodplain Extent

- Former Wet Areas Now Dry
- Former Dry Areas Now Wet

Rev	Date	Details of issues/ revision	Drw	Rev
P5	08.10.19	GENERAL UPDATE	RG	RG
P4	28.11.18	GENERAL UPDATE	LT	RG
P3	29.10.18	GENERAL UPDATE	LT	RG
P2	14.05.18	GENERAL UPDATE	RG	RG
P1	06.02.18	PRELIMINARY ISSUE	LT	RG

Issues & Revisions

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Client

BLOOR HOMES

Project Title

LOWER BULLINGHAM HEREFORD

Drawing Title

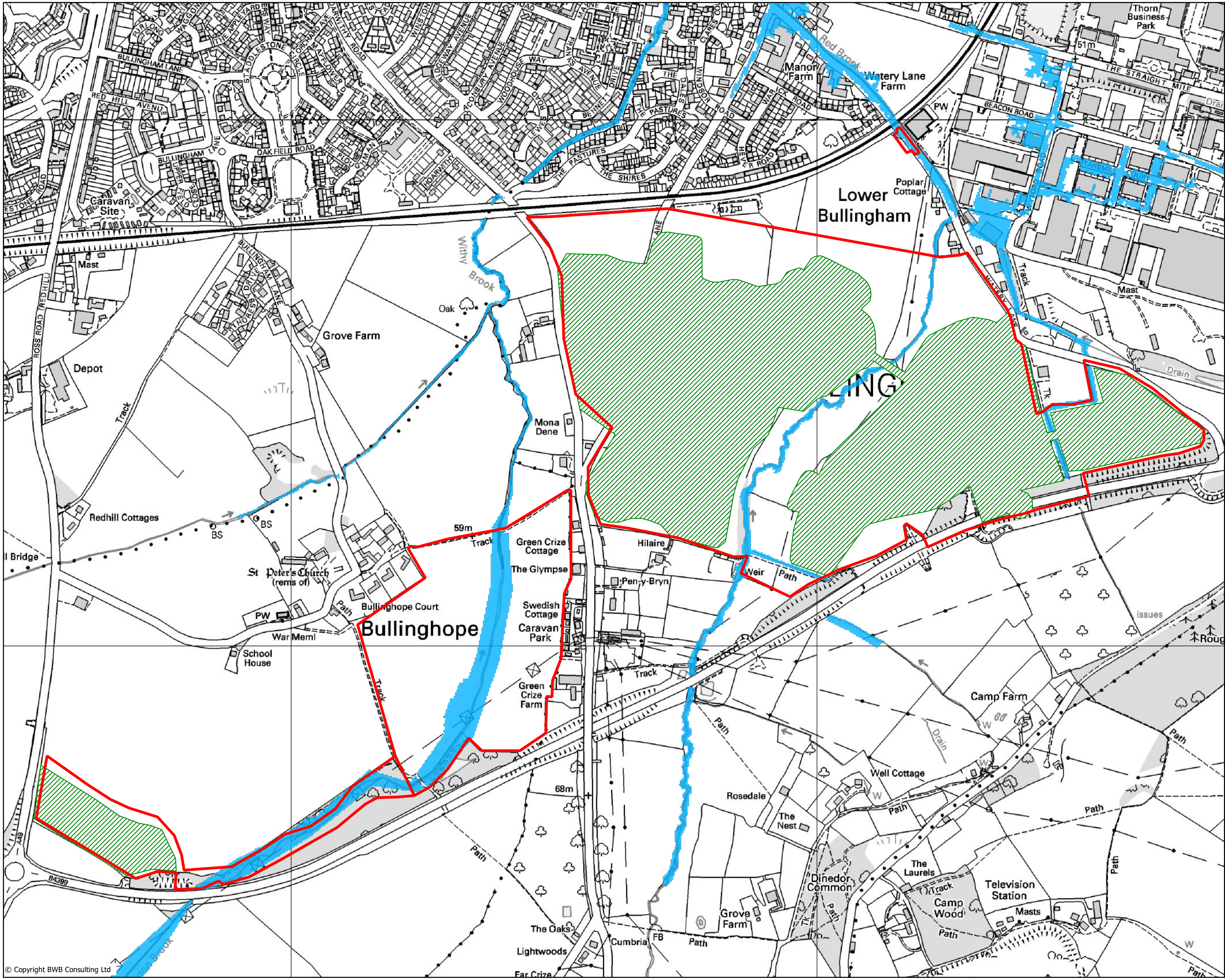
ILLUSTRATIVE DEVELOPMENT ANALYSIS: 1 IN 20-YEAR

Drawn:	L Towle	Reviewed:	R Green
BWB Ref: BMW 2135	Date: 28.11.18	Scale@A3: NTS	

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
BULL-BWB-ZZ-XX-DR-YE-0136	S2	P5



Notes

1. Do not scale this drawing. All dimensions must be checked/ verified on site. If in doubt ask.

2. This drawing is to be read in conjunction with all relevant architects, engineers and specialists drawings and specifications.

3. All dimensions in millimetres unless noted otherwise. All levels in metres unless noted otherwise.

4. Any discrepancies noted on site are to be reported to the engineer immediately.

Key

- Illustrative Site Boundary
- Illustrative Development Parcels

Change in Peak Flood Level (m)

- <= -0.125
- -0.125 - -0.100
- -0.100 - -0.075
- -0.075 - -0.050
- -0.050 - -0.025
- -0.025 - -0.01
- -0.01 - 0.01 (No Change)
- 0.01 - 0.025
- 0.025 - 0.050
- 0.050 - 0.075
- 0.075 - 0.100
- 0.100 - 0.125
- > 0.125

Change in Floodplain Extent

- Former Wet Areas Now Dry
- Former Dry Areas Now Wet

Rev	Date	Details of issues/ revision	Drw	Rev
P5	08.10.19	GENERAL UPDATE	RG	RG
P4	28.11.18	GENERAL UPDATE	LT	RG
P3	29.10.18	GENERAL UPDATE	LT	RG
P2	14.05.18	GENERAL UPDATE	RG	RG
P1	06.02.18	PRELIMINARY ISSUE	LT	RG

Issues & Revisions

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Client

BLOOR HOMES

Project Title

LOWER BULLINGHAM HEREFORD

Drawing Title

ILLUSTRATIVE DEVELOPMENT ANALYSIS: 1 IN 5-YEAR

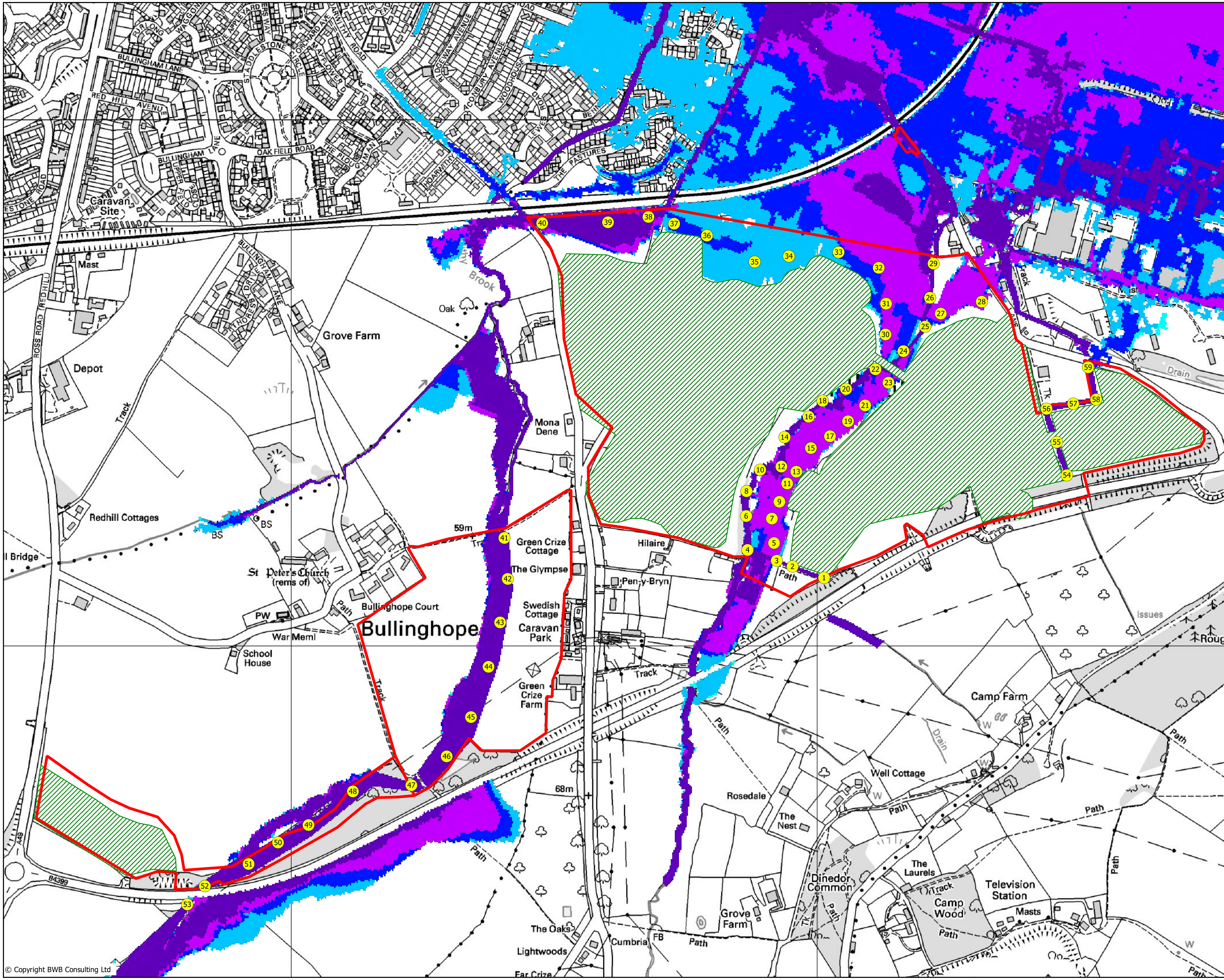
Drawn:	L Towle		Reviewed:	R Green	
BWB Ref:	BMW 2135	Date:	28.11.18	Scale@A3:	NTS

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
BULL-BWB-ZZ-XX-DR-YE-0137	S2	P5

APPENDIX 7: Tabulated Flood Levels



Notes

1. Do not scale this drawing. All dimensions must be checked/ verified on site. If in doubt ask.

2. This drawing is to be read in conjunction with all relevant architects, engineers and specialists drawings and specifications.

3. All dimensions in millimetres unless noted otherwise. All levels in metres unless noted otherwise.

4. Any discrepancies noted on site are to be reported to the engineer immediately.

Key

Illustrative Site Boundary
Flood Level Interrogation Points
Illustrative Development Parcels

Floodplain Extent
1 in 20-Year
1 in 100-Year
1 in 100-Year+35%
1 in 100-Year+70%
1 in 1000-Year

Rev	Date	Details of issues/ revision	Drw	Rev
P5	08.10.19	GENERAL UPDATE	RG	RG
P4	28.11.18	GENERAL UPDATE	LT	RG
P3	29.10.18	GENERAL UPDATE	LT	RG
P2	14.05.18	GENERAL UPDATE	RG	RG
P1	06.02.18	PRELIMINARY ISSUE	LT	RG

Issues & Revisions

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Client

BLOOR HOMES

Project Title

LOWER BULLINGHAM HEREFORD

Drawing Title

FLOOD LEVEL INTERROGATION LOCATIONS

Drawn:	L Towle	Reviewed:	R Green		
BWB Ref:	BMW 2135	Date:	28.11.18	Scale@A3:	NTS

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
BULL-BWB-ZZ-XX-DR-YE-0138	**S2**	**P5**

ID	Modelled Flood Levels (mAOD)														
	Design Flood Events					Sensitivity Tests (@ 1 in 100-Year Event)									
	1 in 20	1 in 100	1 in 100+35%	1 in 100+70%	1 in 1000	Roughness - 20%	Roughness + 20%	Blockage 8	Blockage 7	Blockage 6	Blockage 5	Blockage 4	Blockage 3	Blockage 2	Blockage 1
1	63.06	63.08	63.11	63.14	63.15	63.03	63.13	63.08	63.08	63.08	63.08	63.10	63.08	63.08	63.08
2	60.37	60.40	60.44	60.46	60.47	60.36	60.45	60.40	60.40	60.40	60.40	60.41	60.40	60.40	60.40
3	59.71	59.72	59.72	59.75	59.75	59.70	59.73	59.72	59.72	59.72	59.72	59.72	59.72	59.72	59.72
4	58.72	58.86	58.97	59.03	59.04	58.76	58.93	58.86	58.86	58.86	58.86	58.86	58.85	58.86	58.86
5		58.84	58.85	58.86	58.86		58.85	58.84	58.84	58.84	58.84	58.84	58.84	58.84	58.84
6	58.14	58.25	58.31	58.34	58.34	58.17	58.30	58.25	58.25	58.25	58.25	58.25	58.24	58.25	58.25
7		58.25	58.28	58.30	58.31		58.27	58.25	58.25	58.25	58.25	58.25	58.24	58.25	58.25
8	57.71	57.81	57.85	57.86	57.86	57.74	57.83	57.81	57.81	57.81	57.81	57.81	57.80	57.81	57.81
9		57.70	57.73	57.74	57.75		57.72	57.70	57.70	57.70	57.70	57.70	57.69	57.70	57.70
10	57.28	57.36	57.40	57.42	57.43	57.31	57.39	57.36	57.36	57.36	57.36	57.36	57.36	57.36	57.36
11		57.28	57.32	57.35	57.35		57.31	57.28	57.28	57.28	57.28	57.28	57.27	57.28	57.28
12	56.99	57.10	57.14	57.16	57.17	57.04	57.11	57.10	57.10	57.10	57.10	57.10	57.09	57.10	57.10
13		57.21	57.24	57.26	57.26		57.24	57.21	57.21	57.21	57.21	57.21	57.21	57.21	57.21
14	56.37	56.49	56.57	56.62	56.62	56.41	56.54	56.49	56.49	56.49	56.49	56.49	56.48	56.49	56.49
15		56.67	56.68	56.69	56.69		56.68	56.67	56.67	56.67	56.67	56.67	56.66	56.67	56.67
16	55.70	55.84	55.93	55.98	55.99	55.74	55.90	55.84	55.84	55.84	55.84	55.84	55.83	55.84	55.84
17		56.04	56.05	56.06	56.06		56.05	56.04	56.04	56.04	56.04	56.04	56.04	56.04	56.04
18	55.54	55.70	55.78	55.83	55.83	55.59	55.74	55.70	55.70	55.70	55.70	55.70	55.68	55.70	55.70
19		55.66	55.68	55.69	55.69		55.67	55.66	55.66	55.66	55.66	55.66	55.66	55.66	55.66
20	55.00	55.14	55.25	55.30	55.30	55.04	55.22	55.14	55.14	55.14	55.14	55.14	55.13	55.14	55.14
21		55.26	55.28	55.31	55.31		55.27	55.26	55.26	55.26	55.26	55.26	55.25	55.26	55.26
22	54.44	54.55	54.62	54.66	54.66	54.46	54.61	54.55	54.55	54.55	54.55	54.55	54.54	54.55	54.55
23		54.72	54.73	54.75	54.75		54.73	54.72	54.72	54.72	54.72	54.72	54.72	54.72	54.72
24	54.07	54.23	54.31	54.35	54.35	54.11	54.29	54.23	54.23	54.23	54.23	54.23	54.21	54.23	54.23
25	53.64	53.76	53.81	53.82	53.83	53.67	53.80	53.76	53.76	53.76	53.76	53.76	53.75	53.76	53.76
26	53.18	53.27	53.29	53.30	53.30	53.21	53.29	53.27	53.27	53.27	53.27	53.27	53.26	53.27	53.27
27		53.26	53.27	53.28	53.28		53.27	53.26	53.26	53.26	53.26	53.26	53.26	53.26	53.26
28		52.45	52.45	52.45	52.45		52.45	52.45	52.45	52.45	52.45	52.45	52.44	52.45	52.45
29	52.68	52.73	52.73	52.74	52.74	52.70	52.73	52.73	52.73	52.73	52.73	52.73	52.72	52.73	52.73
30		53.93	53.95	53.96	53.96		53.94	53.93	53.93	53.93	53.93	53.93	53.93	53.93	53.93
31		53.49	53.53	53.55	53.55		53.52	53.49	53.49	53.49	53.49	53.49	53.49	53.49	53.49
32		52.89	52.89	52.90	52.90		52.89	52.89	52.89	52.89	52.89	52.89	52.89	52.89	52.89
33			52.23	52.24	52.24		52.23								
34				52.25	52.14										52.09

ID	Modelled Flood Levels (mAOD)														
	Design Flood Events					Sensitivity Tests (@ 1 in 100-Year Event)									
	1 in 20	1 in 100	1 in 100+35%	1 in 100+70%	1 in 1000	Roughness - 20%	Roughness + 20%	Blockage 8	Blockage 7	Blockage 6	Blockage 5	Blockage 4	Blockage 3	Blockage 2	Blockage 1
35			52.06	52.26	52.14										52.13
36			52.06	52.27	52.14	51.89		51.87							52.13
37			52.13	52.29	52.16										52.15
38	52.43	52.49	52.53	52.56	52.55	52.49	52.49	52.49	52.45	52.49	52.49	52.49	52.49	52.49	52.58
39	52.73	52.76	52.79	52.80	52.81	52.76	52.76	52.76	52.74	52.76	52.76	52.76	52.76	52.76	52.82
40	53.64	53.70	53.74	53.77	53.77	53.70	53.70	53.70	53.66	53.70	53.70	53.70	53.70	53.70	53.80
41	58.29	58.31	58.33	58.34	58.34	58.33	58.31	58.32	58.16	58.31	58.31	58.31	58.31	58.31	58.31
42	58.31	58.34	58.36	58.37	58.37	58.35	58.35	58.35	58.19	58.34	58.34	58.34	58.34	58.34	58.34
43	58.50	58.52	58.54	58.55	58.55	58.52	58.53	58.53	58.40	58.52	58.52	58.52	58.52	58.52	58.52
44	58.75	58.76	58.78	58.78	58.78	58.75	58.78	58.77	58.69	58.76	58.76	58.76	58.76	58.76	58.76
45	59.14	59.15	59.15	59.16	59.16	59.14	59.16	59.15	59.12	59.15	59.15	59.15	59.15	59.15	59.15
46	59.38	59.39	59.41	59.41	59.41	59.38	59.43	59.35	59.35	59.39	59.39	59.39	59.39	59.39	59.39
47	59.83	59.88	59.94	60.00	60.00	60.01	59.88	60.24	59.69	59.88	59.88	59.88	59.88	59.88	59.88
48	60.46	60.49	60.51	60.52	60.52	60.49	60.51	60.53	60.38	60.49	60.49	60.49	60.49	60.49	60.49
49	60.93	60.93	60.94	60.94	60.94	60.92	60.93	60.83	60.89	60.93	60.93	60.93	60.93	60.93	60.93
50	61.16	61.17	61.18	61.18	61.18	61.16	61.18	61.12	61.12	61.17	61.17	61.17	61.17	61.17	61.17
51	61.40	61.42	61.43	61.44	61.44	61.40	61.43	61.42	61.36	61.42	61.42	61.42	61.42	61.42	61.42
52	61.91	61.94	61.97	61.98	61.98	61.92	61.98	61.94	61.82	61.94	61.94	61.94	61.94	61.94	61.94
53	62.11	62.22	62.27	62.30	62.30	62.19	62.23	62.20	62.32	62.22	62.22	62.22	62.22	62.22	62.22
54	60.67	60.71	60.73	60.76	60.76	60.68	60.72	60.71	60.71	60.71	60.71	60.71	60.71	60.71	60.71
55	58.52	58.58	58.60	58.63	58.64	58.59	58.60	58.58	58.58	58.58	58.63	58.58	58.58	58.58	58.58
56	57.41	57.47	57.49	57.51	57.52	57.45	57.49	57.47	57.47	57.47	57.51	57.47	57.47	57.47	57.47
57	56.02	56.10	56.12	56.15	56.15	56.08	56.12	56.10	56.10	56.10	56.19	56.10	56.10	56.10	56.10
58	54.72	54.79	54.80	54.81	54.81	54.76	54.81	54.79	54.79	54.79	54.88	54.79	54.79	54.79	54.79
59	52.94	53.64	53.65	53.66	53.66	53.65	53.64	53.64	53.64	53.64	53.68	53.64	53.64	53.64	53.64

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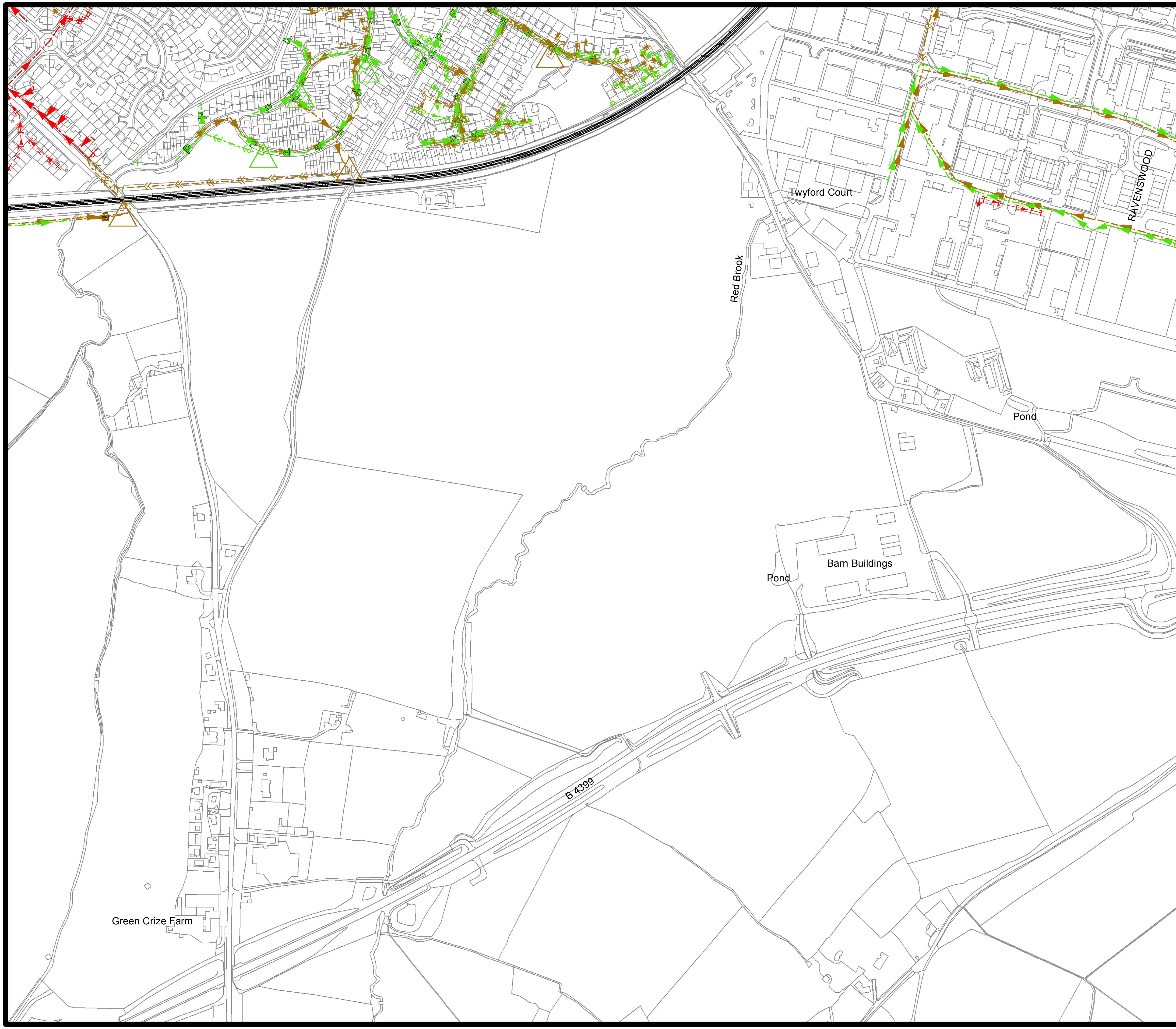
APPENDIX 4: Sewer Records



Dŵr Cymru
Welsh Water

hereford

N
W E
S

LEGEND(Representative of most common features)

Waste network:

Foul chamber	Outfall
Surface water chamber	LH Lamphole
Combined chamber	Storm Overflow
C O Combined sewer overflow	Rising main
SPC Special purpose chamber	Gravity sewer
Treatment works	P Private sewer
Pumping station	S 104 P Private sewer subject to Sect. 104 adoption agreement
	T Private Sewer Transfer
	L Lateral Drain
	Inspection Chamber

NB: Sewer symbol colour indicates the type.

RED - Combined
GREEN - Surface Water
BROWN - Foul
Purple - Former S24 sewers (for indicative purposes only)

Notes:

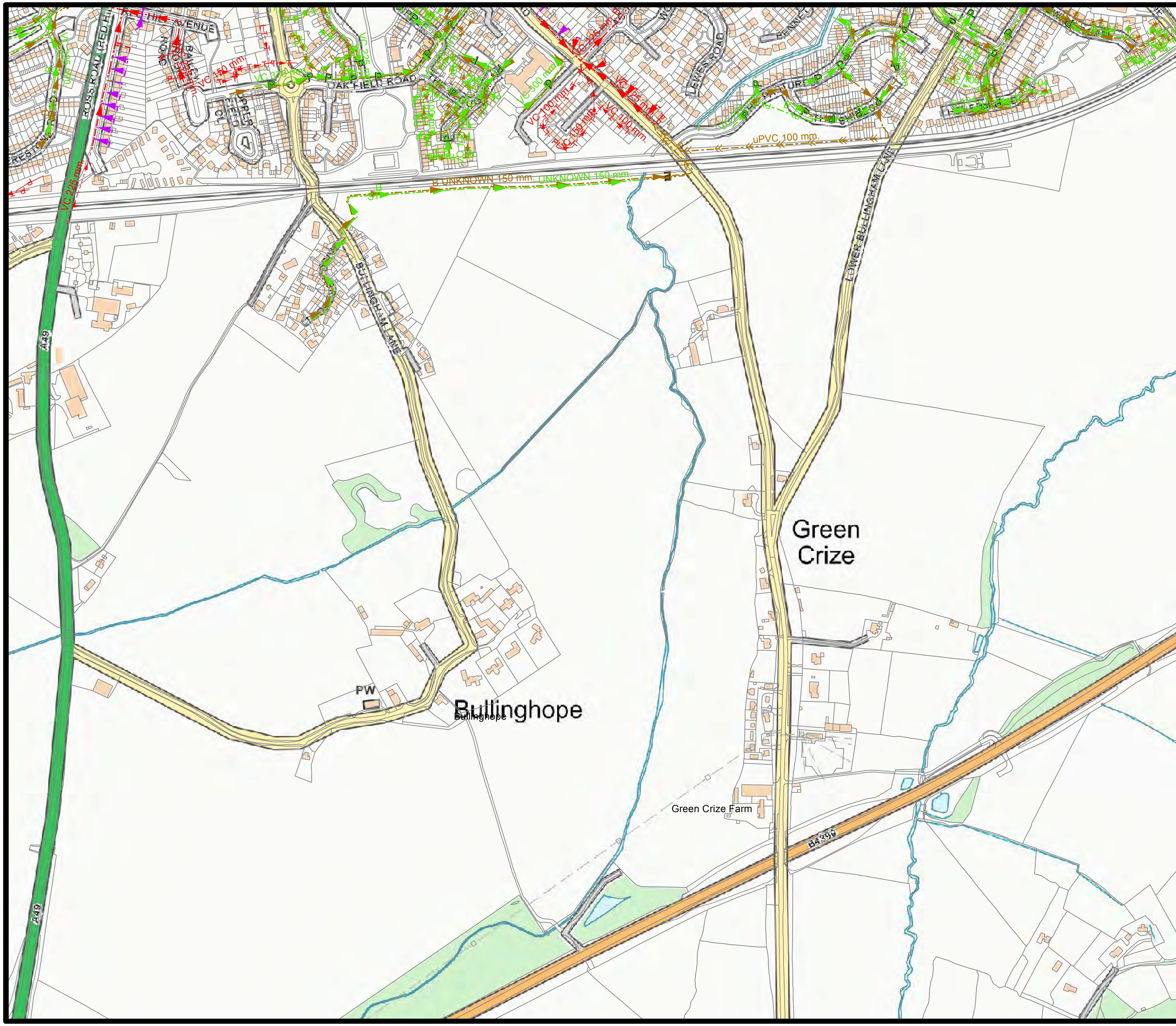
Whilst every reasonable effort has been taken to correctly record the pipe material of DCWW assets, there is a possibility that in some cases pipe material (other than Asbestos Cement or Pitch Fibre) may be found to be asbestos cement (AC) or Pitch Fibre (PF) . It is therefore advisable that the possible presence of AC or PF pipes be anticipated and considered as part of any risk assessment prior to excavation

Dwr Cymru Cyf gives this information as to the position of its underground apparatus by way of general guidance only on the strict understanding that it is based on the best information available and no warranty as to its correctness is relied upon in the event of excavations or other works made in the vicinity of the Company's apparatus and any onus of locating the apparatus before carrying out any excavations rests entirely on you. It must be understood that the furnishing of the information is entirely without prejudice to the provision of the New Roads and Streetworks Act 1991 and of the Company's right to be compensated for any damage to its apparatus.

Service pipes are not generally shown but their presence should be anticipated.

EXACT LOCATIONS OF ALL APPARATUS TO BE DETERMINED ON SITE.

Map Ref:	352026,237381
Map scale:	1:4,500
Printed by:	NP
Printed on:	17-07-17



Dŵr Cymru
Welsh Water

Lower Bullingham, Herefordshire

N
W E
S

LEGEND(Representative of most common features)

Waste network:

	Foul chamber		Outfall
	Surface water chamber	LH	Lamphole
	Combined chamber		Storm Overflow
C O	Combined sewer overflow		Rising main
SPC	Special purpose chamber		Gravity sewer
	Treatment works	P	Private sewer
	Pumping station	S 104 P	Private sewer subject to Sect. 104 adoption agreement
		T	Private Sewer Transfer
		L	Lateral Drain
			Inspection Chamber

NB: Sewer symbol colour indicates the type.

RED - Combined
GREEN - Surface Water
BROWN - Foul
Purple - Former S24 sewers (for indicative purposes only)

Notes:

Whilst every reasonable effort has been taken to correctly record the pipe material of DCWW assets, there is a possibility that in some cases pipe material (other than Asbestos Cement or Pitch Fibre) may be found to be asbestos cement (AC) or Pitch Fibre (PF) . It is therefore advisable that the possible presence of AC or PF pipes be anticipated and considered as part of any risk assessment prior to excavation

Dwr Cymru Cyf gives this information as to the position of its underground apparatus by way of general guidance only on the strict understanding that it is based on the best information available and no warranty as to its correctness is relied upon in the event of excavations or other works made in the vicinity of the Company's apparatus and any onus of locating the apparatus before carrying out any excavations rests entirely on you. It must be understood that the furnishing of the information is entirely without prejudice to the provision of the New Roads and Streetworks Act 1991 and of the Company's right to be compensated for any damage to its apparatus.

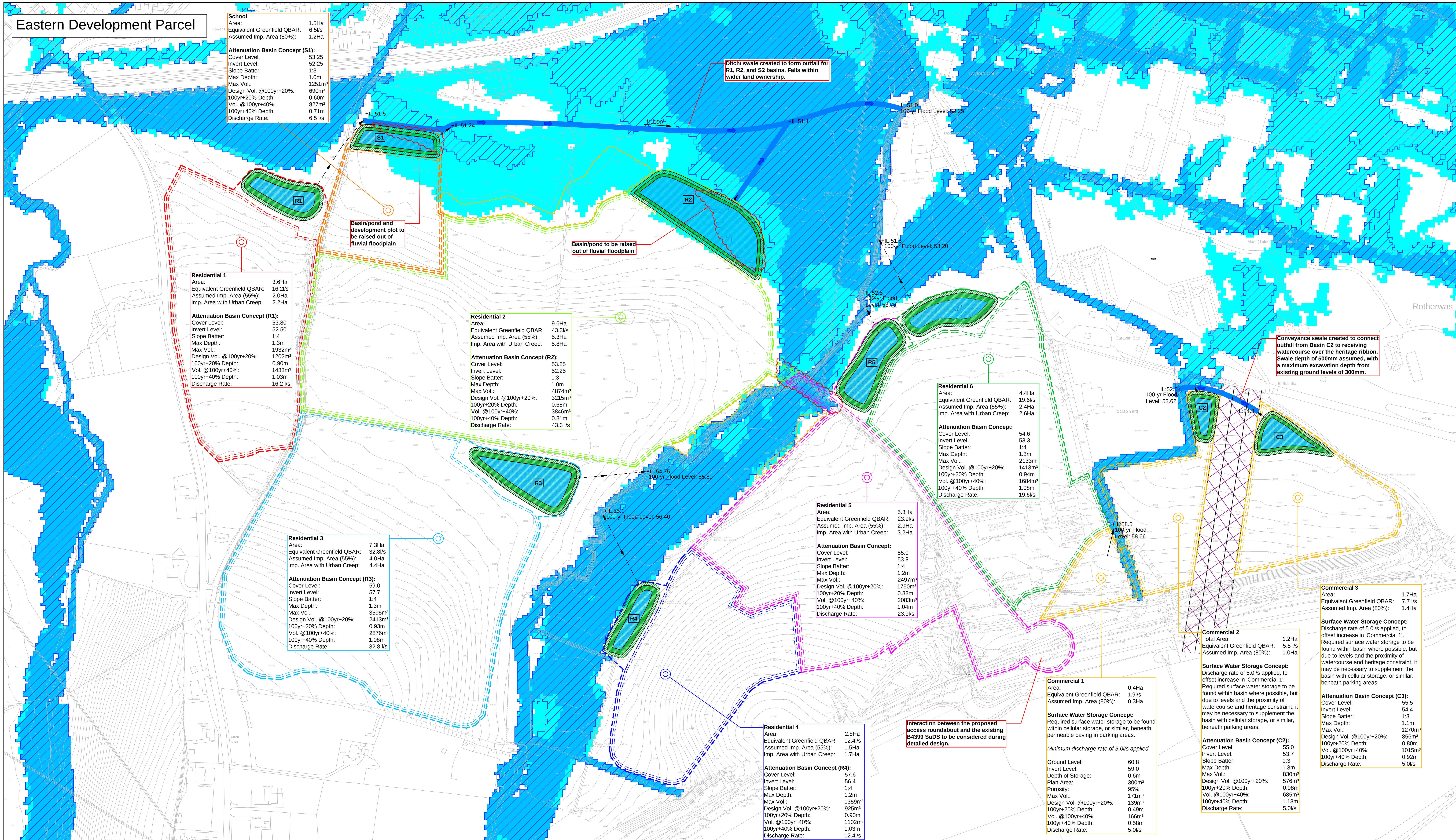
Service pipes are not generally shown but their presence should be anticipated.

EXACT LOCATIONS OF ALL APPARATUS TO BE DETERMINED ON SITE.

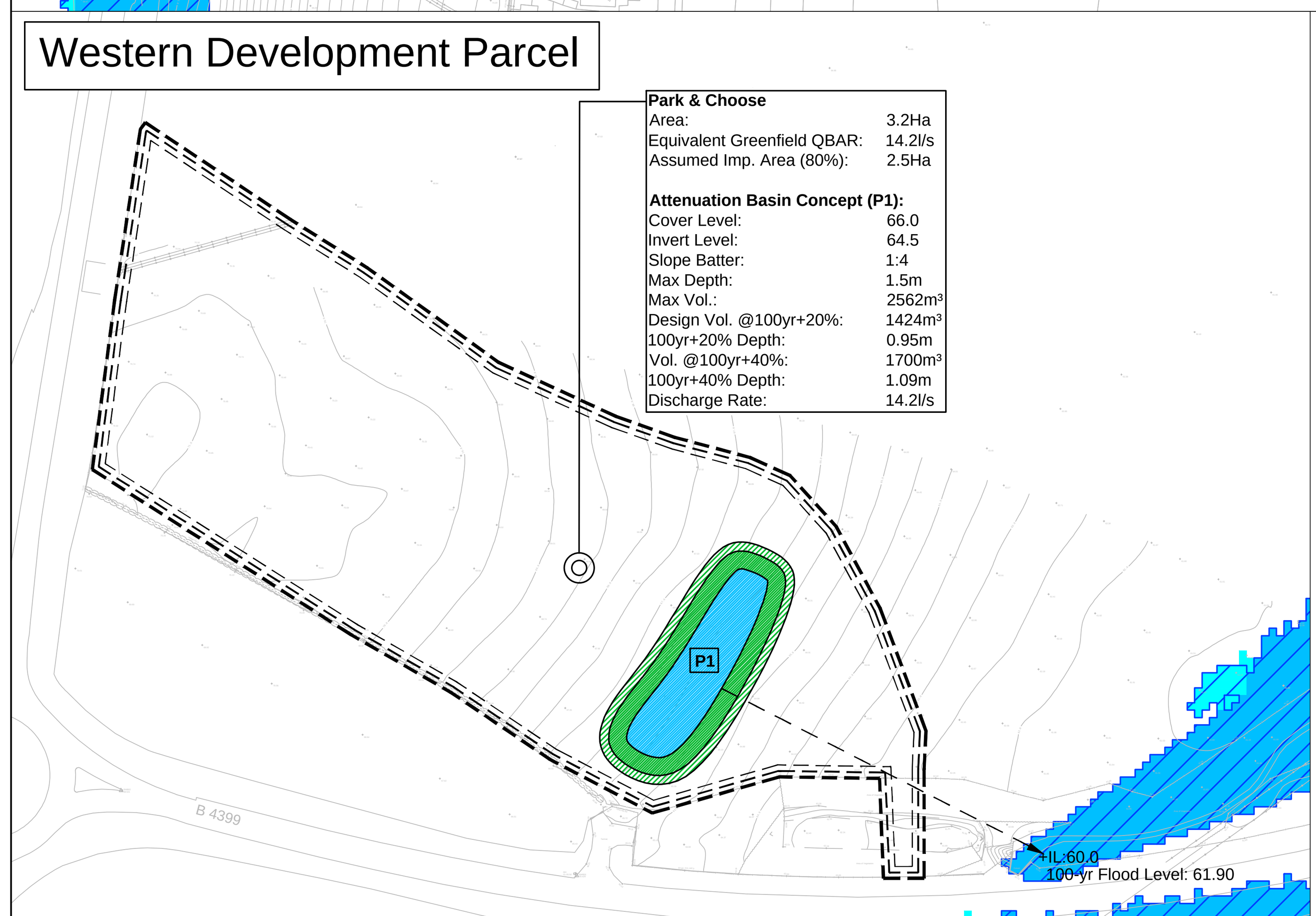
Map Ref:	351297,237330
Map scale:	1:5000
Printed by:	Twidle David
Printed on:	05 Sep 2017

APPENDIX 5: Illustrative Surface Water Drainage Strategy

Eastern Development Parcel



Western Development Parcel



Drainage Catchment	Area (Ha)	Equivalent Greenfield QBAR runoff Rate (@ 4.5l/s/ha)	Assumed Development Coverage	Drainage Area (Ha)	Future Drainage Area (Ha) *following application of 10% Urban Creep to Resi area*	Proposed Discharge Rate (l/s)^	Conceptual Storage Provision (m³)	
							Design Event (100yr+20%)	Resilience Check (100yr+40%)
Residential 1	3.6	16.2	55%	2.0	2.2	16.2	1202	1433
Residential 2	9.6	43.3	55%	5.3	5.8	43.3	3215	3846
Residential 3	7.3	32.8	55%	4.0	4.4	32.8	2413	2876
Residential 4	2.8	12.4	55%	1.5	1.7	12.4	925	1102
Residential 5	5.3	23.9	55%	2.9	3.2	23.9	1750	2083
Residential 6	4.4	19.6	55%	2.4	2.6	19.6	1413	1684
School	1.5	6.5	80%	1.2	1.2	6.5	690	827
Commercial 1	0.4	1.9	80%	0.3	0.3	5.0	139	166
Commercial 2	1.2	5.5	80%	1.0	1.0	5.0	576	685
Commercial 3	1.7	7.7	80%	1.4	1.4	5.0	856	1015
Park & Choose	3.2	14.2	80%	2.5	2.5	14.2	1424	1700
TOTAL	40.9	184.1	-	24.5	26.3	184.0	14603	17417

^Minimum flow restriction of 5l/s adopted.

Return Period (Yrs)	Runoff Rates (l/s)	
	Existing	Proposed
QBAR	184.1	184.0
30YR	324.8	184.0
100YR	401.5	184.0
100YR+40%	-	184.0

Flow Control:
The Hereford SFRA identifies that over attenuation of surface water runoff from a development can lead to an increase in flood risk in the next sequential watercourse due to the extension of the discharge hydrograph. It suggests using a variable greenfield discharge rate to mimic the existing conditions, but also that each development should be reviewed separately to understand all the local issues.

The Hereford SFRA identifies that the Red Brook is likely to be overloaded by additional runoff from the site. Therefore, it is believed that restricting runoff from the site to the equivalent greenfield QBAR rate would represent the best approach to minimise the impact of the development:
- as it mitigates any increase in runoff rates and volumes from the development to the Red Brook;
- it is believed that the attenuated flows leaving the development will be insignificant when compared to the flood flows on the River Wye.

Discharge Location:
The underlying ground conditions are understood to have little infiltration potential, and the site currently drains via overland flows towards the local watercourses.It is proposed that the development continues to outfall to the local watercourse at the equivalent greenfield QBAR rate.

Volume Control:
Development of the site will increase the equivalent runoff volume due to the introduction of new impermeable surfaces. It is proposed to mitigate this increase through adopting a maximum discharge rate set to the equivalent greenfield QBAR rate.

Storage Volumes:
Potential surface water storage volumes have been calculated for the 100-year storm event, with a 20% allowance for climate change, for the illustrative drainage areas. Storage requirements and locations presented are based on an outline assessment, and are subject to change as the masterplan develops and as any potential constraints become apparent.

The illustrative storage provision have also been tested against the 100-year storm event, with a 40% allowance for climate change as a resilience check.

Water Treatment & Conveyance:
The required surface water storage has been located within attenuation basins where possible, these will provide a level of treatment to the runoff from the development prior to it leaving the site. It is recommended that permeable materials and other source control techniques such as filter strips, swales, bio-retention and filter drains are considered throughout the development to provide additional levels of water treatment.

It is recommended that runoff is put through a minimum of 2 levels of treatment prior to leaving the site.

It is recommended that swales are used where possible in preference to a piped drainage system to convey surface water through the site.

Notes

1. Do not scale this drawing. All dimensions must be checked/ verified on site. If in doubt ask.
2. This drawing is to be read in conjunction with all relevant architects, engineers and specialists drawings and specifications.
3. All dimensions in millimetres unless noted otherwise. All levels in metres unless noted otherwise.
4. Any discrepancies noted on site are to be reported to the engineer immediately.
5. This strategy is purely indicative and has been prepared to demonstrate the principles of the surface water drainage strategy. This is not for construction.
6. The topographic survey and masterplan have been used to locate and size the surface water storage features. Their location does not account for the presence of potential underground services or utilities.
7. The illustrated storage areas do not account for the batter required to meet existing ground levels.
8. The illustrated drainage catchments assume that development levels will be re-profiled where necessary.
9. All discharge rates, SuDS, storage locations and volumes are indicative only and are subject to change during detailed design.
10. An assumed offset of 8m has been provided from each side of the watercourse channels.

Legend

Heritage Ribbon

Floodplain
- 2019 Modelled 1 in 100-year Floodplain
- 2019 Modelled 1 in 100-year + 35% Floodplain
- 2019 Modelled 1 in 1000-year Floodplain
- Areas of Potential Encroachment into the 100-year+35% Floodplain (subject to final design)
- Areas Available for any Necessary Floodplain Compensation (subject to final design)

Illustrative Surface Water Drainage Stratgey
- Drainage Catchments (Colours Vary).
- Strategic Ditch/Swale(s)
- Outfall Locations
- Attenuation Basins, as follows:
  - Base
  - Side slope
  - 3m Maintenance Offset

Rev	Date	Details of issue / revision	Drw	Rev
P11	10.10.19	Latest Modelled Floodplain Added	RG	HG
P10	13.11.18	Latest Modelled Floodplain Added	HG	RG
P09	16.08.18	Updated to reflect heritage constraints	HG	RG
P08	29.05.18	General Update	HG	RG
P07	17.05.18	General Update	HG	RG
P06	16.02.18	Basin P1 Relocated	HG	RG
P05	08.02.18	Latest Floodplain Extents Added	HG	RG
P04	01.02.18	General Update	HG	RG
P03	30.01.18	General Update	HG	RG
P02	27.01.18	General Update	HG	RG
P01	25.01.18	Preliminary Issue	HG	RG

Issues & Revisions

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Client
BLOOR HOMES LIMITED

Project Title
LOWER BULLINGHAM, HEREFORD

Drawing Title
CONCEPTUAL SURFACE WATER DRAINAGE STRATEGY

Drawn:	H. GRIFFITHS	Reviewed:	R. GREEN	
BWB Ref:	BMW 2135	Date:	25.01.18	Scale@A1: 1:2000

Drawing Status
PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
BUL-BWB-ZZ-XX-SK-YE-0001	S2	P11

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