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ENVIRONMENT

Richborough Estates Ltd and Lone Star Land
Heyford Park
Upper Heyford, Oxfordshire
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 Richborough Estates Ltd and Lone Star Land in respect of an outline planning application for the erection of up to 230 dwellings, creation of new vehicular access from Camp Road and all associated works. The proposed development is located at Heyford Park, Camp Road, Upper Heyford, Oxfordshire (NGR: SP520259).

This report demonstrates that the proposed development is at an acceptable level of flood risk, subject to the recommended flood mitigation strategies being implemented.

Following review of the Environment Agency (EA) Flood Map for Planning, the site is shown to be located wholly in Flood Zone 1. The Gallos Brook, an ordinary watercourse, flows north to south through the site. This is not represented on the Flood Map for Planning due to its catchment area being <3km^2, which is the threshold used by the national mapping tool. Subsequently, a capacity assessment has been undertaken to inform an understanding of the fluvial flood risk posed by the local watercourse network. This exercise uses a combination of peak flow estimates derived from ReFH2, a watercourse survey and the Manning's equation for determining open channel flows. A conservative freeboard of 300mm has been added to estimated design flood levels to account for any uncertainties.

Following the capacity assessment, all residential units are shown to be located on land above the estimated 1 in 100-year +15%CC design flood level (including a 300mm freeboard). As such, the proposed development could be considered safe for its lifetime, including the impacts of climate change, without displacing flood water and increasing flood risk elsewhere.

The risk of surface water flooding has also been assessed following a review of available data. The surface water flood extents show similar patterns to the estimated fluvial risk, with flows largely contained to the Gallos Brook and tributaries during the 1 in 30-year and 1 in 100-year storm events. Small, isolated areas of surface water flooding are predicted to affect up to four properties during the 1 in 1000-year event. Given that these area of surface water flooding is detached from any other extents, this would be managed within the proposed surface water drainage strategy and would not be anticipated to be a risk to the site post-development.

The FRA also demonstrates that the site is at a low level of risk from other sources, including groundwater, canals, reservoirs, and sewers.

Attenuation of surface water runoff will be provided through SuDS detention basins with capacity for the 1 in 100-year storm +40%CC. Runoff is to be managed by a combination of infiltration (where viable) and restricted discharge methods at the south of the site. The restriction in the southern catchment will limit discharge rates to the Gallos Brook at no greater than 2.3 l/s/ha. Foul water is proposed to be drained separately. Further information is provided within the Sustainable Drainage Statement (Ref: UHO-BWB-XX-ZZ-RP-CD-0002_SDS).

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 area subject to suitable management of surface water runoff discharging from the site.

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APPENDICES

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 Richborough Estates Ltd and Lone Star Land in respect of an outline planning application for the erection of up to 230 dwellings, creation of new vehicular access from Camp Road and all associated works. The proposed development is located at Heyford Park, Camp Road, Upper Heyford, Oxfordshire.

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. Summary information is included as **Table 1.1**.

Table 1.1: Site Summary

Site Name	Heyford Park
Location	Upper Heyford, Oxfordshire
NGR (approx.)	SP520259
Application Site Area (ha)	11.3ha (approximately)
Development Type	Residential
Flood Zone Classification	Flood Zone 1
NPPF Vulnerability	More Vulnerable
Environment Agency Office	Thames
Lead Local Flood Authority	Oxfordshire County Council
Local Planning Authority	Cherwell District Council

Sources of Data

i. Topographical Survey by Greenhatch Group, (reference: 41240_T)
ii. Watercourse Survey by BWB Consulting, (reference: UHO-BWB-ZZ-M2-G-0060-S2-P1)
iii. Local Authority Surface Water Flood Risk Maps
iv. Cherwell District Council Strategic Flood Risk Assessment Level 1
v. Oxfordshire Country Council Preliminary Flood Risk Assessment
vi. Oxfordshire Local Flood Risk Management Strategy
vii. Cherwell Local Plan
viii. Site visit undertaken by BWB Consulting Ltd on 24/08/2021

ix. Ground Investigations undertaken by BWB Consulting Ltd (reference: HPO-BWB-ZZ-XX-RP-YE-0001_Ph1).

x. Thames Water Sewer Records

xi. British Geological Survey Drift & Geology Maps

Existing Site

1.3 The site is located approximately 3.15km west of the M40 and approximately 5km northwest from Bicester. The site is bound on the east and south by agricultural greenfield land and mixed-use development on the west. To the north of the site is the former Upper Heyford Airfield, now disused. The site's location is shown in **Figure 1.1.**

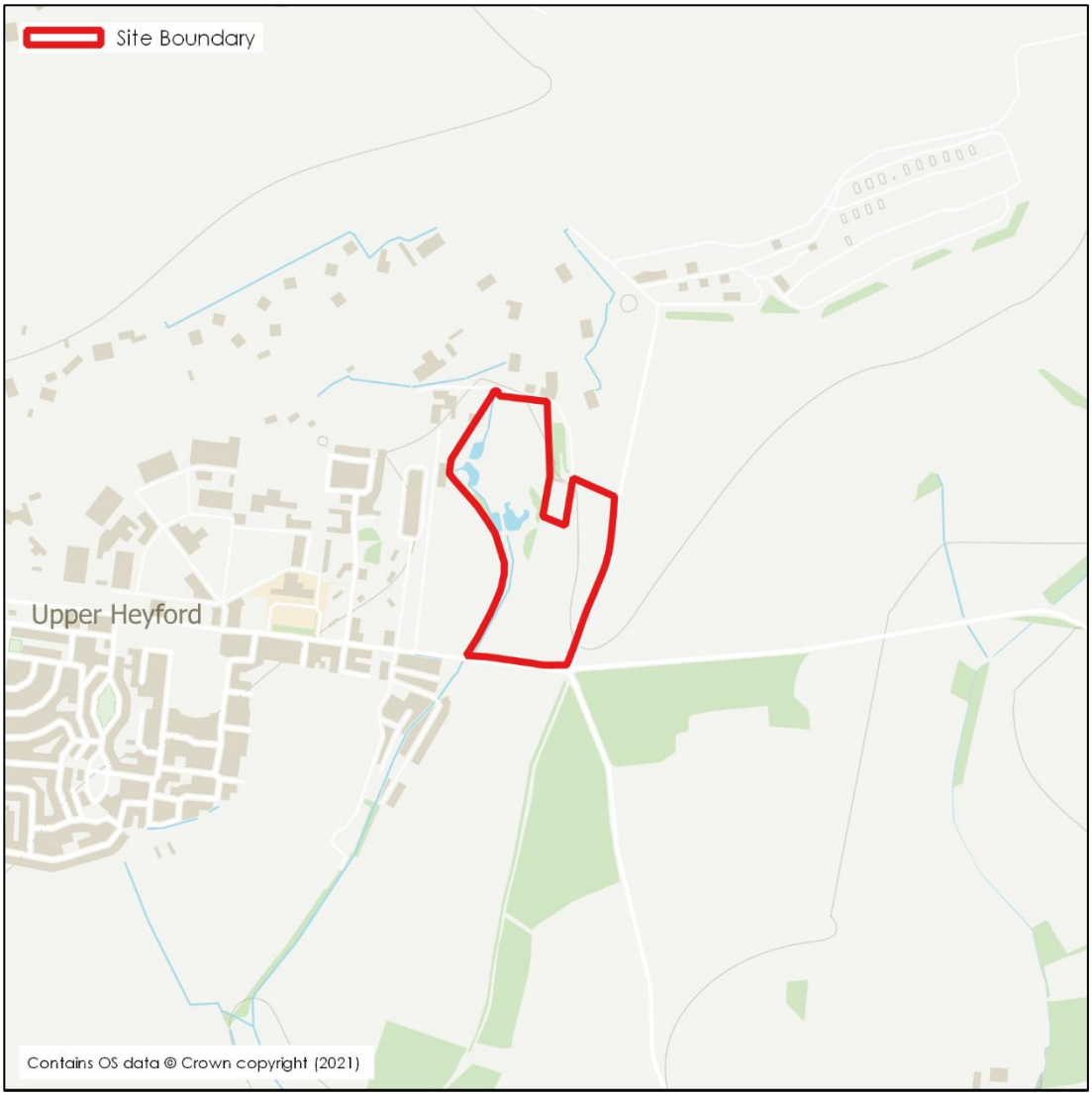


Figure 1.1: Site Location

1.4 The site has remained undeveloped since at least the mid-19th century and is currently comprised of agricultural greenfield land. The primary point of existing access to the site is from the south, via Camp Road.

1.5 The topographical survey of the site, included as **Appendix 1**, demonstrates that the land generally falls from north to south. Ground levels also fall from high ground at the east (where the development is to be proposed) towards the Gallos Brook, which forms the western boundary of the site. Levels are shown to range from approximately 121m AOD (Above Ordnance Datum) in the north east to 115m AOD within the south west corner of the Site. The generalised topography of the site is illustrated within **Figure 1.2**:

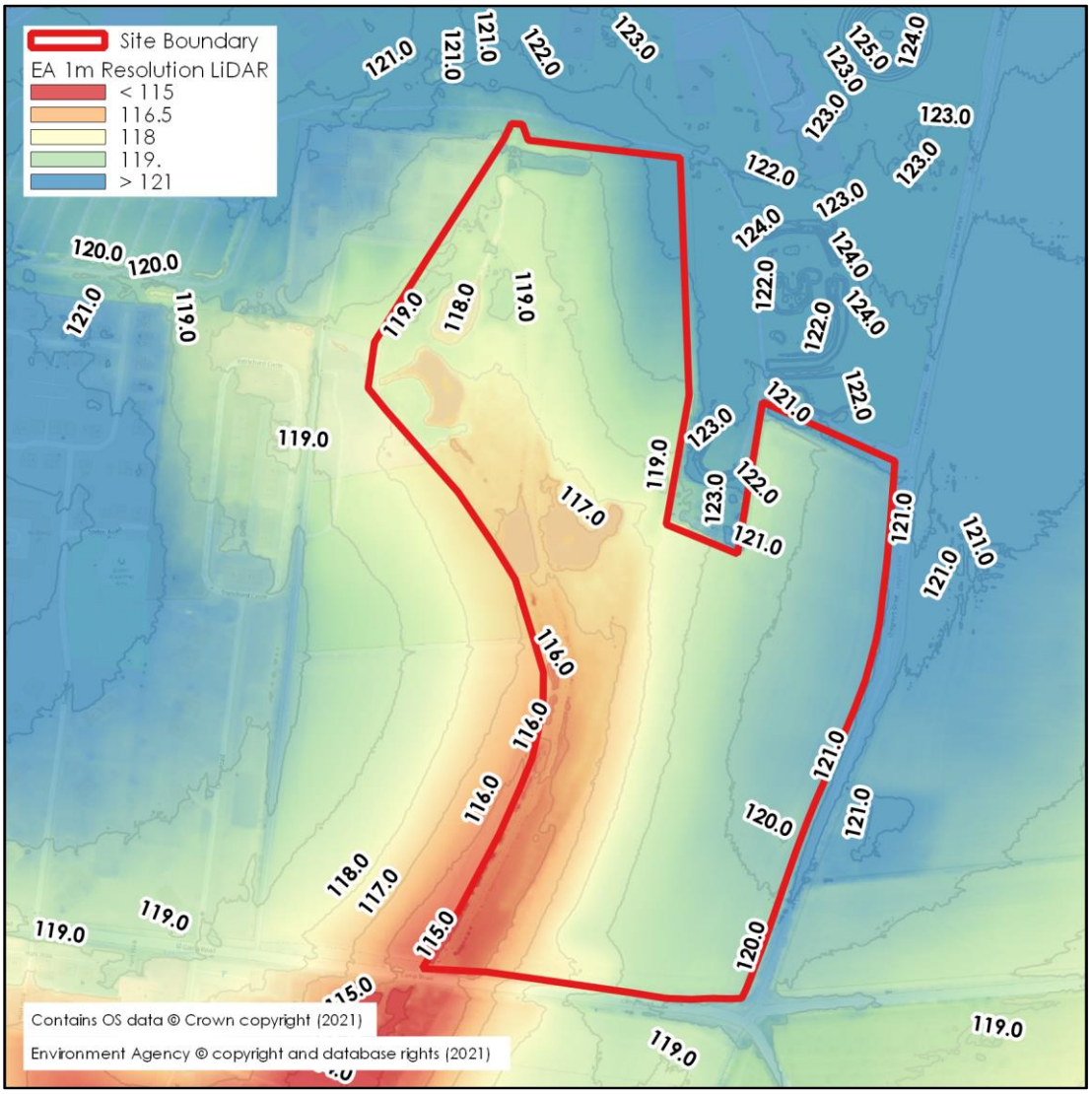


Figure 1.2: Generalised Topography of the Site

Local Watercourses

1.6 The Gallos Brook is a tributary of the River Ray with a total catchment area of approximately 34.9km^2. The proposed development site is located at the very upstream limit of the catchment. The watercourse has a catchment area of approximately 1.28km^2 upstream of Camp Road.

1.7 The watercourse flows from north to south through the site and forms the western boundary of the land parcel. **Figure 1.3** shows the local watercourse network.

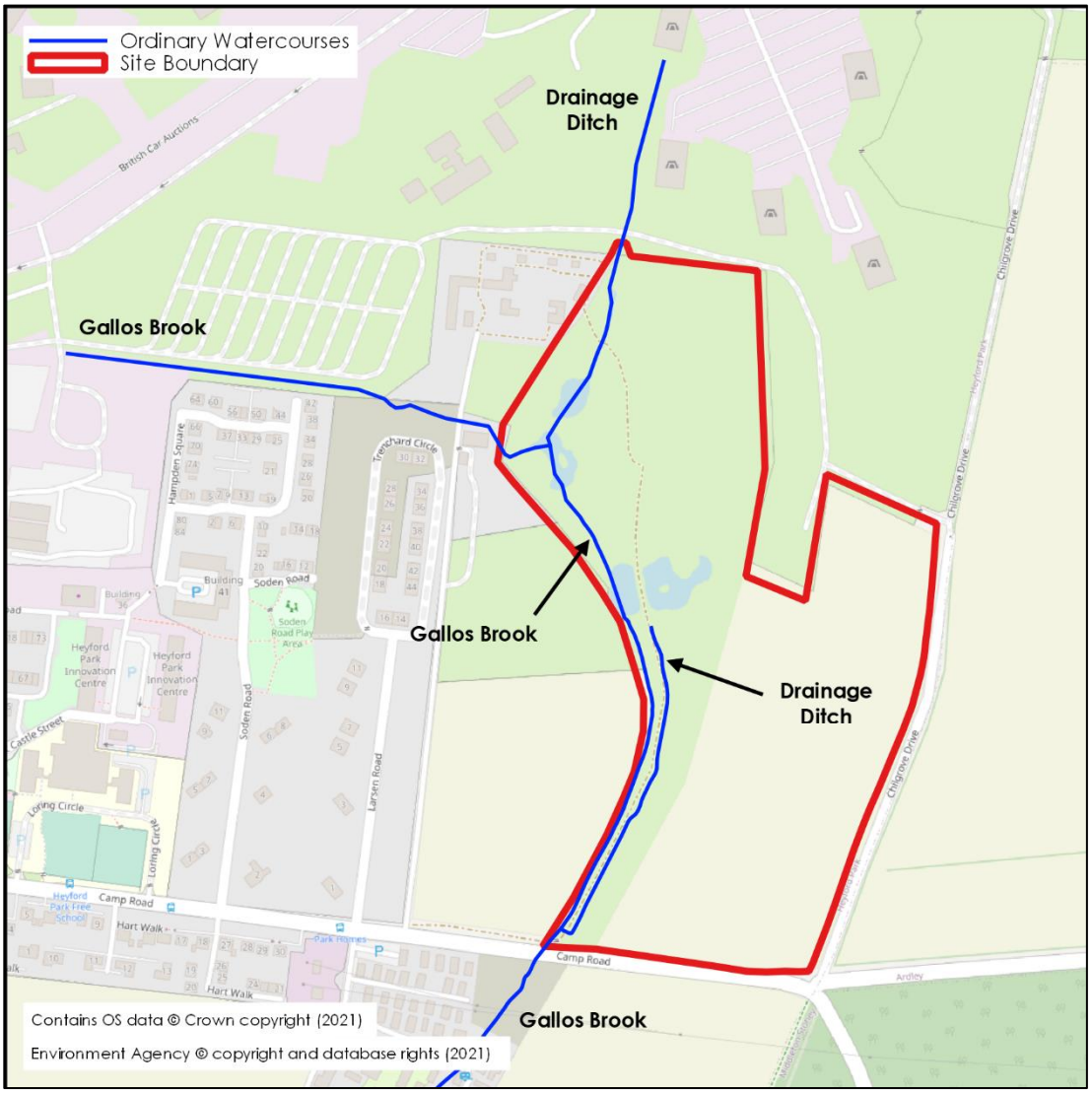


Figure 1.3: Local Watercourse Network

Proposed Development

1.8 It is understood that the proposed development is for an outline planning application for the erection of up to 230 dwellings, creation of new vehicular access from Camp Road and all associated works.

1.9 The developable area is to be contained to the eastern portion of the site where ground levels are higher. Incorporated within the proposed development are landscaped areas, as well as open spaces for community use. The remainder of the site area to the east is set to be retained as areas which boast high ecological value, as well as being used to naturally retain and attenuate surface water from the site.

1.10 It is proposed that access will be provided to the site via a junction onto Camp Road to the south. Access and egress to the site will also be possible along the eastern boundary. Appropriate pedestrian and cycling infrastructure will also be included within the design of the development. The latest proposed layout plan is included as **Appendix 3**.

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 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 identifies Flood Zones in accordance with Table 1 of the Planning Practice Guidance. Further details on the Flood Zone classifications are outlined in **Table 2.1**.

Table 2.1: Flood Zone Classifications

Flood Zone	Description
Flood Zone 1 (Low Probability)	Land having less than a 1 in 1000 annual probability of river or sea flooding (<0.1% Annual Exceedance Probability).
Flood Zone 2 (Medium Probability)	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).
Flood Zone 3a (High Probability)	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.

[1] Revised National Planning Policy Framework, Ministry of Housing, Communities & Local Government, amended 2021
[2] Planning Practice Guidance: https://www.gov.uk/government/collections/planning-practice-guidance

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

2.7 The site is shown to be located wholly within Flood Zone 1, as shown in **Figure 2.1**. This is believed to be due to the national flood mapping tool being limited to representing watercourses with a catchment above 3km2.

2.8 As per the map below, the Gallos Brook is not defined as a Main River. There are no formal spatial flood defences at the site or in the wider area and subsequently no areas are identified as benefitting from the presence of flood defences.

2.9 The closest Flood Zones to the site are located approximately 1.2km south of the site. This is associated with the Gallos Brook, but further downstream in the catchment.

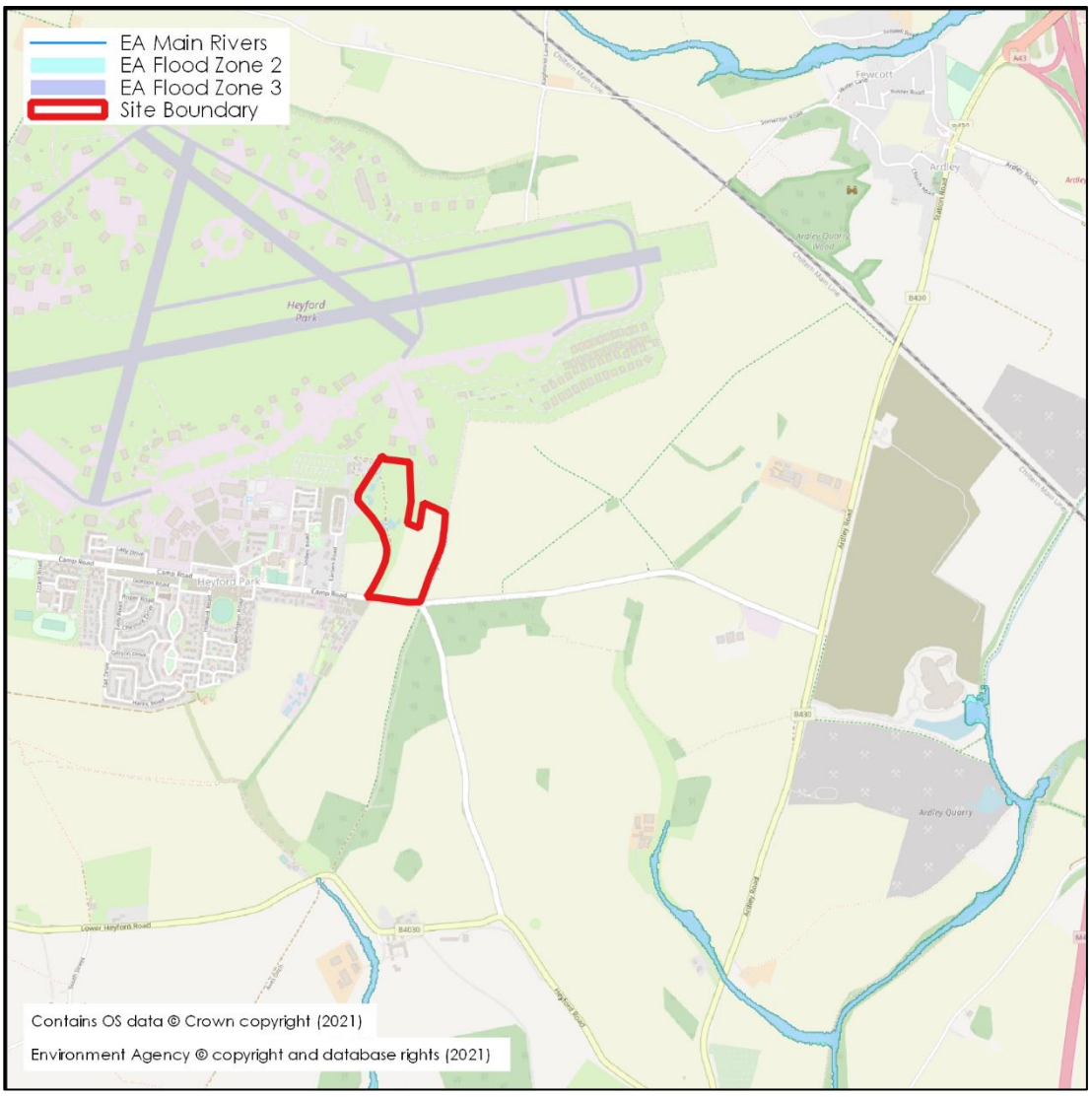


Figure 2.1: Flood Map for Planning

The Design Flood

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

2.11 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

2.12 Predicted future changes in peak river flows caused by climate change are provided by the Environment Agency[3], with a range of projections applied to regionalised 'River Basin Districts', which are further subdivided into Management Catchments.

2.13 The Site falls within the Cherwell and Ray Management Catchment of the Thames River Basin District. **Table 2.2**: Peak River Flow Allowances for the Cherwell and Ray Management Catchment within the Thames River Basin District identifies the relevant peak river flow allowances from this Management Catchment.

Table 2.2: Peak River Flow Allowances for the Cherwell and Ray Management Catchment within the Thames 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 2125)
Upper End	24%	27%	49%
Higher Central	11%	10%	25%
Central	6%	4%	15%

2.14 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. **Table 2.3** provides a matrix summarising the Environment Agency's guidance on determining the appropriate allowance(s).

Table 2.3: Application of the Appropriate Climate Change Allowance

Flood Zone	Essential Infrastructure	Highly Vulnerable	More Vulnerable	Less Vulnerable	Water Compatible
1	Use the central allowance if the site may be at risk in the future				Use none of the allowances

[3] Environment Agency, Flood risk assessments: climate change allowances: https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances#table-1

2 or 3a	Use the higher central allowance	Use the central allowance	
3b	Use the higher central allowance	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.			

2.15 The site is located entirely within Flood Zone 1, the proposed development is classified as 'More Vulnerable', and it has an anticipated lifespan of at least 100 years. The guidance does not include information on what allowance to apply to Flood Zone 1. However, the lack of Flood Zones at the site is likely to be due to due to the national flood mapping tool being limited to representing watercourses with a catchment above 3km^2. As such, a capacity assessment has been undertaken to inform an understanding of the fluvial flood risk posed by the local watercourse network. The central allowance (+15%) is to be considered.

Strategic Flood Risk Assessment

2.16 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.

2.17 The Cherwell 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 3.0** where applicable.

2.18 The Cherwell Level 2 SFRA[5] was produced to facilitate the application of Sequential and Exception Tests to screen allocated development sites. The proposed application site is not referenced within the Level 2 SFRA. However, the site is referenced as a potential development site within the Level 1 SFRA following a "call for sites" in January 2016 as part of the Cherwell Local Plan. Information from the Level 2 SFRA will be referenced within **Section 3.0** where applicable.

Preliminary Flood Risk Assessment

2.19 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.

2.20 The Oxfordshire County Council PFRA[6] considers flooding from surface water runoff, groundwater, ordinary watercourses and canals. It also references the historical river flooding which occurred in the local area in 2001 to 2008. However, no historical

[4] Level 1 Strategic Flood Risk Assessment (AECOM, 2017)
[5] Level 2 Strategic Flood Risk Assessment (AECOM, 2017)
[6] Preliminary Flood Risk Assessment (Oxfordshire County Council, 2011)

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

2.21 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.

2.22 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.

2.23 The Oxfordshire Country Council LFRMS[7] has been reviewed and will be referenced within this report where applicable.

Local Plan

2.24 The Cherwell Local Plan[8] has been reviewed in the preparation of this report. Polcies ESD 6 and 7 set out requirements for new developments.

2.25 Flood risk assessments should assess all sources of flood risk and demonstrate that:

i. There will be no increase in surface water discharge rates or volumes during storm events up to and including the 1 in 100-year storm event with an allowance for climate change (the design storm event).

ii. Developments will not flood from surface water up to and including the design storm event or any surface water flooding beyond the 1 in 30-year storm event, up to and including the design storm event will be safely contained on site.

2.26 Development should be safe and remain operational (where necessary) and proposals should demonstrate that surface water will be managed effectively on site and that the development will not increase flood risk elsewhere, including sewer flooding.

2.27 Policy ESD 7 states that:

i. All development will be required to use sustainable drainage systems (SuDS) for the management of surface water run-off. Where site specific Flood Risk Assessments are required in association with development proposals, they should be used to determine how SuDS can be used on particular sites and to design appropriate systems.

ii. In considering SuDS solutions, the need to protect ground water quality must be considered, especially where infiltration techniques are proposed. Where possible, SuDS should seek to reduce flood risk, reduce pollution and provide landscape and wildlife benefits. SuDS will require the approval of Oxfordshire County Council as LLFA and SuDS Approval Body, and proposals must include

[7] Local Flood Risk Management Strategy (Oxfordshire County Council, 2014)
[8] Local Plan (Cherwell District Council, 2011)

an agreement on the future management, maintenance and replacement of the SuDS features.

Other Relevant Policy and Guidance

Flood Risk to People and New Developments

2.28 The Flood Risk to People (FD2321/TR1)[9] document was prepared as a research project considering flood hazard and factors that affect it.

2.29 Flood Risk Assessment Guidance for New Development (FD2320/TR2)[10] provides a framework and guidance for assessing and managing flood risks for new developments and sets flood hazard thresholds.

2.30 Hazard ratings are derived using the following equation in line with the above:

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

Where:
D = depth
V = velocity
DF = debris factor

2.31 A supplementary note[11] provides clarification of the hazard rating thresholds which should be used for development planning and control use. **Table 2.4** identifies the thresholds of the flood hazard categories.

Table 2.4: Hazard to People[12]

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"

[9] Flood Risk to People Methodology (FD2321/TR1), Defra/Environment Agency, 2006
[10] Flood Risk Assessment Guidance for New Development (FD2320/TR2), Defra/Environment Agency, 2005
[11] Supplementary Note on Flood Hazard Ratings and Thresholds for Development Planning and Control Purpose – Clarification of the Table 13.1 of FD2320/TR2 and Figure 3.2 of FD2321/TR1. (http://randd.defra.gov.uk/Document.aspx?Document=FD2321_7400_PR.pdf)
[12] 2008, DEFRA. Supplementary Note on Flood Hazard Ratings and Thresholds for Development Planning and Control Purposes.

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 wholly within Flood Zone 1.
	X				There is an ordinary watercourse, the Gallos Brook, that flows from north to south through the site. An open channel flow capacity assessment has determined that the proposed development is located topographically above the estimated design flood levels. Parts of the wider site are shown to be at fluvial risk.
Canals			X		The site Is located approximately 2.5km east of the Oxford Canal. The site is elevated approximately 42m above the canal.
Groundwater			X		The site is shown to fall within a 1km^2 grid tile which is predicted to be at a low susceptibility (<25%) to groundwater flooding.
Reservoirs and waterbodies			X		The site is shown to fall outside of areas at risk of reservoir failure, during both the wet and dry scenarios.
Pluvial runoff	X				Land falls away from the developable area and drains towards the Gallos Brook. Areas of the site are affected during the 1 in 30-year and 1 in 100-year events, though these are largely contained to the watercourse. The proposed development is shown to be affected by some localised surface water ponding during the 1 in 1000-year event which, if left unmitigated, could pose a low risk to the development.

Flood Source	Potential Risk				Description
	High	Medium	Low	None	
Sewers		X			Thames Water records show that there are sewers to the north which could affect the site if exceeded. The Thames Water DG5 record suggests the site has between 0 and 5 reported incidents of sewer flooding.
Effect of Development on Wider Catchment			X		Development will not result in loss of surface or fluvial water flow routes or increase flood risk elsewhere.
	X				The development will increase the area of impermeable surfaces at the site. If left unmitigated, this could lead to an increase in surface water 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 wholly in Flood Zone 1, which is land defined as having a low probability of flooding from rivers or sea. The nearest EA main river, the River Cherwell, lies approximately 2.65km west of the site. There is an ordinary watercourse, the Gallos Brook, that flows through the site, however, there are no Flood Zones associated with this watercourse at the site. This is due to the national flood mapping tool being limited to representing watercourses with a catchment above 3km^2. The Gallos Brook does have associated flood zones approximately 1km south of the site (from downstream of Lower Heyford Road). At this location, the FEH Web Service defines the Gallos Brook catchment area as 3.02km^2.

3.4 Given that there are no Flood Zones provided at the site, the Environment Agency's risk of flooding from surface water mapping offers the best available data as an indicative proxy of fluvial flood extents. This mapping tool gives an indication for the estimated fluvial river corridor and how flows are conveyed through the site and the wider catchment area. The surface water proxy extents are displayed in **Figure 3.1**.

3.5 The proposed development is for residential use and subsequently it is necessary to demonstrate that the development can be considered safe for its lifetime, including the impacts of climate change, without increasing flood risk elsewhere. As such, further analysis is considered necessary to determine whether the proposed development could be considered safe from fluvial sources for its lifetime.

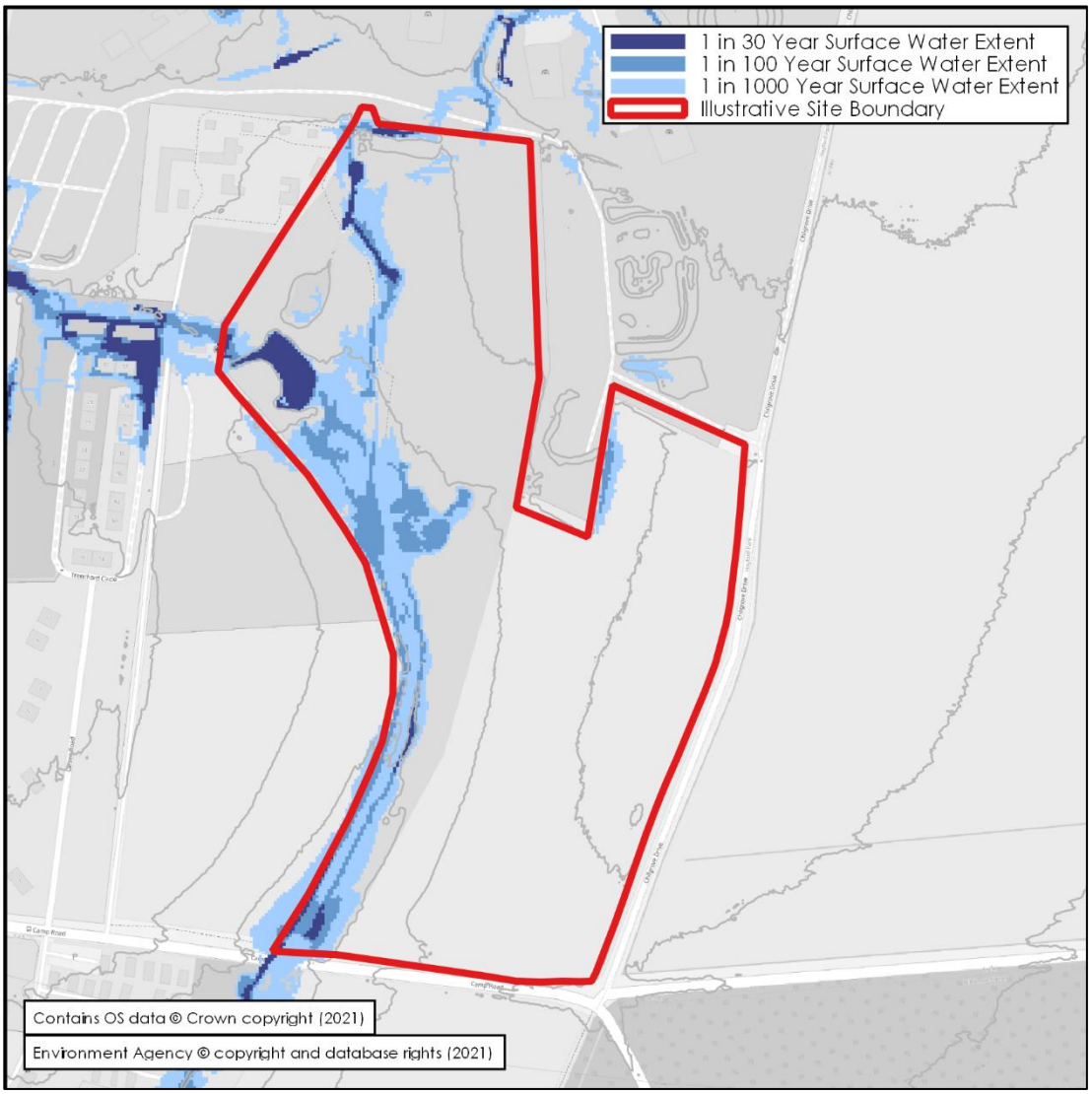


Figure 3.1: Surface Water Flood Extents – Proxy for Fluvial River Corridor

3.6 Whilst the surface water flood extents provide a proxy and indication of what the fluvial river corridor could be expected to look like, a Manning's capacity assessment has been conducted to further assess the risk of fluvial flooding to the site. This analysis also allows for the 1 in 100-year +15%CC design flood level to be estimated across the site.

Manning's Capacity Assessment

3.7 To inform the capacity assessment, a watercourse survey has been undertaken at the site, which is provided in **Appendix 2**. The capacity assessment has been completed at five cross-section locations across the length of the site boundary. This allows for a

representation of fluvial flood risk across all parts of the proposed development. The five chosen cross-section locations are displayed in **Figure 3.2**.

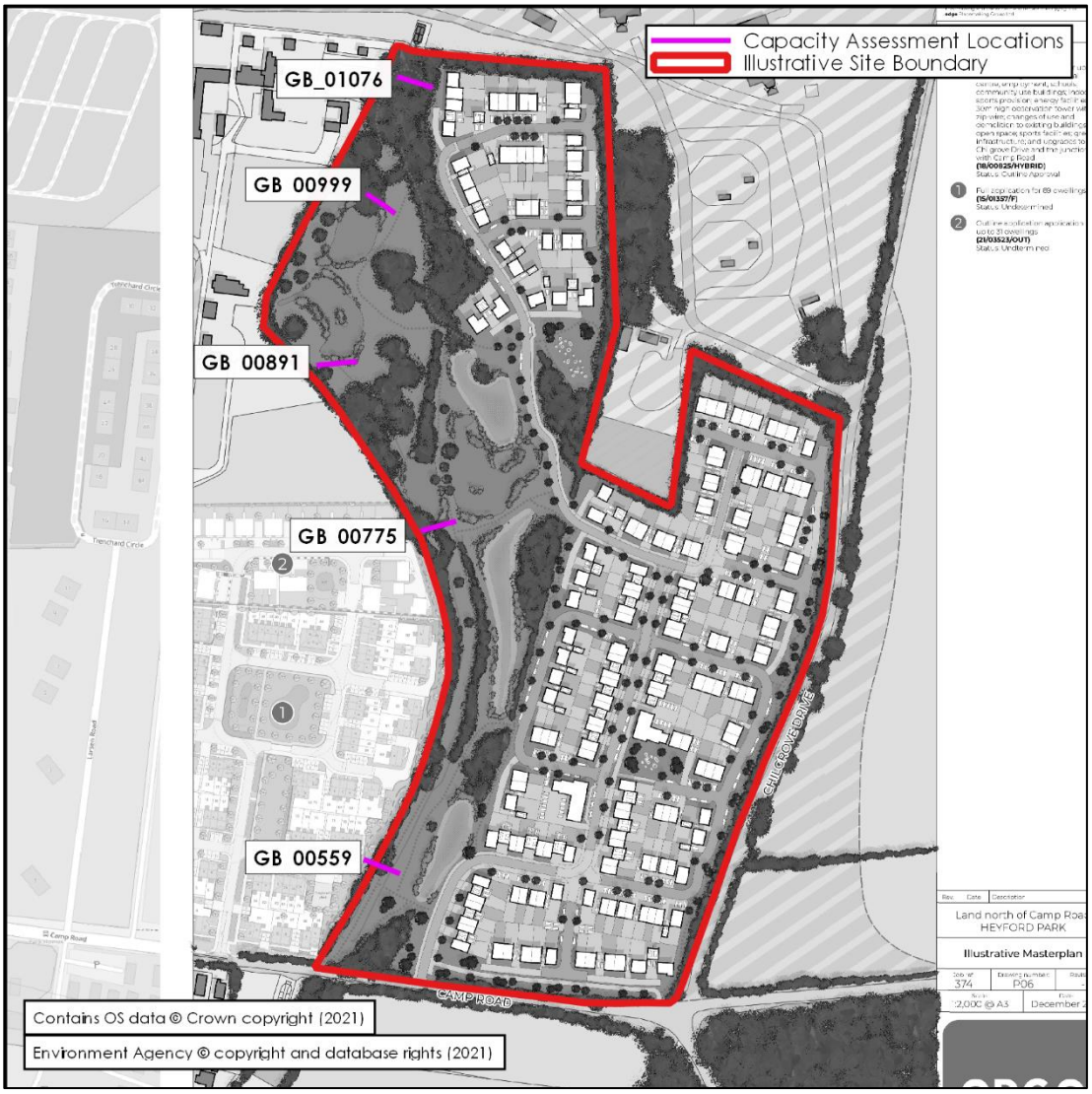


Figure 3.2: Capacity Assessment Cross-Section Locations

3.8 The capacity assessment involves the following primary sources of input data sources:

- Watercourse Survey (reference: UHO-BWB-ZZ-M2-G-0060-S2-P1).
- Topographic Survey (reference: 41240_T).
- 1m resolution Light Detection and Ranging (LiDAR) data.
- Peak Flows derived through a combination of FEH Catchment Areas, Catchment Descriptors and ReFH2 software.

3.9 These data sources are then used in combination with the Manning's equation for determining open channel flows, which is as follows:

$$Q = \frac{K\ A\ R^{2/3}\ S^{1/2}}{\mathrm{n}}$$

Whereby:

Q = Flow rate (m^3/s)
A = Cross-sectional area of flow
R = Hydraulic radius (cross-sectional area divided by wetted perimeter)
S = Slope of the channel at the point of measurement
n = Surface roughness (based upon channel material and condition)
K = Constant dependent upon units

3.10 The methodology behind how the Manning's capacity assessment is provided in detail in **Appendix 4**. The estimated flood levels are assessed against the site proposals within this Flood Risk Assessment to determine the risk of fluvial flooding to the proposed development. The required mitigation measures are outlined within **Section 4**.

3.11 Peak flows, as derived by ReFH2 are reported in **Appendix 4**. These flows are calculated for the entire catchment area that drains towards the FEP, located south of Camp Road. The peak flows are then scaled for each cross-section location so that the peak flows are reflective of the total area draining to each assessment location.

3.12 The FEP and scaled peak flows for each cross-section are reported in **Appendix 4** and in **Table 3.2** below.

Table 3.2: ReFH2 FEP and Scaled Peak Flows

Location	AREA (km^2)	Flood peak (m^3/s)							
		2	5	10	20	50	100	200	1000
FEP	1.28	0.12	0.17	0.21	0.24	0.30	0.35	0.41	0.59
GB_00559	1.19	0.11	0.16	0.19	0.23	0.28	0.32	0.38	0.55
GB_00775	1.10	0.11	0.15	0.18	0.21	0.26	0.30	0.35	0.51
GB_00891	1.03	0.10	0.14	0.17	0.20	0.24	0.28	0.33	0.48
GB_00999	0.38	0.04	0.05	0.06	0.07	0.09	0.10	0.12	0.18
GB_01076	0.34	0.03	0.05	0.05	0.06	0.08	0.09	0.11	0.16

3.13 The peak flows for the 1 in 100-year event with the projected climate change allowances are reported in **Table 3.3**. The site is located within the Cherwell and Ray Management Catchment of the Thames River Basin District. As such, uplifts of +15% (Central), +25% (Higher Central) and +49% (Upper End) are considered.

Table 3.3: 1 in 100-year + Climate Change Peak Flows

Location	Flood peak (m^3/s)			
	100	100 +15%CC*	100 +25%CC	100 +49%CC
GB_00559	0.32	0.37	0.40	0.48
GB_00775	0.30	0.35	0.38	0.45
GB_00891	0.28	0.32	0.35	0.42
GB_00999	0.10	0.12	0.13	0.15
GB_01076	0.09	0.10	0.11	0.13

**100 +15%CC is considered the design event for "More Vulnerable" developments*

3.14 The scaled ReFH2 peak flows were subsequently applied against the flow rate vs water level rating curves that were derived at each cross-section as part of the Manning's capacity assessment. The rating curves and methodology behind calculating these is provided in **Appendix 4**. Through comparing the ReFH flood peaks against the rating curves, estimated peak flood levels for the respective return periods can be determined.

3.15 The estimated peak flood levels for the design event (1 in 100-year +15%CC) are presented in **Table 3.4**. The surveyed left bank and right bank crest levels have also been provided to determine whether the design flood level is predicted to remain in-channel.

3.16 A freeboard of 300mm has been applied to the estimated peak flood levels to account for potential uncertainties that may have been introduced through the Manning's equation and to adopt a conservative approach to assessing fluvial risk.

Table 3.4: Estimated Maximum Flood Levels

Cross-Section	1 in 100-year +15%CC (mAOD)		Surveyed Bank Height (mAOD)		Clearance to Lowest Bank Crest Level (m)	
	Original	+300mm	Left	Right	Original	+300mm
GB_00559	114.83	115.13	115.53	115.44	0.61	0.31
GB_00775	116.84	117.14	117.01	116.82	-0.02	-0.32
GB_00891	117.41	117.71	118.02	118.39	0.61	0.31
GB_00999	117.58	117.88	118.17	117.95	0.37	0.07
GB_01076	118.19	118.49	118.81	118.77	0.58	0.28

3.17 As per **Table 3.4**, the maximum estimated flood levels for the 1 in 100-year +15%CC design event is shown to remain in-channel at GB_00559, GB_00891, GB_00999 and GB_01076. This includes the addition of the +300mm freeboard allowance.

3.18 When the +300mm freeboard allowance is applied to the derived peak flood levels at GB_00775, the estimated peak flood level for the 1 in 100-year +15%CC event is predicted to exceed the surveyed left and right bank heights.

3.19 To assess the risk of fluvial flooding from an exceedance of the channel capacity a flood extent has been derived by projecting the design flood levels (including freeboard) for each cross-section onto the topographical survey. The extent is displayed in **Figure 3.3.**

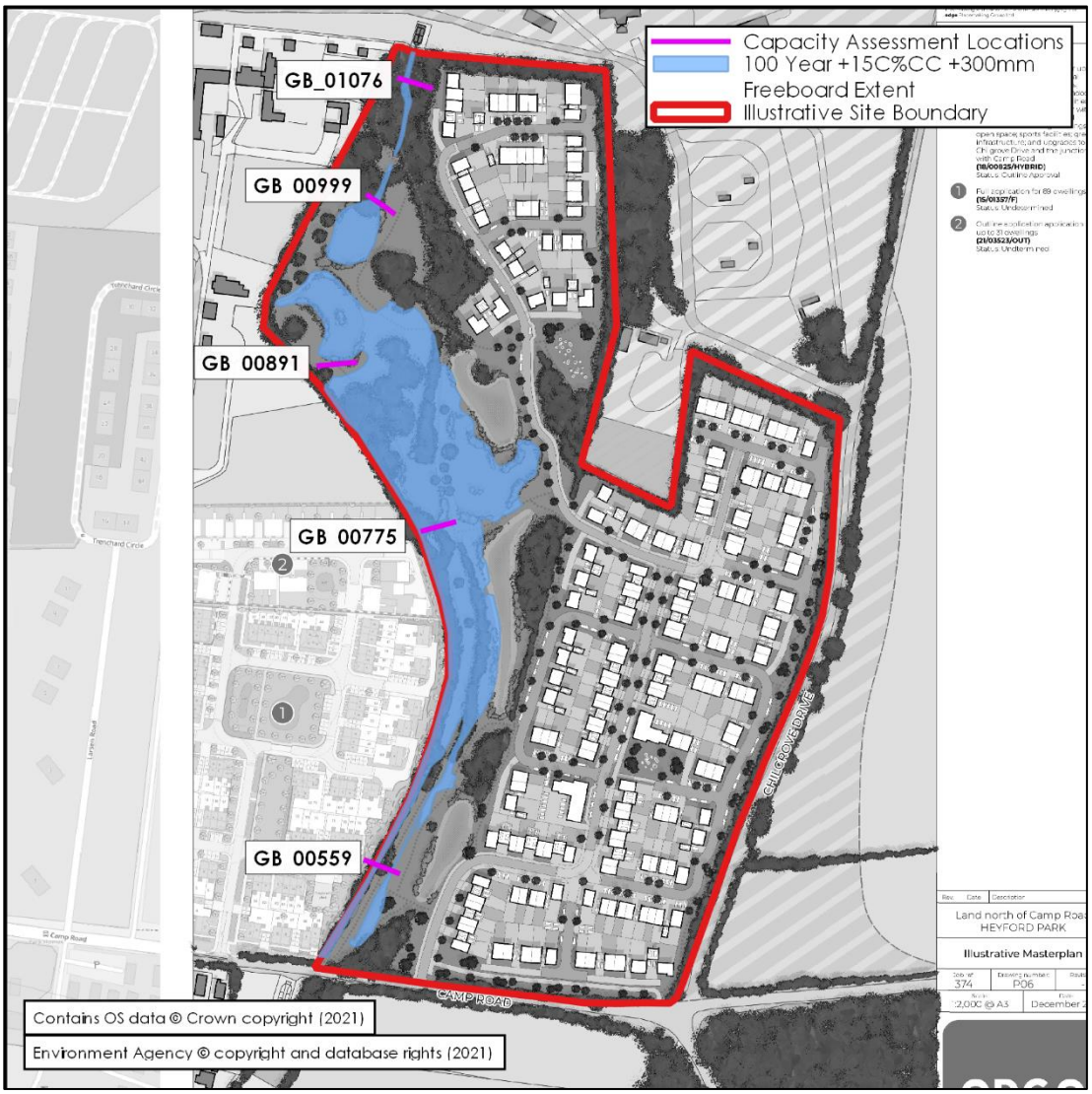


Figure 3.3: 1 in 100-year +15%CC +300mm Freeboard Flood Extent

3.20 The proposed development is shown to remain located topographically outside of the 1 in 100-year +15%CC +300mm freeboard flood extent. As such, the proposed development can be seen to demonstrate no displacement of fluvial flood water and will not increase flood risk elsewhere.

Validation of Capacity Assessment

3.21 As a validation exercise, the 1 in 100-year +15%CC +300mm freeboard fluvial flood extent has been compared against the Environment Agency's risk of flooding from surface water mapping 1 in 1000-year extent.

3.22 It should be noted that the extents derived by the capacity assessment does not include the impacts of hydraulic structures. On the other hand, the surface water mapping will have structures represented at the site, but likely as fully blocked (therefore encouraging flood water to back up upstream and pass over the deck or floodplain). The fluvial flood extent has also been derived based off a site-specific topographic survey. The surface water flood extents will have been mapped using plane-flown LiDAR data of a coarser resolution.

3.23 The comparison between the flood extents is displayed in **Figure 3.4**.

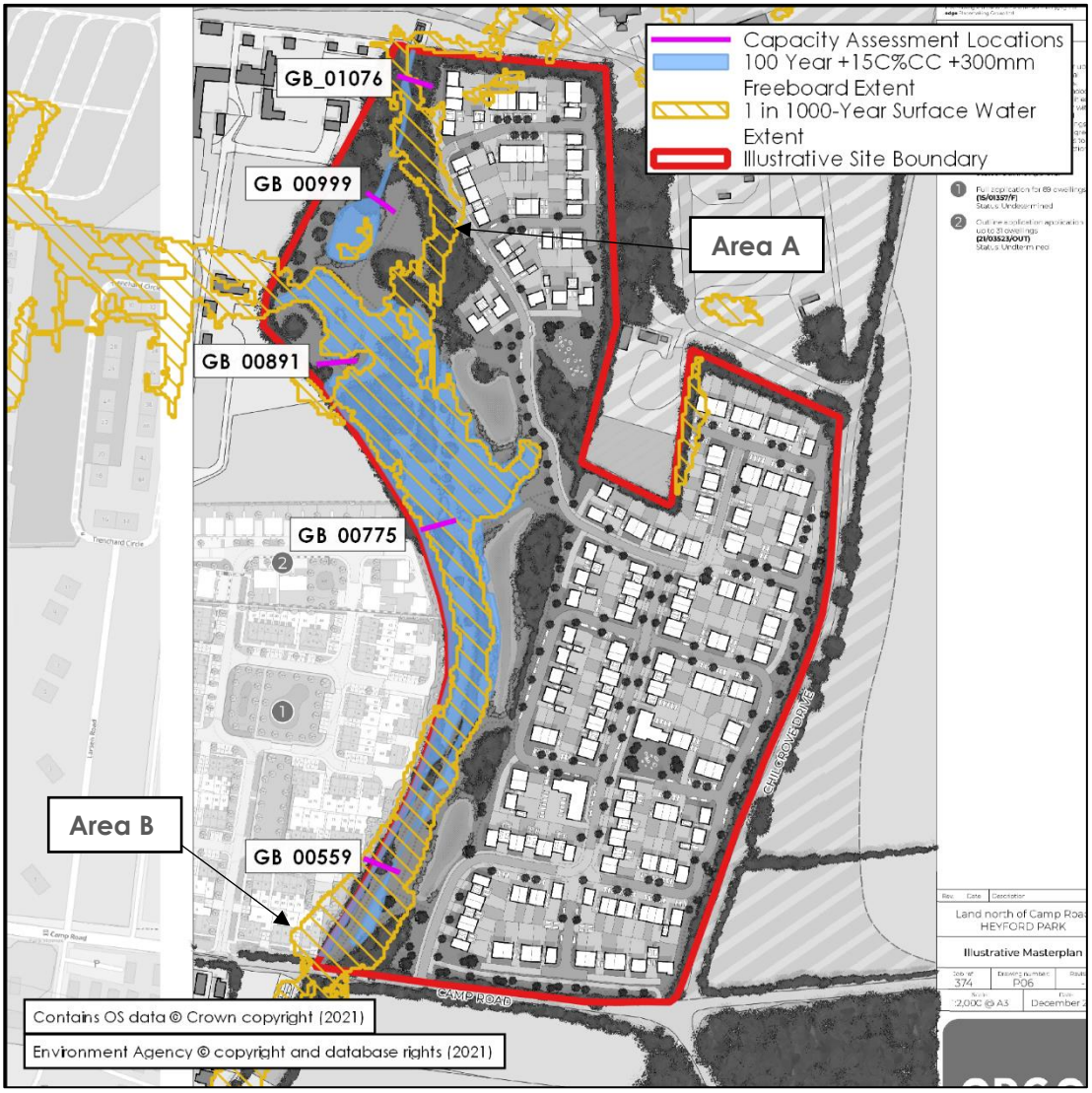


Figure 3.4: 1 in 100-year +15%CC +300mm Freeboard Flood Extent Compared to 1 in 1000-year Surface Water Extent

3.24 As per **Figure 3.4**, the fluvial 1 in 100-year +15%CC extent shows a close agreement to the 1 in 1000-year surface water extent at the site. There are two areas where more notable differences can be seen between the extents, as annotated on the map by "Area A" and "Area B".

3.25 At "Area A", the 1 in 1000-year surface water extents show flows to be conveyed through the floodplain. This differs to the fluvial 1 in 100-year +15%CC extent which shows flows to be contained within the channel of the Gallos Brook. The reasoning for this difference can be attributed to the modelling methods undertaken as part of the Environment Agency's Risk of Flooding from Surface Waster (RoFSW) dataset. This tool does not account for conveyance through minor hydraulic structures such as the bridge at location GB_1028 (see **Appendix 2**). Subsequently, the deck level of the arch bridge will have been picked up by the LiDAR used within the surface water mapping model, effectively representing the channel as fully blocked, and therefore diverting flows around the structure via the floodplain.

3.26 A similar justification can be used to explain the difference in flood extents at "Area B". The surface water mapping model will not have accounted for the culvert at the downstream limit of the model (GB_00495). Subsequently, the LiDAR data will have captured the crest level of Camp Road. Surface water flows are therefore shown to back up at the southern limit of the site until flood levels are great enough to overtop the road level. This has subsequently resulted in a significantly larger flood extent than what the fluvial 1 in 100-year +15%CC extent shows. As per the capacity assessment in **Appendix 4**, the 1.05m pipe at GB_00495 has sufficient capacity to convey the peak flows for all return periods including the 1 in 100-year +15%CC and 1 in 1000-year events.

3.27 The validation exercise concludes that the fluvial extents show a close agreement to the river corridor defined by the surface water extents for similar magnitude events. Differences between the data sources can be attributed to limitations with the surface water mapping model.

3.28 Neither the Cherwell District Council SFRA or the Environment Agency have provided any evidence to suggest that the site has historically flooded from fluvial sources.

3.29 As such, the risk of fluvial flooding to the site could be considered to be high in areas, however these are largely contained to the western portion of the site boundary. The eastern portion of the site boundary, where the development proposals are located, could be considered at low risk of fluvial flooding.

Flood Risk from Canals

3.30 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.

3.31 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.

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

3.33 The nearest canal is the Oxford Canal which is approximately 2.5km west of the site. Levels at the canal at this located are set approximately 42m lower than those at the site. Therefore, the risk of flooding from canals is negligible.

Groundwater Flood Risk

3.34 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.

3.35 British Geological Survey (BGS) mapping shows that the site is underlain by White Limestone Formation, which is designated by the EA as a Principal Aquifer. Principal Aquifers are layers of rock or drift deposits that have high intergranular and/or fracture permeability - meaning they usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale. There are no superficial deposits recorded at the site.

3.36 BWB Consulting were appointed by the client to undertake BRE365 soakaway testing at the site. A total of 3 trial pits were excavated across the site, 'SA01', SA02 and 'SA03B' as shown by **Figure 3.5**. No groundwater was encountered within any of the BRE365 trial pits, however groundwater at a depth of 1.2m below ground level (bgl) was identified within trial pit 'SA03'. This pit is located in close proximity to the watercourse.

3.37 The site is located outside of all Environment Agency groundwater source protection zones.

3.38 The Cherwell District Council SFRA identifies areas susceptible to groundwater flooding in a strategic scale map showing groundwater flood areas in a 1km^2 grid. The site is situated in a tile that is considered to be of low susceptibility (<25%) to groundwater flooding.

3.39 Neither the Environment Agency nor Cherwell District Council have provided any evidence to suggest that the site has historically flooded from groundwater sources.

3.40 As such, the risk of groundwater flooding to the proposed development could be considered low.

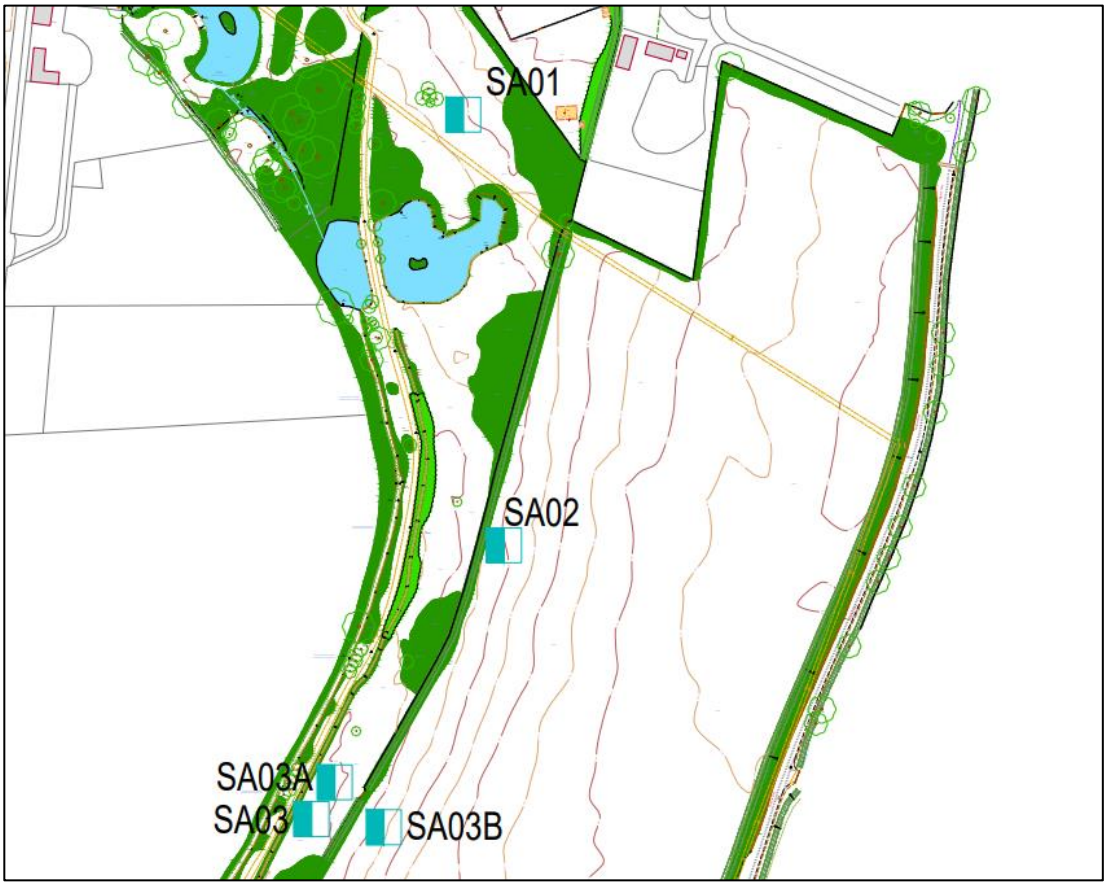


Figure 3.5: Trial Pit Locations

Flood Risk from Reservoirs & Large Waterbodies

3.41 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.

3.42 To help identify this risk, reservoir failure flood risk mapping has been prepared by the EA. 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 of the mapping is provided within **Figure 3.6**. Two scenarios are presented: a 'dry day' scenario occurs when rivers are at normal level, and a 'wet day' scenario occurs when rivers are in flood.

3.43 The site is located outside of all reservoir flood extents (for both scenarios). The nearest extent to the site is approximately 2.5km west of the site.

3.44 There are several waterbodies located at the northern extent of the site boundary where topographic levels are higher. However, if these were to fail or to be breached, flood waters would flow southwards and affect areas towards the western boundary of the site first, where levels are topographically lower. Whilst there are areas of the proposed development that are south of the on-site waterbodies, the proposed development is not situated topographically lower and so would remain unaffected if

these were to fail or be breached. Due to the maintenance responsibilities associated with the ownership of waterbodies, the probability of such an event occurring is considered low.

3.45 Subsequently, flooding from reservoirs or large waterbodies is not considered to be a barrier to development at the site and the risk is considered low.

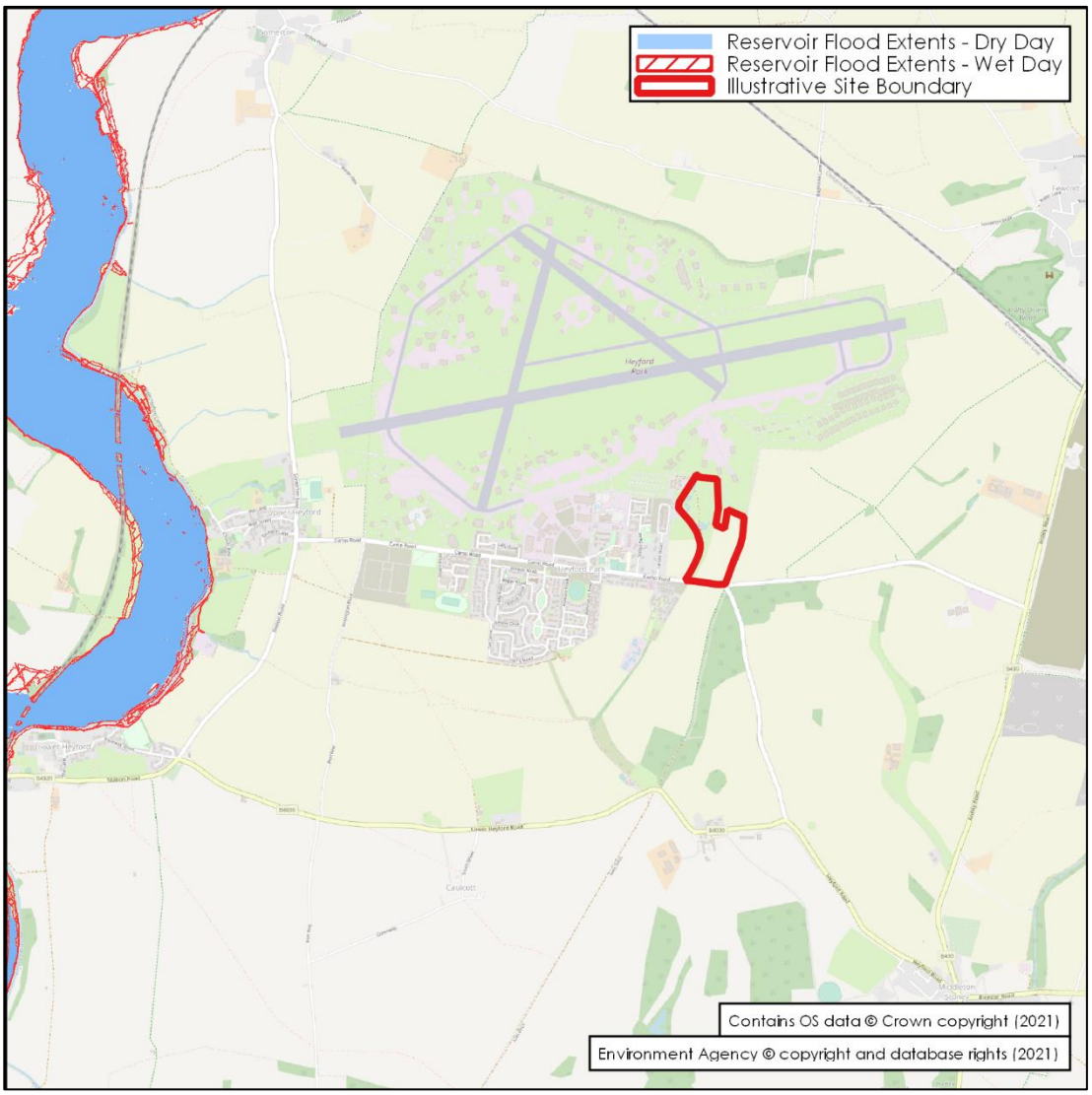


Figure 3.6: Reservoir Failure Flood Risk Map

Pluvial Flood Risk

3.46 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.

3.47 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 3.7**.

Figure 3.7: Surface Water Flood Map

3.48 The site is shown to be at a low (1 in 1000-year) to high (1 in 30-year) risk of pluvial flooding. The extents of pluvial flood risk are largely contained towards the Gallos Brook and waterbodies along the western boundary of the Site. Here, topographic levels are relatively lower than the eastern portion of the site where the development is proposed.

3.49 There are, however, two areas of isolated surface water ponding located at Areas A and B on **Figure 3.7**. Area A is limited to the Low Risk scenario only (1 in 1000-year event), whereby up to three properties are shown to be located in an area that is predicted to experience depths of up to 150mm. At Area B, pluvial depths largely range between 150mm and 300mm which is shown to affect up to one property. At its deepest point, there is a small area that reports depths of between 300mm and 600mm. A smaller pluvial extent is predicted at Area B for the 1 in 100-year event whereby up to one property could be affected with depths between 150mm and 300mm.

3.50 The primary access point to the site is from Camp Road, which forms the southern boundary of the site. As per **Figure 3.7**, the primary point of access is shown to be

unaffected during all modelled surface water events. As such, safe access and egress will be maintained for the lifetime of the proposed development.

3.51 Mitigatory actions to address the risk of surface water flooding to the proposed development is discussed within **Section 4**.

3.1 Overall, the site is considered to be at high risk from pluvial sources, however, the greatest risk is contained to the existing watercourse network and waterbodies at the site. The majority of the proposed development could be considered to be at very low risk, with up to three properties at low risk and one property at moderate risk. Mitigation measures to provide protection against the risk of surface water flooding are outlined within **Section 4**.

Flood Risk from Sewers

3.2 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.

3.3 Due to the greenfield nature of the site, there are believed to be no sewer assets located within the site boundary. Thames Water sewer records are included as **Appendix 5**.

3.4 The sewer records identify a network of sewers upstream of the site associated with the Heyford Park airfield sewer assets located in the surrounding area. Pluvial flood mapping illustrates potential exceedance routes of surrounding sewer networks should they flood, which generally follows the topography of the surrounding area and Site.

3.5 The Cherwell District Council SFRA separates areas by postcode and indicates historical flood events caused by sewer. The site is shown to be located within an area with 0 to 5 reported incidents per postcode region, as per the Thames Water DG5 register. No information is provided with regards to the specific location, magnitude or date of the recorded incidents.

3.6 The overall risk posed by the sewer source is therefore considered to be low.

Effect of Development on Wider Catchment

Displacement of Floodplain

3.7 The proposed development is shown to be located outside of the estimated design 1 in 100-year +15%CC flood extent. As such there would be no displacement of fluvial flood water as a result of the proposed development.

3.8 There are three proposed dwellings that are shown to be potentially affected by surface water flooding during the 1 in 1000-year event (Low risk scenario), as well as one

property that may potentially be affected during the 1 in 100-year event (Medium risk scenario).

3.9 Mitigatory actions to address the risk of potential flood water displacement from pluvial sources is discussed in detail within **Section 4**.

Development Land Use/Drainage Considerations

3.10 The proposed development will lead to an increase in impermeable area and subsequently an increase in runoff. Appropriate surface water management will be required to manage this. Further details are outlined within **Section 4**.

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 masterplan shows all residential plots are sequentially located within Flood Zone 1.

4.3 Furthermore, following conducting a Manning's capacity assessment, all residential plots are shown to be located outside of the 1 in 100-year +15%CC design flood extent, including a +300mm conservative freeboard allowance.

Development Levels

4.4 The Cherwell District Council Level 1 SFRA provides guidance on development levels, stating that:

"All More Vulnerable and Highly Vulnerable developments within Flood Zone 2 and 3 should set Finished Floor Levels 300mm above the known or modelled 1 in 100 annual probability (1% AEP) flood level including an allowance for climate change."

4.5 The proposed development is sequentially located in Flood Zone 1. Following a Manning's capacity assessment at the site, the proposed development is shown to be located outside of the extent of the 1 in 100-year +15%CC design event, with 300mm freeboard allowance.

4.6 As per **Figure 4.1**, all plots can be seen to be located topographically a minimum of 300mm above the 1 in 100-year +15%CC with 300mm freeboard allowance maximum flood levels.

4.7 To offer further mitigation against any potential uncertainties that could be introduced through this approach to estimating flood levels at the site, it is also recommended that development levels for all dwellings are raised to 150mm above the surrounding ground level. This will also offer mitigation against other residual risks such as groundwater, sewer and surface water flooding.

4.8 Ground levels should also be profiled to encourage pluvial runoff and overland flows away from the built development and towards the nearest drainage point.

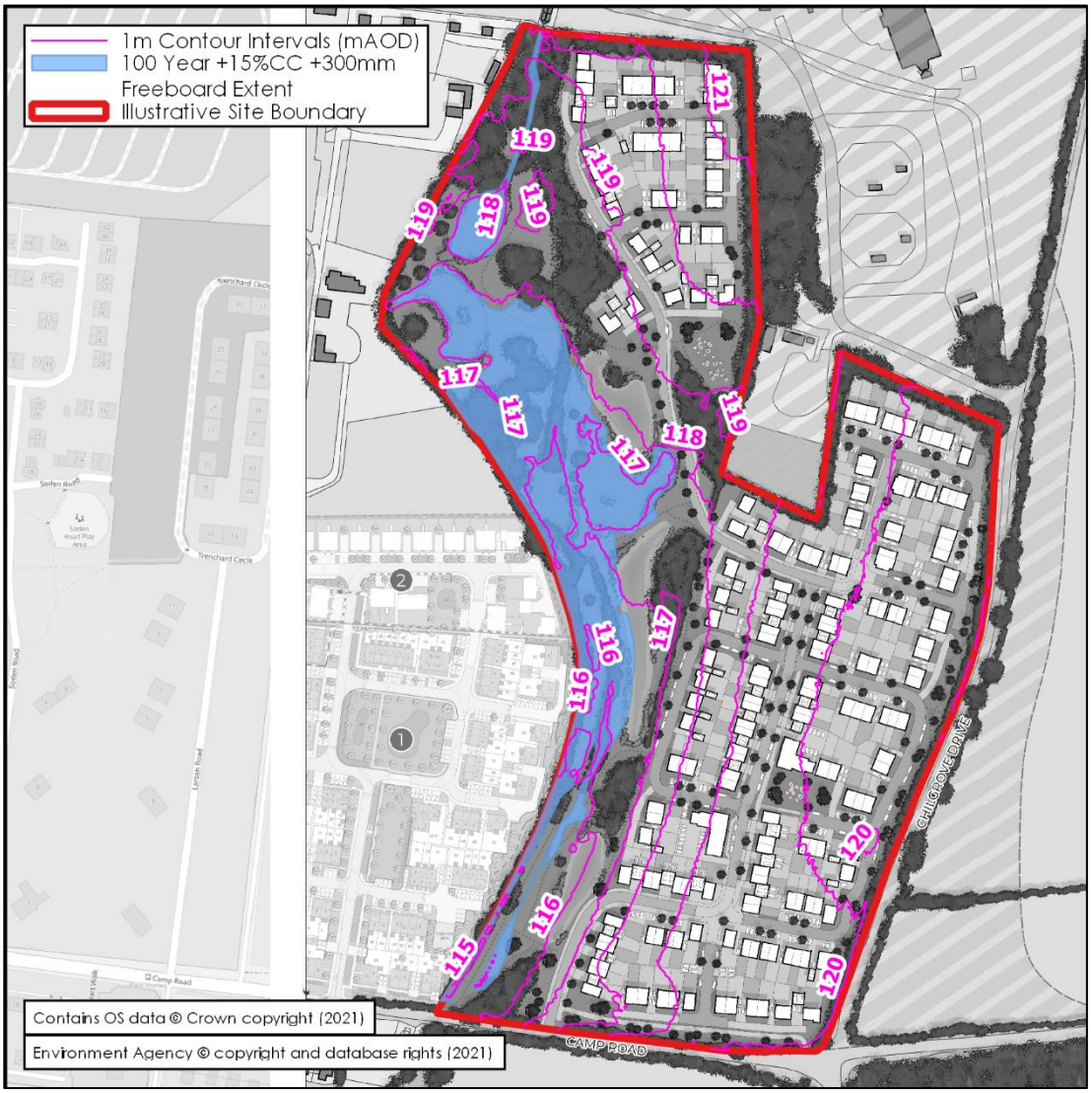


Figure 4.1: 1 in 100-year +15%CC +300mm Freeboard Flood Extent with 1m Contours

Safe Access and Egress

4.9 Safe access and egress via the primary access route off Camp Road is shown to be located within Flood Zone 1. The Manning's capacity assessment also demonstrates that fluvial inflows are shown to remain in-channel at GB_00559 during the 1 in 100-year +15%CC design event (including a +300mm freeboard).

4.10 Whilst flows are estimated to remain in-bank, the maximum flood extent is displayed in **Figure 4.2**. The access road is shown to remain unaffected.

1.1 As part of the study, a pipe capacity assessment has been undertaken at the culvert located at the very southern limit of the site (cross-section GB_00495). The calculation sheet provided in **Appendix 4** shows that the 1.05m diameter pipe has a maximum capacity of 2.960m³/s. There is subsequently sufficient capacity to convey flows for all events through this structure.

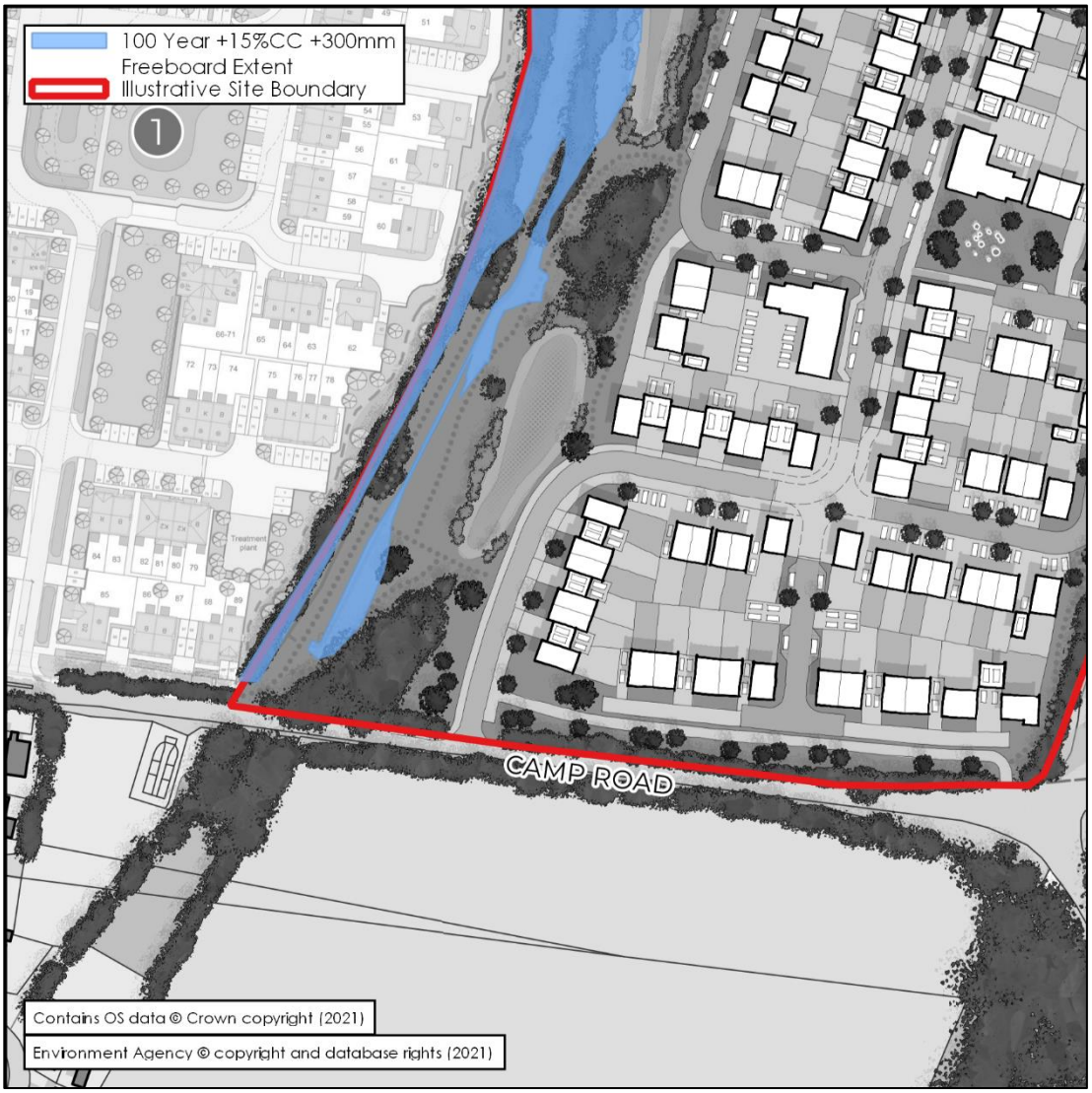


Figure 4.2: 1 in 100-year +15%CC +300mm Freeboard Flood Extent at Camp Road

4.11 Following review of the Environment Agency's risk of flooding from surface water mapping (**Figure 3.7**), the primary access route is also shown to be at a very low risk of surface water flooding. Therefore, safe and dry access and egress would remain achievable.

Flood Contingency Plan and Evacuation Procedures

Flood Warning and Evacuation

4.12 Due to the low risk of flooding to the site, the site is not located within an EA Flood Alert or Flood Warning service area.

Safe Refuge

4.13 In the unlikely event that a flood event was to affect the site, residents could seek safe refuge at upper floor levels of the proposed properties.

Surface Water Drainage

4.14 To mitigate the development's impact on the current runoff regime it is proposed to incorporate surface water attenuation and storage as part of the development proposals.

4.15 In brief, attenuation of surface water runoff will be provided through SuDS detention basins with capacity for the 1 in 100-year storm +40%CC. Runoff is to be managed by infiltration in the northern and central catchments. Traces of hydrocarbons have been identified in the southern catchment and subsequently restricted discharge methods are to be adopted. The restriction in the southern catchment will limit discharge rates to the Gallos Brook at no greater than 2.0 l/s/ha.

4.16 Further information on the drainage approach is provided within the accompanying Sustainable Drainage Statement (Ref: UHO-BWB-XX-ZZ-RP-CD-0002_SDS).

Foul Water Drainage

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

4.18 Further information can be found within the accompanying Sustainable Drainage Statement, (Ref: UHO-BWB-XX-ZZ-RP-CD-0002_SDS).

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 Richborough Estates Ltd and Lone Star Land in respect of an outline planning application for the erection of up to 230 dwellings, creation of new vehicular access from Camp Road and all associated works. The proposed development is located at Heyford Park, Camp Road, Upper Heyford, Oxfordshire.

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 at an acceptable level of 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

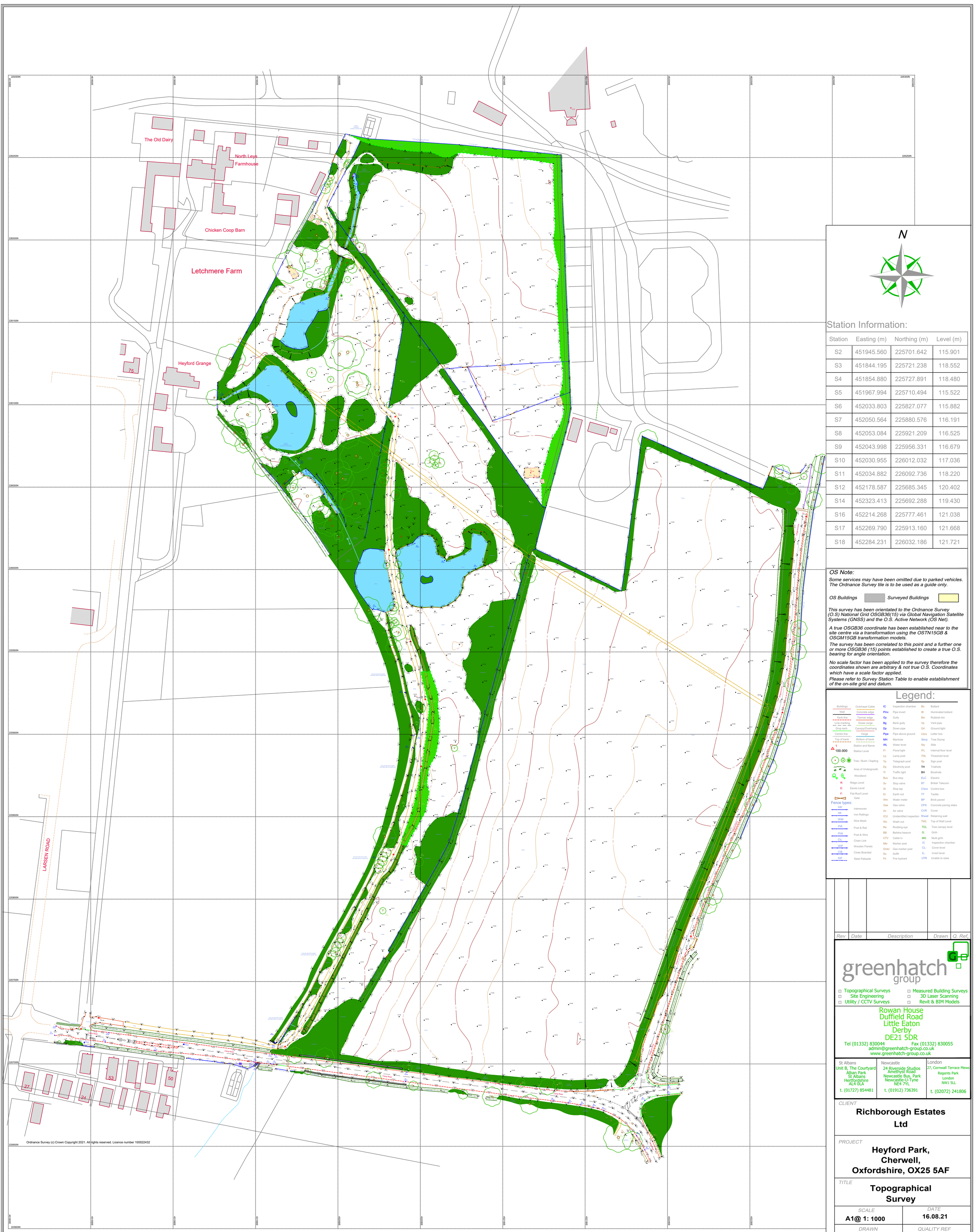
Flood Source	Risk & Proposed Mitigation Measures
Fluvial	The site is shown to be located in Flood Zone 1. No Flood Zones are available for the Gallos Brook at the site due to the catchment area being smaller than 3km^2. As such, a capacity assessment has been completed to estimate flood levels at five locations across the length of the site. Flood levels have been estimated for a suite of return periods including the 1 in 100-year +15%CC design event. The proposed development is shown to be located outside of the 1 in 100-year +15%CC extent, which is largely predicted to remain in-channel. It is recommended that development levels for all dwellings are set 150mm above the surrounding ground level. This will offer mitigation to any potential residual risk of fluvial flooding.
Canals	The site Is located approximately 2.5km east of the Oxford Canal. The site is elevated approximately 42m above the canal. The risk is therefore low.
Groundwater	The site is shown to fall within a 1km^2 grid tile which is predicted to be at a low susceptibility (<25%) to groundwater flooding. BWB conducted BRE365 ground testing at the site. No groundwater was encountered within any of the BRE365 trial pits, however, groundwater at a depth of 1.2m below ground level (bgl) was identified at a trial pit in close proximity to the Gallos Brook. It is recommended that development levels for all dwellings are set 150mm above the surrounding ground level. This will offer mitigation to the risk of groundwater flooding.
Reservoirs and waterbodies	The EA reservoir failure flood extents for the dry and wet scenarios do not affect the site. The nearest extent to the site is approximately 2.5km west. As such, the risk is therefore low.
Pluvial runoff and Sewer exceedance	Land falls away from the developable area and drains towards the Gallos Brook. The proposed development is shown to be unaffected during the 1 in 30-year and 1 in 100-year surface water events. The proposed development is largely at very low risk. There is some localised surface water ponding

	predicted during the 1 in 1000-year event which will be managed and mitigated as part of the proposed surface water drainage strategy. It is recommended that development levels for all dwellings are set 150mm above the surrounding ground level. This will offer mitigation to the risk of surface water flooding and/or a sewer exceedance event. Ground levels are to also be profiled to encourage pluvial runoff and overland flows away from the built development and towards the nearest drainage point.
Impact of the Development	The site has been located so as to not encroach or displace any floodplain. Surface water runoff from the development will be controlled appropriately and infiltrate into the ground or discharge to the local watercourse at the equivalent greenfield QBAR rate. The foul water from the development will be drained separately to clean water.
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 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 subject to suitable management of surface water runoff discharging from the site.

APPENDICES

Appendix 1: Topographical Survey



N

Station Information:

Station	Easting (m)	Northing (m)	Level (m)
S2	451945.560	225701.642	115.901
S3	451844.195	225721.238	118.552
S4	451854.880	225727.891	118.480
S5	451967.994	225710.494	115.522
S6	452033.803	225827.077	115.882
S7	452050.564	225880.576	116.191
S8	452053.084	225921.209	116.525
S9	452043.998	225956.331	116.679
S10	452030.955	226012.032	117.036
S11	452034.882	226092.736	118.220
S12	452178.587	225685.345	120.402
S14	452323.413	225692.288	119.430
S16	452214.268	225777.461	121.038
S17	452269.790	225913.160	121.668
S18	452284.231	226032.186	121.721

OS Note:

Some services may have been omitted due to parked vehicles. The Ordnance Survey tile is to be used as a guide only.

OS Buildings *Surveyed Buildings*

This survey has been orientated to the Ordnance Survey (O.S) National Grid OSGB36(15) via Global Navigation Satellite Systems (GNSS) and the O.S. Active Network (OS Net).

A true OSGB36 coordinate has been established near to the site centre via a transformation using the OSTN15GB & OSGM15GB transformation models.

The survey has been correlated to this point and a further one or more OSGB36 (15) points established to create a true O.S. bearing for angle orientation.

No scale factor has been applied to the survey therefore the coordinates shown are arbitrary & not true O.S. Coordinates which have a scale factor applied.

Please refer to Survey Station Table to enable establishment of the on-site grid and datum.

Legend:

Buildings, Wall, Kerb line, Line marking, Drop kerb, Centre line, Top of bank
Overhead Cable, Concrete edge, Tarmac edge, Grass verge, Canopy/Overhang, Verge, Bottom of bank
Station and Name (1), Station Level (100.000)
Tree / Bush / Sapling, Area of Undergrowth, Woodland
R: Ridge Level, E: Eaves Level, F: Flat Roof Level
Gate

Fence types:
- FW Interwoven
- FR Iron Railings
- WM Wire Mesh
- PR Post & Rail
- PW Post & Wire
- CL Chain Link
- WP Wooden Panels
- CB Close Boarded
- SP Steel Palisade

IC	Inspection chamber	Bo	Bollard
PInv	Pipe invert	IB	Illuminated bollard
Gy	Gully	Bin	Rubbish bin
Bg	Back gully	Vp	Vent pipe
Dp	Down pipe	Grl	Ground light
Pipe	Pipe above ground	Lbox	Letter box
MH	Manhole	Stmp	Tree Stump
WL	Water level	Sty	Stile
Fl	Flood light	IFL	Internal floor level
Lp	Lamp post	THL	Threshold level
Tp	Telegraph post	Sp	Sign post
Ep	Electricity post	TH	Trialhole
Tl	Traffic light	BH	Borehole
Bus	Bus stop	ELC	Electric
Sv	Stop valve	BT	British Telecom
St	Stop tap	C'box	Control box
Er	Earth rod	TT	Tactile
Wm	Water meter	BP	Brick paved
Gas	Gas valve	CPS	Concrete paving slabs
Av	Air valve	CVR	Cover
ICU	Unidentified inspection	R/wall	Retaining wall
Wo	Wash out	TWL	Top of Wall Level
Re	Rodding eye	TCL	Tree canopy level
BB	Belisha beacon	G:	Girth
CTV	Cable tv	MG	Multi girth
Mkr	Marker post	IC	Inspection chamber
Gmkr	Gas marker post	CL:	Cover level
So	Soffit	IL:	Invert level
Fh	Fire hydrant	UTR	Unable to raise

Rev	Date	Description	Drawn	Q. Ref.

greenhatch group

- Topographical Surveys
- Site Engineering
- Utility / CCTV Surveys
- Measured Building Surveys
- 3D Laser Scanning
- Revit & BIM Models

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St Albans: Unit B, The Courtyard, Alban Park, St Albans, Hertfordshire, AL4 0LA, t. (01727) 854481
Newcastle: 24 Riverside Studios, Amethyst Road, Newcastle Bus. Park, Newcastle-U-Tyne, NE4 7YL, t. (01912) 736391
London: 27, Cornwall Terrace Mews, Regents Park, London, NW1 5LL, t. (02072) 241806

CLIENT
Richborough Estates Ltd

PROJECT
Heyford Park, Cherwell, Oxfordshire, OX25 5AF

TITLE
Topographical Survey

SCALE	DATE
A1@ 1: 1000	16.08.21
DRAWN: ER	QUALITY REF: GH11383

Level datum	See note
Grid orientation	See note
Job number	41240

Drawing No.: 41240_T
Rev.: 0

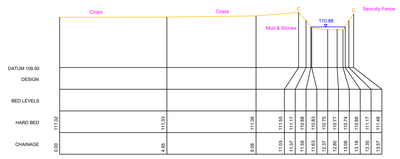
Comments
This plan should only be used for its original purpose. Greenhatch Group accepts no responsibility for this plan if supplied to any party other than the original client.

All dimensions should be checked on site prior to design and construction.

Drainage information (where applicable) has been visually inspected from the surface and therefore should be treated as approximate only.

Notes:

Appendix 2: Watercourse Survey



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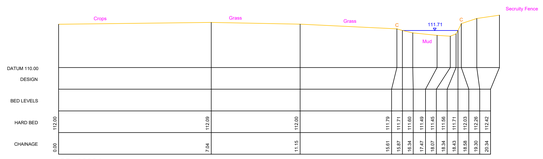

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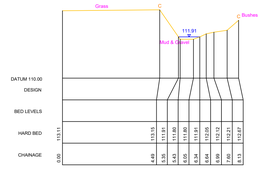

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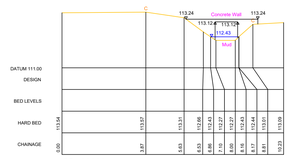

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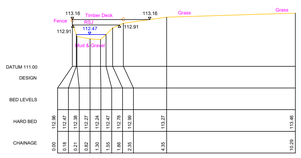

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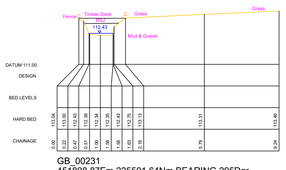

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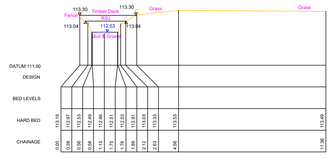

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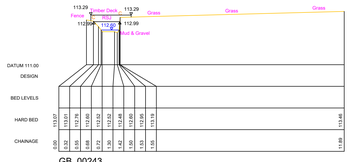

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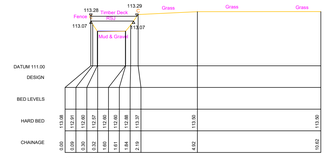

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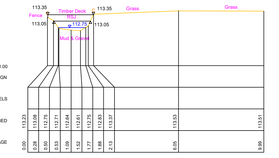

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Timber Deck

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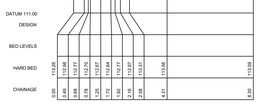
Timber Deck



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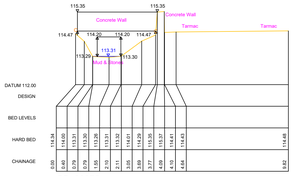

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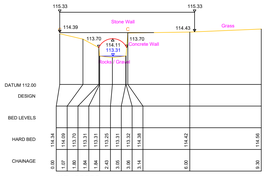
Road Bridge



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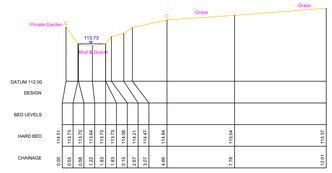
Road Bridge



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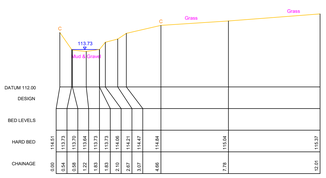
Open Channel



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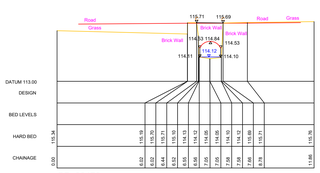

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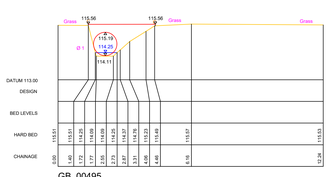

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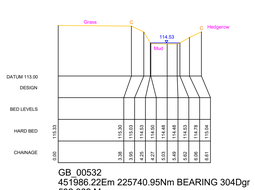

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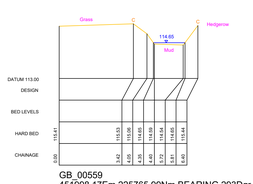

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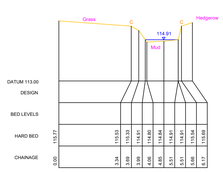

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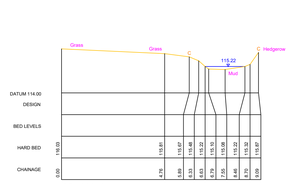

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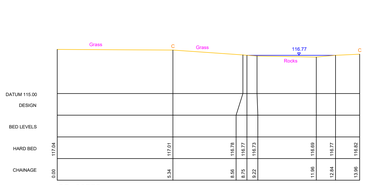

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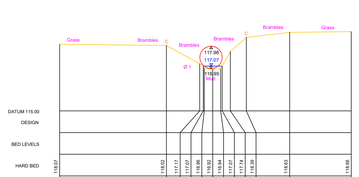

GB_00891
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890.793 M
Culvert

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.
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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.
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
Flow direction and pipe diameter
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
		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 Cell Box
DC	Drainage Channel	FP	Flagpole		
		Gas	Gas	THL	Threshold Level
DK	Drop Kerb	GV	Gas Valve	TL	Traffic Light
DP	Down Pipe	GY	Gully	TP	Telegraph Post
Elec	Electric	Ht	Height	TS	Traffic Signal
EP	Electricity Post	IC	Inspection Chamber	UTS	Unable to Survey
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	26.11.21	First Issue	IR	DS

Issues & Revisions

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Client
RICHBOROUGH ESTATES LTD

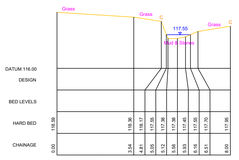
Project Title
UPPER HAYFORD OXFORDSHIRE

Drawing Title
WATERCOURSE SURVEY GALLOS BROOK SHEET 1 Of 5

Drawn:	I.Riley	Reviewed:	D.Smith	
BWB Ref:	BMW 3171	Date:	26.11.21	Scale@A0: 1:100

Drawing Status
Information

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
UHO-BWB-01-ZZ-M2-G-0060	**S2**	**P1**



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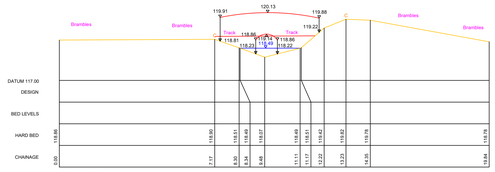

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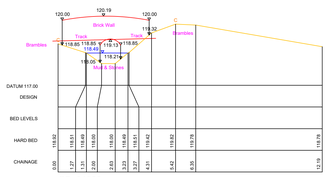

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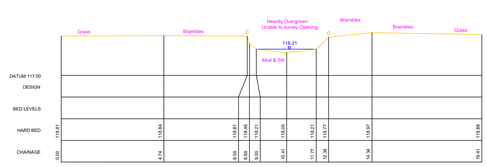

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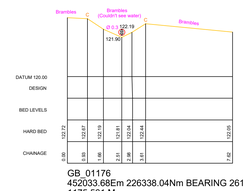

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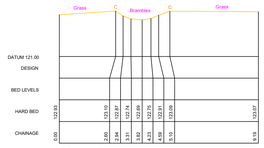

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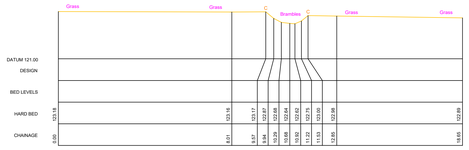

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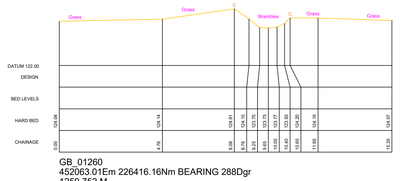

GB_01260
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Open Channel

Notes

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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
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
		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 Cell Box
DC	Drainage Channel	FP	Flagpole	THL	Threshold Level
DK	Drop Kerb	Gas	Gas	TL	Traffic Light
DP	Down Pipe	GV	Gas Valve	TP	Telegraph Post
Elec	Electric	GY	Gully	TS	Traffic Signal
EP	Electricity Post	Ht	Height	UTS	Unable to Survey
ER	Earth Rod	IC	Inspection Chamber	WL	Water Level
FH	Fire Hydrant	IFL	Internal Floor Level	WM	Water Meter
FL	Floodlight	IL	Invert Level (as a reduced level)	WO	Wash Out

Rev	Date	Details of issue / revision	Drw	Rev
P1	26.11.21	First Issue	IR	DS

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Client
RICHBOROUGH ESTATES LTD

Project Title
UPPER HAYFORD OXFORDSHIRE

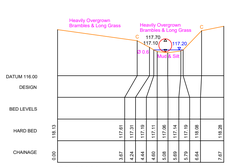
Drawing Title
WATERCOURSE SURVEY GALLOS BROOK SHEET 2 Of 5

Drawn:	I.Riley		Reviewed:	D.Smith	
BWB Ref:	BMW 3171	Date:	26.11.21	Scale@A2:	1:100

Drawing Status
Information

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
UHO-BWB-02-ZZ-M2-G-0060	**S2**	**P1**

C:\Users\ian.riley\Documents\LSS FILES\JOBS\2021 JOBS\BMW3171-Upper Hayford Watercourse\FINAL\UHO-BWB-ZZ-M2-G-0060-S2-P1.dwg



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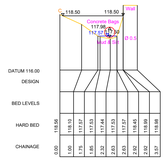

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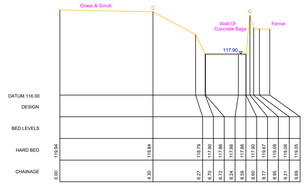

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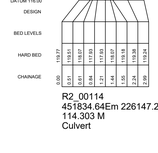

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Notes

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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
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
		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 Cell Box
DC	Drainage Channel	FP	Flagpole	THL	Threshold Level
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DK	Drop Kerb	GV	Gas Valve	TP	Telegraph Post
DP	Down Pipe	GY	Gully	TS	Traffic Signal
Elec	Electric	Ht	Height	UTS	Unable to Survey
EP	Electricity Post	IC	Inspection Chamber	WL	Water Level
ER	Earth Rod	IFL	Internal Floor Level	WM	Water Meter
FH	Fire Hydrant	IL	Invert Level (as a reduced level)	WO	Wash Out
FL	Floodlight				

Rev	Date	Details of issue / revision	Drw	Rev
P1	26.11.21	First Issue	IR	DS

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Client
RICHBOROUGH ESTATES LTD

Project Title
UPPER HAYFORD OXFORDSHIRE

Drawing Title
WATERCOURSE SURVEY REACH 2 SHEET 3 Of 5

Drawn:	I.Riley		Reviewed:	D.Smith	
BWB Ref:	BMW 3171	Date:	26.11.21	Scale@A0:	1:100

Drawing Status
Information

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
UHO-BWB-03-ZZ-M2-G-0060	**S2**	**P1**

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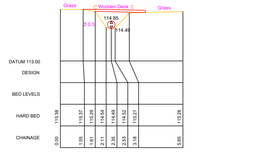

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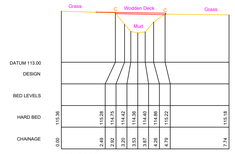

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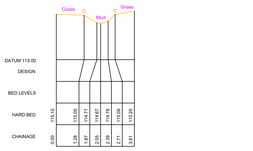

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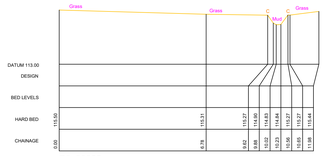

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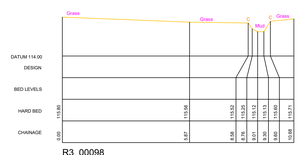

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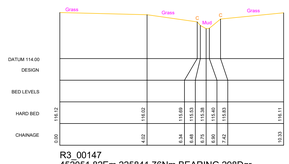

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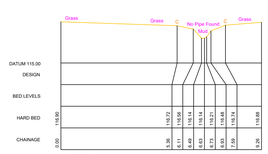

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Key Plan

Legend

OS Buildings
Surveyed Buildings
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Wall
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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
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
		FSP	Fence Steel Palisade	ST	Stop Tap
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DP	Down Pipe	GV	Gas Valve	TP	Telegraph Post
Elec	Electric	GY	Gully	TS	Traffic Signal
EP	Electricity Post	Ht	Height	UTS	Unable to Survey
ER	Earth Rod	IC	Inspection Chamber	WL	Water Level
FH	Fire Hydrant	IFL	Internal Floor Level	WM	Water Meter
FL	Floodlight	IL	Invert Level (as a reduced level)	WO	Wash Out

Rev	Date	Details of issue / revision	Drw	Rev
P1	26.11.21	First Issue	IR	DS

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Client

RICHBOROUGH ESTATES LTD

Project Title

UPPER HAYFORD OXFORDSHIRE

Drawing Title

WATERCOURSE SURVEY REACH 3 SHEET 4 Of 5

Drawn:	I.Riley		Reviewed:	D.Smith	
BWB Ref:	BMW 3171	Date:	26.11.21	Scale@A2:	1:100

Drawing Status

Information

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
UHO-BWB-04-ZZ-M2-G-0060	**S2**	**P1**

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Key Plan

Legend

OS Buildings		Contour Lines	
Surveyed Buildings		Inspection Chamber	
Building		Flow direction and pipe diameter	225
Wall		Station and Name	
Kerb Channel Line		Monitoring Borehole	BH 1
Top of Kerb		Tree / Bush / Sapling	
Edge of Surface		Area of Vegetation/ Extent of Tree Canopy	
Top of Bank		Hedge	
Bottom of Bank		Body of Water	
Canopy / Overhang		Body of Water from OS	
Line Marking		Spot Level	50.00
Centre Line		Assumed Surface Water Drainage Line	
Watercourse		Surface Water Drainage Line	
Centre Line Barrier			
Fence			
Gate			
Overhead Powerline			
Overhead Utilities			

AP	Anchor Point	FBW	Fence Barbed Wire	LB	Litter Bin
BG	Back Gully	FCB	Fence Closed Board	LP	Lamp Post
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Elec	Electric	GV	Gas Valve	TP	Telegraph Post
EP	Electricity Post	GY	Gully	TS	Traffic Signal
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Project Title

UPPER HAYFORD OXFORDSHIRE

Drawing Title

EXISTING WATERCOURSE LAYOUT SHEET 1 Of 5

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BWB Ref:	BMW 3171	Date:	26.11.21	Scale@A0:	1:100

Drawing Status

Information

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
UHO-BWB-05-ZZ-M2-G-0060	S2	P1

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Appendix 3: Site Plan

PLANNING

Site boundary *(11.68ha)*

Hybrid/mixed application for upto 1,235 dwellings; retail; medical centre; employment; schools; community use buildings; indoor sports provision; energy facilities; 30m high observation tower with zip-wire; changes of use and demolition to existing buildings; open space; sports facilities; green infrastructure; and upgrades to Chilgrove Drive and the junction with Camp Road
(18/00825/HYBRID)
Status: Outline Approval

1. Full application for 89 dwellings
(15/01357/F)
Status: Undetermined

2. Outline application application for up to 31 dwellings
(21/03523/OUT)
Status: Undtermined

1. Proposed vehicular and pedestrian access via Camp Road
2. Proposed pedestrian/cycle connection to Camp Road
3. Proposed pedstrian/cycle connection to Chilgrove Drive
4. Primary tree lined street with foot/cycleway
5. Secondary street
6. Shared surface
7. Linked private drive
8. Private drive/lane
9. Proposed footpaths/recreational routes
10. Central green space to act as focal point with playspace (LAP)
11. Playspace (LEAP)
12. 'Wet corridor' public open space to provide ecological enhancement and recreation benefits
13. Attenuation basins
14. Existing ponds
15. Existing vegetation retained and enhanced as necessary with locally characteristic and native species
16. Proposed hedgerow strengthening the field pattern by planting up gappy existing hedges
17. Proposed native wet woodland
18. Proposed native tree belts around airfield to enhance urban fringe and reduce the the visual impact using locally characteristic and native species
19. Proposed scattered clusters of native tree planting to give impression of linear tree belt to enhance urban fringe and softening of built form

Rev.	Date	Description

Land north of Camp Road
HEYFORD PARK

Illustrative Masterplan

Job ref:	Drawing number:	Revision:
374	P06	-

Scale:	Date:
1:2,000 @ A3	December 2021

0 50 100 150 200 m

part of
edge Placemaking Group Ltd
Company Reg No: 11447550 VAT No: 299072069

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OX9 3EW

01865 522395
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Appendix 4: Manning's Capacity Assessment

ENVIRONMENT

Richborough Estates Ltd and Lone Star Land
Heyford Park
Upper Heyford, Oxfordshire
Manning's Capacity Assessment

December 2021

Document Number:	UHO-BWB-ZZ-XX-RP-YE-0003-TN
BWB Reference:	BMW-3171-TN

Revision	Date of Issue	Status	Author:	Checked:	Approved:
P01	20/12/21	S2	Max Brambani BSc (Hons) PgCert MCIWEM	Matthew Day BA (Hons) MSc FRGS MCIWEM C.WEM C.Sci C.Env	Robin Green BSc (Hons)

Notice

1. INTRODUCTION

1.1 BWB Consulting Ltd has been commissioned by Richborough Estates Limited and Lone Star Land (the client) to undertake a Manning's capacity assessment of the Gallos Brook and associated local watercourses to provide an understanding of potential fluvial flood risk to the proposed development site at Heyford Park, Land north of Camp Road, Upper Heyford, Oxfordshire.

Aims and Objectives

1.2 The aim of the exercise is to identify the likely peak flood levels at several locations across the site to inform the associated Flood Risk Assessment for the proposed development. The peak flood levels for key return periods will be compared against the surveyed top of bank levels at the specific locations to determine whether peak flows remain in-channel and whether the proposed development is shown to be at risk of fluvial flooding.

1.3 The EA Flood Map for Planning confirms that the site lies wholly in Flood Zone 1. The EA have confirmed that there is not any modelled data available for this location as existing. This is because no detailed modelling exercise has been completed to date.

1.4 No Flood Zones are associated with the length of the Gallos Brook that flows from north to south through the site. This is believed to be due to the national flood mapping tool being limited to representing watercourses with a catchment area above 3km^2.

1.5 Given that there are no Flood Zones provided at the site, the Environment Agency's risk of flooding from surface water mapping offers the best available data as an indicative proxy of fluvial flood extents. This mapping tool gives an indication for the estimated fluvial river corridor and how flows are conveyed through the site and wider catchment area. The Flood Risk Assessment will compare the surface water extents against estimated fluvial flood extents for the design event (as derived from the capacity assessment) as part of a validation exercise.

1.6 The estimated flood levels and extents derived by the capacity assessment are compared against the site proposals within the Flood Risk Assessment to determine the risk of fluvial flooding to the proposed development. The FRA also outlines the mitigation measures that are to be required in order for the proposed residential development to be deemed safe for its lifetime.

2. METHODOLOGY

Input Data Sources

2.1 The capacity assessment has been completed at five cross-section locations across the length of the site boundary. This allows for a representation of fluvial flood risk across all parts of the proposed development. The five chosen cross-section locations are displayed in **Figure 2.1**.

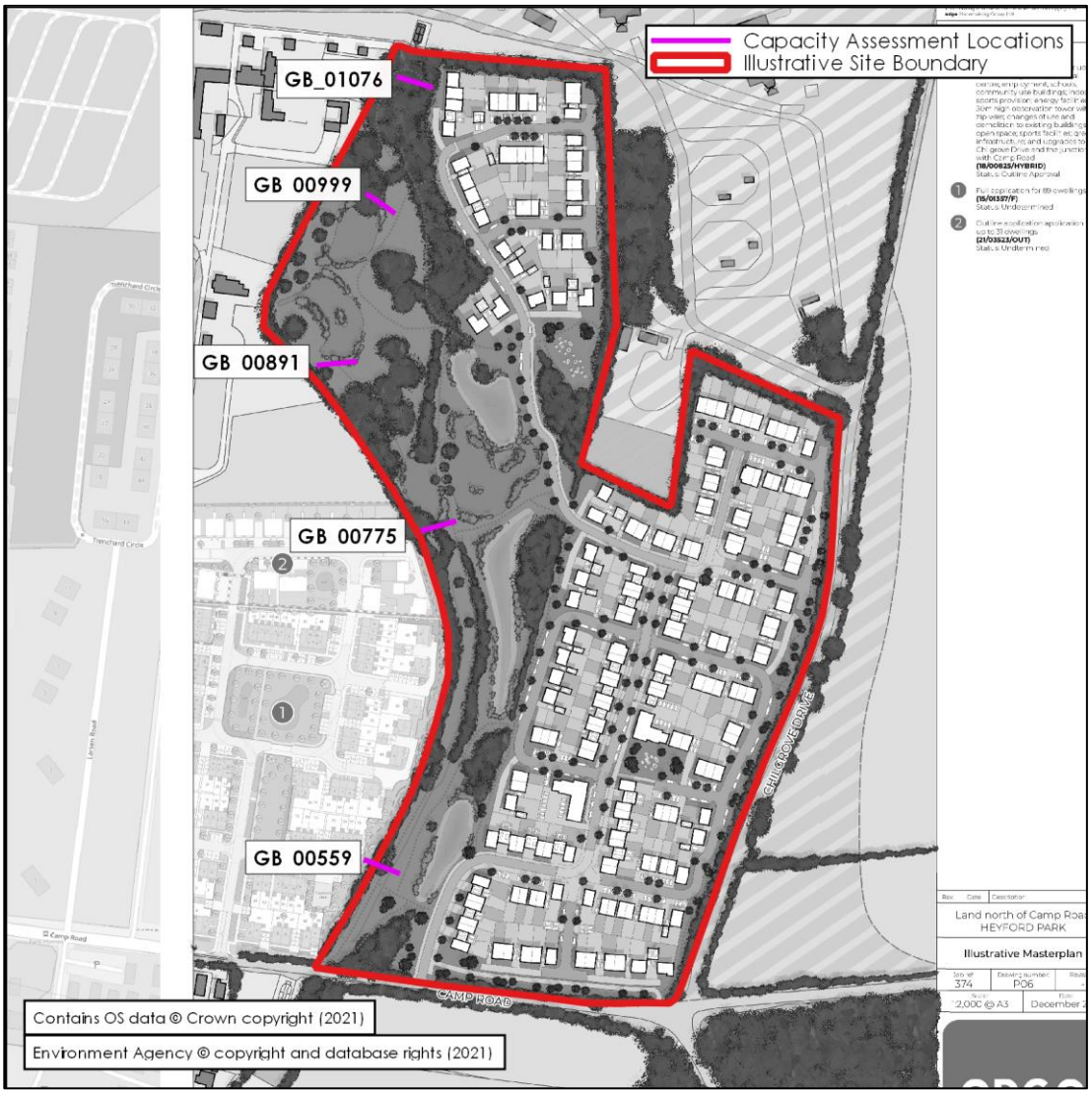

Figure 2.1: Capacity Assessment Cross-Section Locations

2.2 The capacity assessment involves the following primary sources of input data sources:

- Watercourse Survey (reference: UHO-BWB-ZZ-M2-G-0060-S2-P1).
- Topographic Survey (reference: 41240_T).
- 1m resolution Light Detection and Ranging (LiDAR) data.

- Peak Flows derived through a combination of FEH Catchment Areas, Catchment Descriptors and using Revitalised Flood Hydrograph (ReFH) version 2.3 software.

2.3 These data sources are then used in combination with the Manning's equation for determining open channel flows, which is as follows:

$$Q = \frac{K\ A\ R^{2/3}\ S^{1/2}}{\mathrm{n}}$$

Whereby:

Q = Flow rate (m^3/s)
A = Cross-sectional area of flow
R = Hydraulic radius (cross-sectional area divided by wetted perimeter)
S = Slope of the channel at the point of measurement
n = Surface roughness (based upon channel material and condition)
K = Constant dependent upon units

Assumptions and Limitations

2.4 In the absence of hydraulic modelling, the Manning's capacity assessment was considered to be next best alternative method for estimating flood levels at the site for the design event (1 in 100-year +15%CC).

2.5 Several assumptions were made during the study which may lead to implications on the results. However, the study has been based on the best data available at the time of writing. The key assumptions and limitations are as follows:

- The exercise has made use of the best available topographic data at the time of construction and assessment. Survey has been collected of the channel and floodplain. EA 1m resolution LiDAR data has been used elsewhere.
- The modelling exercise has made use of the latest ReFH2 hydrological software at the time of analysis and completion. A statistical assessment of the hydrology has not been conducted as this is perceived to be outside of the scope of works.
- The approach considers no formal representation of conveyance through hydraulic structures.
- The assessment was conducted across five locations that are deemed to provide a representation of risk to the entire development site. Subsequently the risk of flooding to the development can only be assessed at these specific locations.
- The capacity assessment has been undertaken to provide an understanding of fluvial flood risk to the proposed development. It has not been designed to accurately map flooding in the wider catchment.
- Due to the size of the catchment area (1.28km^2) at the Flow Estimation Point, flows have been scaled accordingly to the approximate area that drains each assessment location.

3. HYDROLOGY

3.1 Catchment descriptors were extracted from the below Flood Estimation Point (FEP), immediately south of the site. This has an associated AREA value of 1.28km^2. the location of the FEP is displayed in **Figure 3.1**.

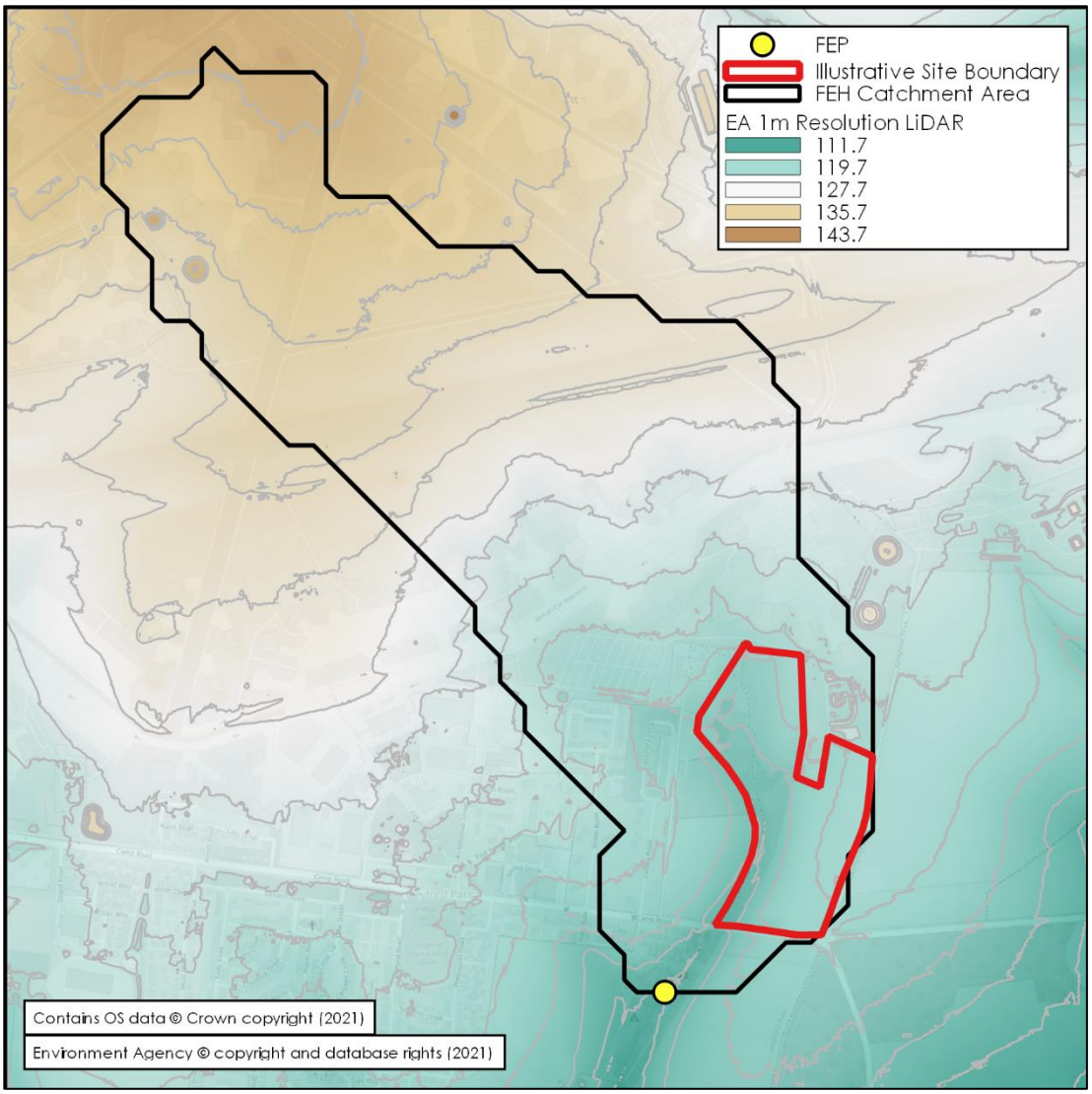

Figure 3.1: Flow Estimation Point and FEH Catchment Area

3.2 The ReFH2 estimated peak flows are reported in **Table 3.1** at the FEP.

Table 3.1: ReFH2 Derived Peak Flows at FEP

Location	Flood peak (m^3/s)							
	2	5	10	20	50	100	200	1000
FEP	0.12	0.17	0.21	0.24	0.30	0.35	0.41	0.59

3.3 As part of the capacity assessment, the catchment area needs to be revised to account for the correct area draining to each cross-section location. The adjusted catchment areas are displayed in **Figure 3.2**.

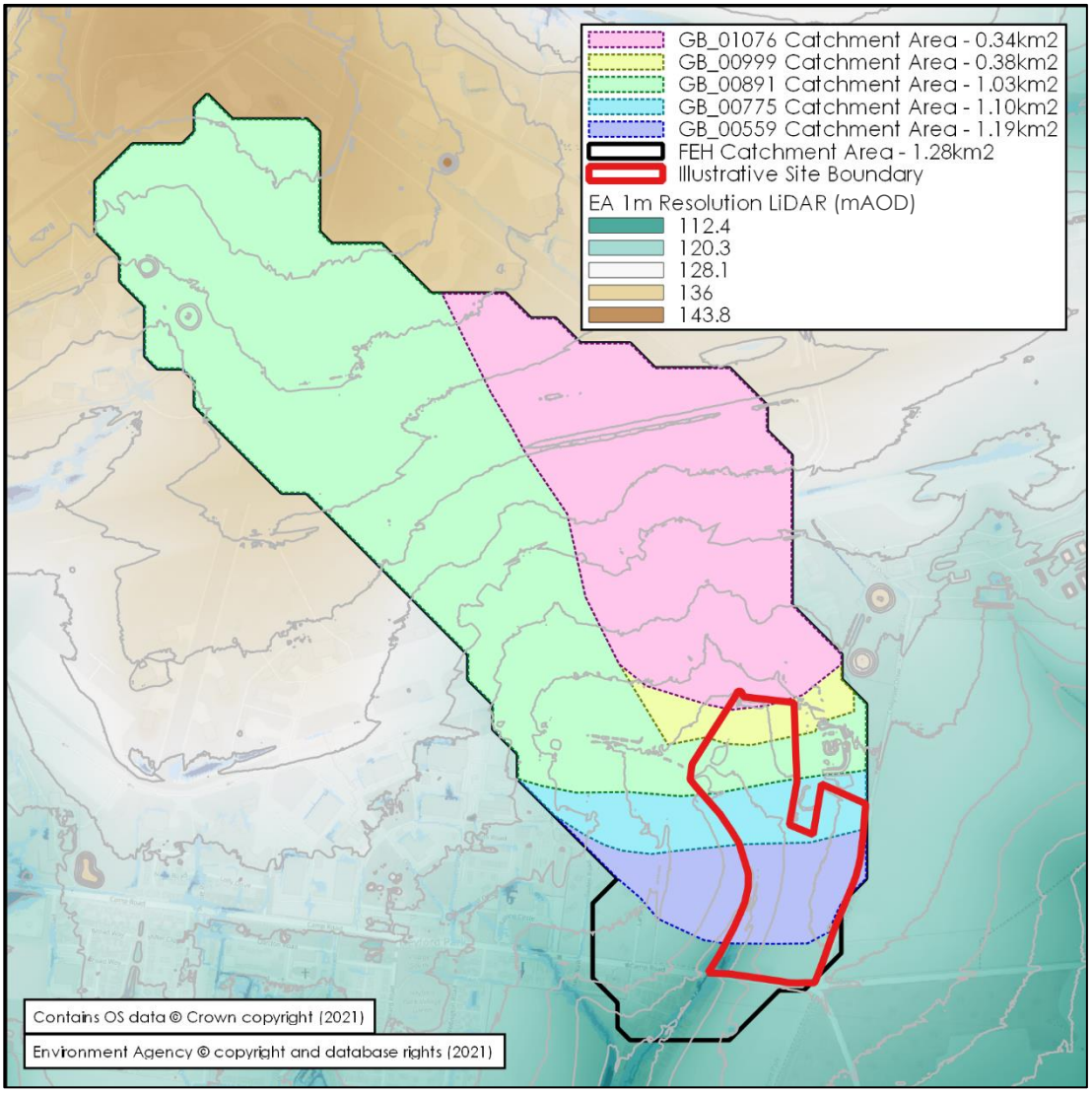

Figure 3.2: Revised Catchment Areas at Each Capacity Assessment Location

3.4 The peak flows have been scaled accordingly and are provided overleaf in **Table 3.2**.

Table 3.2: Scaled ReFH2 Peak Flows

Location	Flood peak (m^3/s)							
	2	5	10	20	50	100	200	1000
FEP	0.12	0.17	0.21	0.24	0.30	0.35	0.41	0.59
GB_00559	0.11	0.16	0.19	0.23	0.28	0.32	0.38	0.55
GB_00775	0.11	0.15	0.18	0.21	0.26	0.30	0.35	0.51
GB_00891	0.10	0.14	0.17	0.20	0.24	0.28	0.33	0.48
GB_00999	0.04	0.05	0.06	0.07	0.09	0.10	0.12	0.18
GB_01076	0.03	0.05	0.05	0.06	0.08	0.09	0.11	0.16

3.5 The peak flows for the 1 in 100-year event with the projected climate change allowances are reported in **Table 3.3**. The site is located within the Cherwell and Ray Management Catchment of the Thames River Basin District. As such, uplifts of +15% (Central), +25% (Higher Central) and +49% (Upper End) are considered.

Table 3.3: 1 in 100 Year + Climate Change Peak Flows

Location	Flood peak (m^3/s)			
	100	100 +15%CC*	100 +25%CC	100 +49%CC
GB_00559	0.32	0.37	0.40	0.48
GB_00775	0.30	0.35	0.38	0.45
GB_00891	0.28	0.32	0.35	0.42
GB_00999	0.10	0.12	0.13	0.15
GB_01076	0.09	0.10	0.11	0.13

***100 +15%CC is considered the design event for "More Vulnerable" developments**

4. MANNING'S CAPACITY ASSESSMENT

4.1 The Manning's equation for determining open channel flows is to be applied at five locations for a series of water levels. This will allow a rating curve to be generated. The ReFH2 peak flows can then be compared to the rating curve to derive estimated flood levels for the suite of return periods. The equation to be calculated is as follows:

$$Q = \frac{K\ A\ R^{2/3}\ S^{1/2}}{\mathrm{n}}$$

Whereby:

Q = Flow rate (m^3/s)
A = Cross-sectional area of flow
R = Hydraulic radius (cross-sectional area divided by wetted perimeter)
S = Slope of the channel at the point of measurement
n = Surface roughness (based upon channel material and condition)
K = Constant dependent upon units

GB_00559

4.2 The surveyed cross-section at this location is as per **Figure 4.1**.

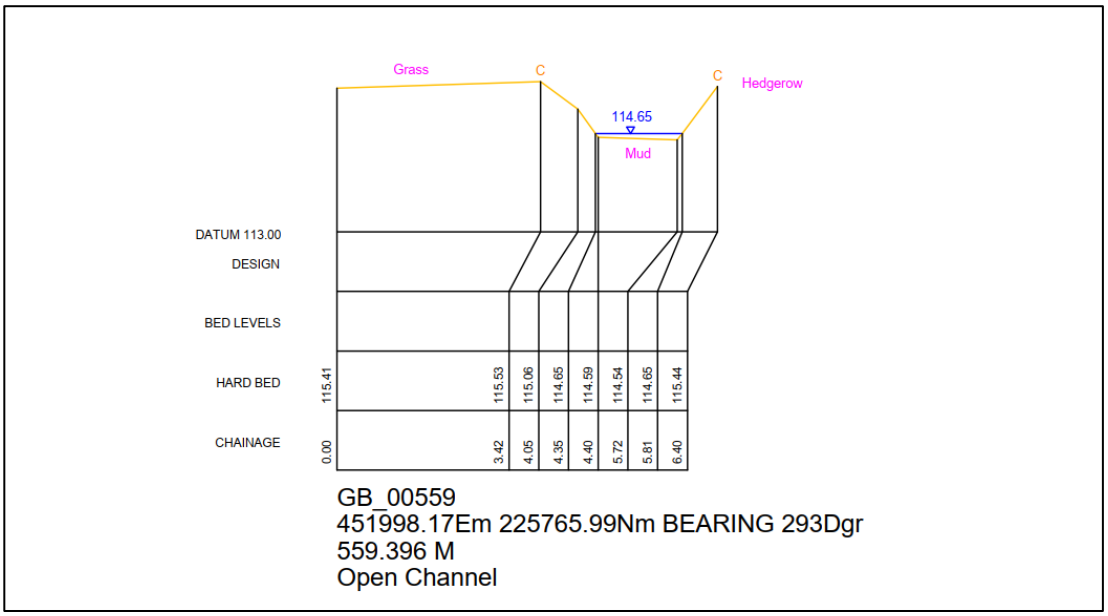

Figure 4.1: Surveyed Cross-Section of GB_00559

4.3 The Manning's equation was calculated at five intervals at this location, based off the following assumed water levels; 114.60metres Above Ordnance Datum (mAOD), 114.80mAOD, 115mAOD, 115.20mAOD, 115.40mAOD.

4.4 Parameters "*S*", "n" and "K" remain the same for all water levels.

4.5 Slope (*S*) has been derived as **0.009** at this location. The general gradient at the cross-section location has been calculated by determining the slope between cross sections

GB_00775 and GB_00495. Over this distance of 280m, the in-channel invert level fell by 2.6m. As such, 2.6 / 280 = **0.009**.

4.6 The surface roughness (n) at this location has been assigned a value of **0.040**. This is based off the photograph provided in **Figure 4.2** and with reference to the Manning's n for Channels[1].

4.7 *K* is considered to be a constant conversion factor which adopts the value of **1**.

Figure 4.2: Photograph of Gallos Brook Channel at GB_00559

4.8 As such following parts of the Manning's equation completed. The remaining values to be determined are A and R. This will then allow for Q to be calculated.

$$Q = \frac{1\ A\ R^{2/3}\ 0.009^{1/2}}{0.040}$$

Whereby:

- *Q* = Flow rate (m^3/s)
- *A* = Cross-sectional area of flow
- *R* = Hydraulic radius (cross-sectional area divided by wetted perimeter)
- *S* = Slope of the channel at the point of measurement
- *n* = Surface roughness (based upon channel material and condition)
- *K* = Constant dependent upon units

[1] Manning's n for Channels (Chow, 1959)

4.9 The cross-sectional area (A) for GB_00559 was determined in AutoCAD using the AREA measure tool. The cross-sectional area was measured for five different water levels; 114.60mAOD, 114.80mAOD, 115.00mAOD, 115.20mAOD and 115.4mAOD. The channel cross-section is displayed in **Figure 4.3** with a water level of 115.00mAOD. The calculated cross sectional area (A) values are reported in **Table 4.1.**

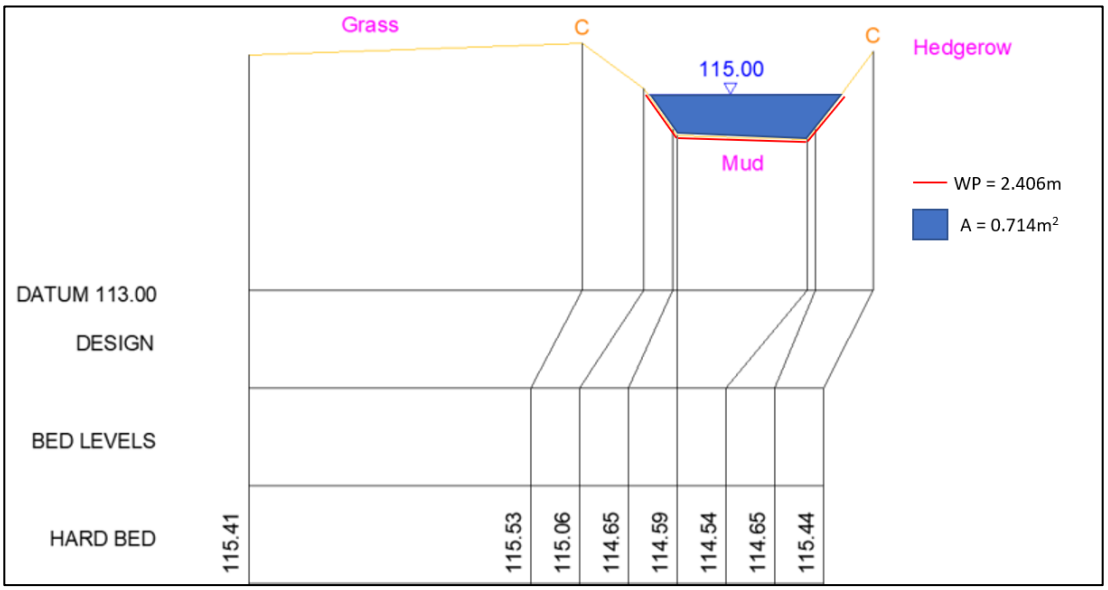

Figure 4.3: Approach to Calculating Cross-Sectional Area and Wetted Perimeter at GB_00559

4.10 Hydraulic Radius (R) is determined by dividing the cross-sectional area by the wetted perimeter for a particular water level. As such, it is first necessary to measure the wetted perimeter (WP) of the cross-section for each water level, this is also shown in **Figure 4.3** for the water level of 115.00mAOD.

4.11 With the wetted perimeter measured and the area determined, it is then possible to determine the hydraulic radius (R). Values for all parameters are therefore reported in **Table 4.1**. It is subsequently therefore possible to complete the equation to calculate the respective flow rate (Q) for each water level.

Table 4.1: Calculated Manning's Equation Values for GB_00559

Manning's Equation Parameters	Values for GB_0559 at Each Water Level				
	114.60	**114.80**	**115.00**	**115.20**	**115.40**
A	0.046	0.353	0.714	1.138	1.633
WP	1.403	1.806	2.406	2.959	3.509
R	0.33	0.195	0.297	0.385	0.465
S	0.009	0.009	0.009	0.009	0.009
n	0.040	0.040	0.040	0.040	0.040
K	1	1	1	1	1
Q	**0.011**	**0.282**	**0.753**	**1.427**	**2.326**

4.12 Given that flow rates have been calculated for a change in water level at the cross-section, it is subsequently possible to plot a rating curve that displays the relationship between flow and water level. This is displayed in **Figure 4.4**.

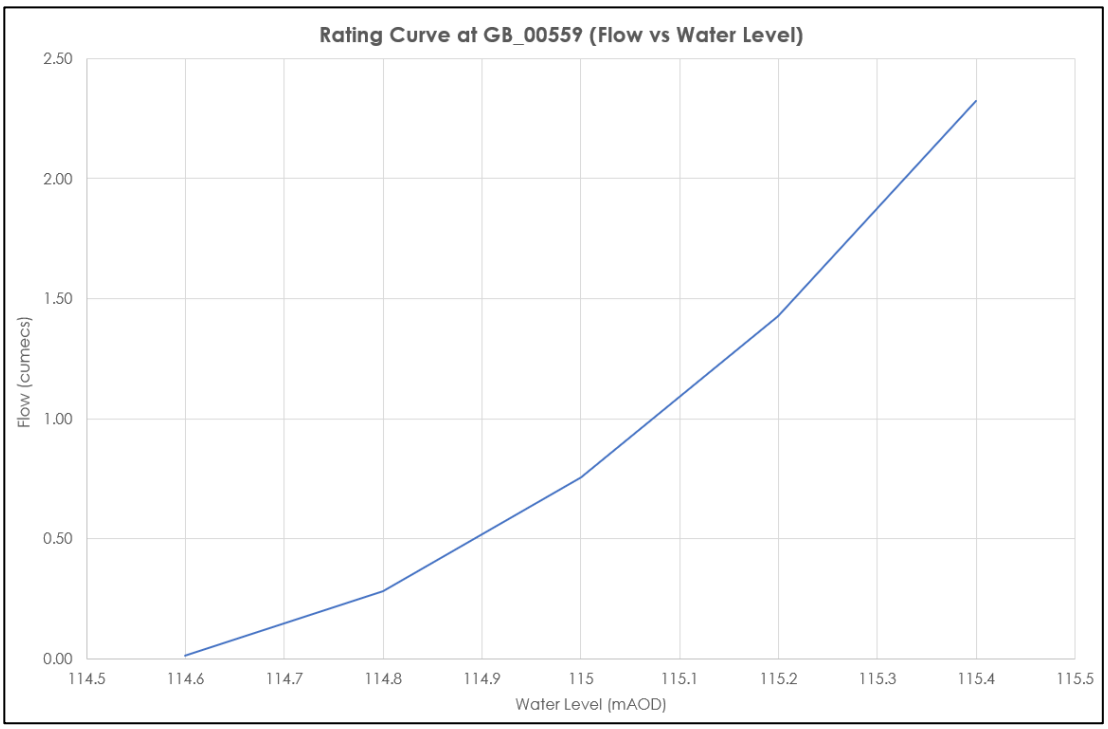

Figure 4.4: Rating Curve at GB_00559

4.13 The scaled ReFH2 peak flows, as reported in **Table 3.2** and **Table 3.3** have subsequently been applied against the rating curve in **Figure 4.4** to derive an estimated peak flood

level for the respective return periods. The corresponding peak flood levels are presented in **Table 4.2**.

Table 4.2: Estimated Maximum Flood Levels at GB_00559

Return Period	GB_00559 Max Flood Level (mAOD)	+300mm Freeboard (mAOD)
2	114.66	114.96
5	114.71	115.01
10	114.73	115.03
20	114.75	115.05
50	114.80	115.10
100	114.82	115.12
100 +15%CC	114.83	115.13
100 +25%CC	114.85	115.15
100 +49%CC	114.88	115.18
200	114.84	115.14
1000	114.92	115.22

1.7 As per the cross-section drawing in **Figure 4.1**, the left bank crest height at GB_00559 has been surveyed as 115.53mAOD, whilst the right bank crest height has been surveyed as 115.44mAOD.

1.8 Subsequently, peak flows are estimated to remain in-channel for all events including the 1 in 100-year +15%CC event and 1 in 1000-year event, including a +300mm freeboard allowance.

1.9 Whilst flood levels are predicted to remain in-bank, a flood extent has been derived by projecting the design flood levels (including freeboard) for each cross-section onto the topographical survey. The estimated flood extent at GB_00559 is displayed in **Figure 4.5**.

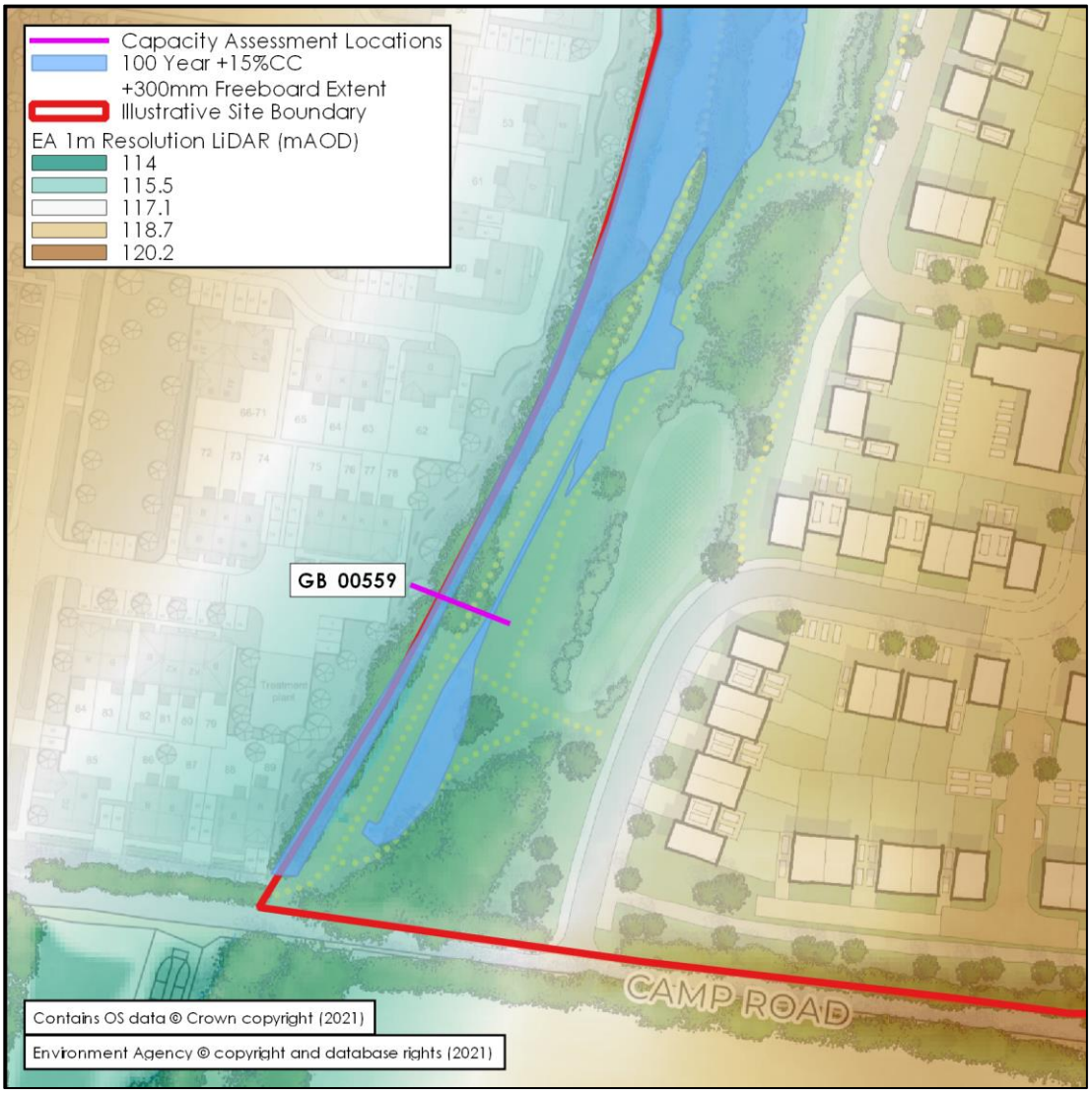

Figure 4.5: 1 in 100-Year +15%CC (Including Freeboard) Projected Flood Extent at GB_00559

4.14 Further downstream, a 1.05m diameter pipe has been surveyed at the bottom of the site at cross-section GB_00495.

4.15 A pipe capacity assessment has subsequently been undertaken. This calculation sheet, provided overleaf, displays the pipe to have a capacity of 2.960m³/s. Subsequently, based off the peak flows estimated in **Table 3.2** and **Table 3.3**, there is sufficient capacity to convey flows for all events through this structure.

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BWB

Job Number: BMW3171	**Calc number: 1**	**Rev: 1**
Project: Heyford Park	**Date: 16.12.21**	**Prepared by: MB**
Title: GB_00495 Pipe Capacity		**Authorised by: CT**

Colebrook-White Formula

$$V = -2\left(2gDS\right)^{0.5} \log\left(\frac{k}{3.7D} + \frac{2.5\nu}{D\left(2gDS\right)^{0.5}}\right)$$

k = Colebrook-White roughness coefficient, in metres

V = velocity, in metres per second

D = circular cross-section pipe, inside diameter, in metres

S = slope, in metres per metre

ν = kinematic viscosity of water, in square metres per second.

g =	Gravity		9.81 m/s^2
n =	kinematic viscosity of water		1.141E-06 m^2/s
k =	Colebrook-White rougł	= 0.030 mm	= 3.000E-05 m
D =	Inside diameter	= 1050 mm	= 1.050 m
S =	Slope, in metres per metre		0.613%
=	(Hydraulic Gradient)	1:	324

Discharge:

Q = V x A

V= 3.42 m/s

A = 0.866 m^2

Q = 2.960 m^3/s = 2960.0 l/s

GB_00775

4.16 The surveyed cross-section at this location is as per **Figure 4.6**.

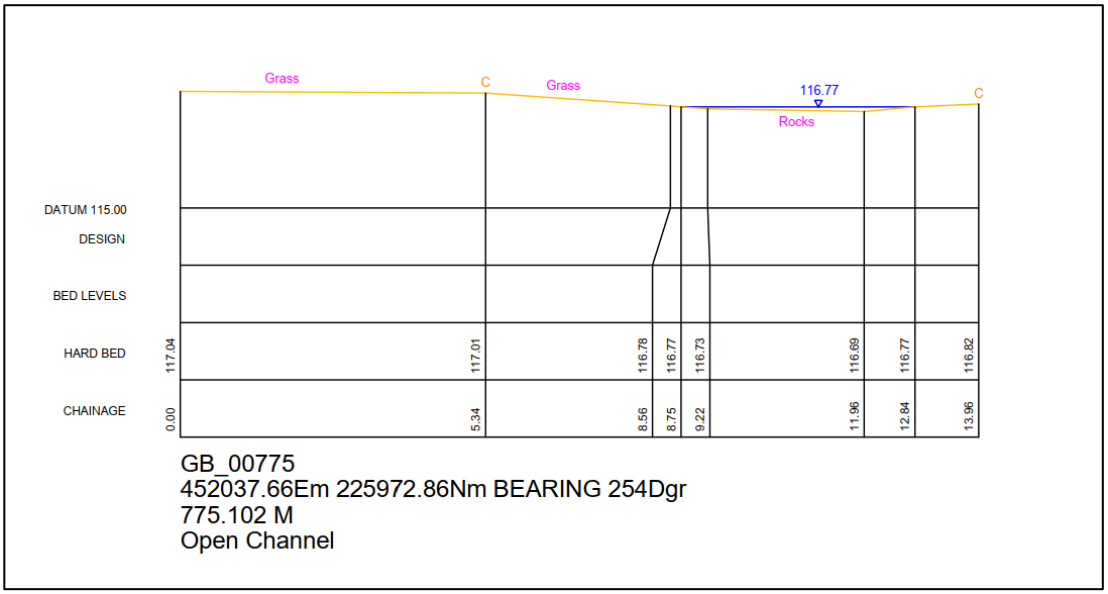

Figure 4.6: Surveyed Cross-Section of GB_00775

4.17 The Manning's equation was calculated at four intervals at this location, based off the following assumed water levels; 116.70mAOD, 116.80mAOD, 116.90mAOD and 117.00mAOD.

4.18 Parameters "*S*", "n" and "K" remain the same for all water levels.

4.19 Slope (*S*) has been derived as **0.008** at this location. The general gradient at the cross-section location has been calculated by determining the slope between cross sections GB_00891 and GB_00649. Over this distance of 242m, the in-channel invert level fell by 1.84m. As such, 1.84 / 242 = **0.008**.

4.20 The surface roughness (n) at this location has been assigned a value of **0.040**. This is based off the photograph provided in **Figure 4.7**. With reference to the Manning's n for Channels[1].

4.21 *K* is considered to be a constant conversion factor which adopts the value of **1**.

Figure 4.7: Photograph of Gallos Brook Channel at GB_00775

4.22 As such following parts of the Manning's equation completed. The remaining values to be determined are A and R. This will then allow for Q to be calculated.

$$Q = \frac{1\ A\ R^{2/3}\ 0.008^{1/2}}{0.040}$$

Whereby:

Q = Flow rate (m^3/s)
A = Cross-sectional area of flow
R = Hydraulic radius (cross-sectional area divided by wetted perimeter)
S = Slope of the channel at the point of measurement
n = Surface roughness (based upon channel material and condition)
K = Constant dependent upon units

4.23 The cross-sectional area (A) for GB_00775 was determined in AutoCAD using the AREA measure tool. The cross-sectional area was measured for four different water levels; 16.70mAOD, 116.80mAOD, 116.90mAOD, 117.00mAOD. The channel cross-section is displayed in **Figure 4.8** for the water level of 116.80mAOD. The calculated cross sectional area (A) values are reported in **Table 4.3.**

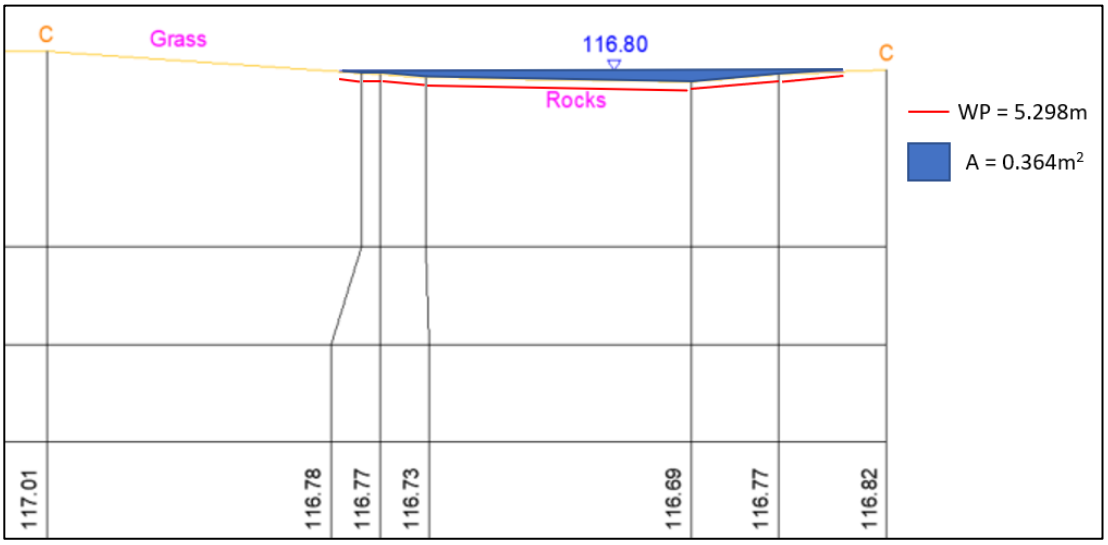

Figure 4.8: Approach to Calculating Cross-Sectional Area and Wetted Perimeter at GB_00775

4.24 Hydraulic Radius (R) is determined by dividing the cross-sectional area by the wetted perimeter for a particular water level. As such, it is first necessary to measure the wetted perimeter (WP) of the cross-section for each water level, this is also shown in **Figure 4.8** for the water level of 116.80mAOD.

4.25 With the wetted perimeter measured and the area determined, it is then possible to determine the hydraulic radius (R). Values for all parameters are therefore reported in **Table 4.3**. It is subsequently therefore possible to complete the equation to calculate the respective flow rate (Q) for each water level.

Table 4.3: Calculated Manning's Equation Values for GB_00775

Manning's Equation Parameters	Values for GB_0775 at Each Water Level			
	116.70	**116.80**	**116.90**	**117.00**
A	0.004	0.364	0.968	1.921
WP	1.581	5.298	7.596	10.47
R	0.002	0.069	0.127	0.183
S	0.008	0.008	0.008	0.008
n	0.040	0.040	0.040	0.040
K	1	1	1	1
Q	**0.001**	**0.137**	**0.548**	**1.387**

4.26 Given that flow rates have been calculated for a change in water level at the cross-section, it is subsequently possible to plot a rating curve that displays the relationship between flow and water level. This is displayed in **Figure 4.9**.

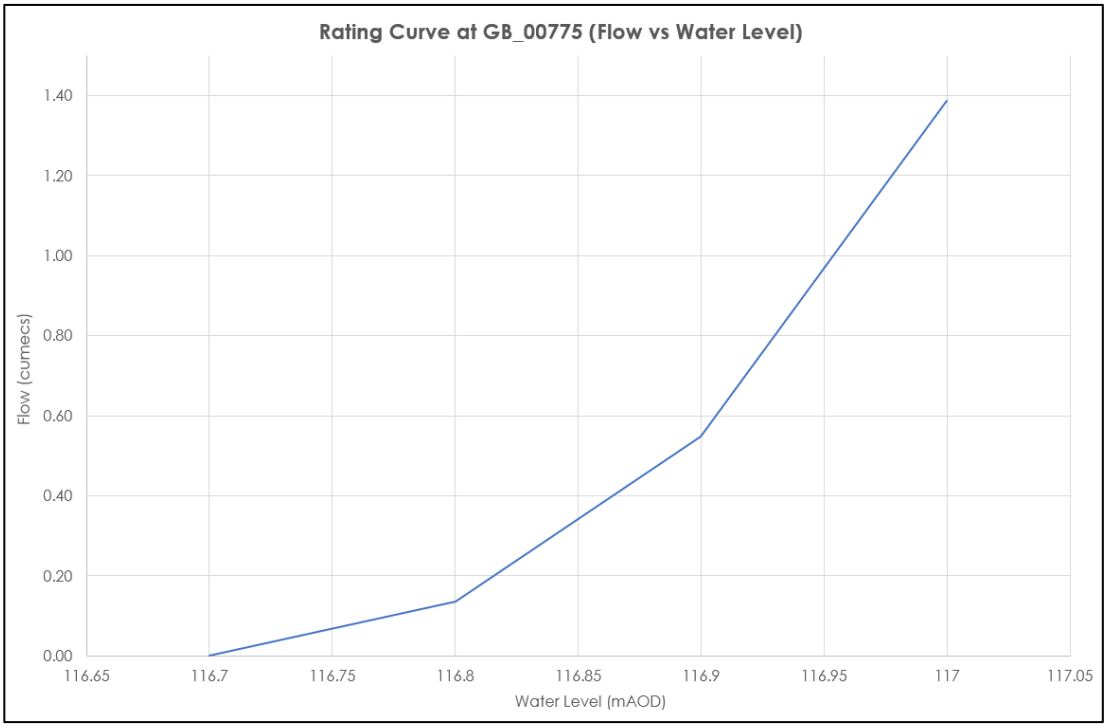

Figure 4.9: Rating Curve at GB_00775

4.27 The scaled ReFH2 peak flows, as reported in **Table 3.2** and **Table 3.3** have subsequently been applied against the rating curve in **Figure 4.9** to derive an estimated peak flood level for the respective return periods. The corresponding peak flood levels are presented in **Table 4.4**.

Table 4.4: Estimated Maximum Flood Levels at GB_00775

Return Period	GB_00775 Max Flood Level (mAOD)	+300mm Freeboard (mAOD)
2	116.77	117.07
5	116.81	117.11
10	116.82	117.12
20	116.82	117.12
50	116.83	117.13
100	116.83	117.13
100 +15%CC	116.84	117.14
100 +25%CC	116.86	117.16
100 +49%CC	116.87	117.17
200	116.85	117.15
1000	116.88	117.18

4.28 As per the cross-section drawing in **Figure 4.6**, the left bank crest height at GB_00775 has been surveyed as 117.01mAOD, whilst the right bank crest height has been surveyed as 116.82mAOD.

4.29 Subsequently, peak flows are estimated to exceed the channel capacity for all events when including the +300mm freeboard allowance.

4.30 A flood extent has been derived by projecting the design flood levels (including freeboard) for each cross-section onto the topographical survey. The estimated flood extent at GB_00775 is displayed in **Figure 4.10**. Please note that this flood extent does not take into account any flow routing within the floodplain.

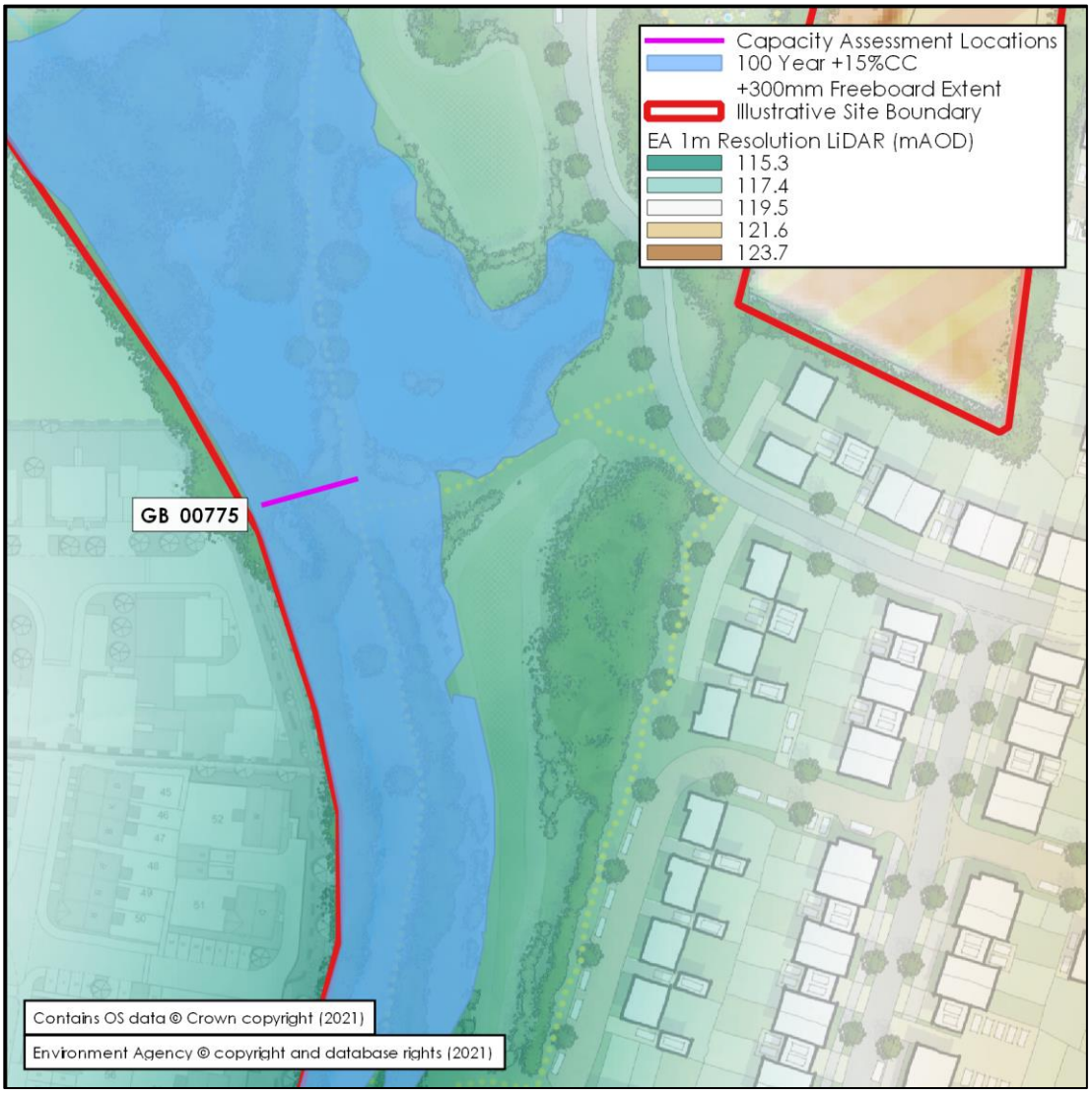

Figure 4.10: 1 in 100-Year +15%CC (Including Freeboard) Projected Flood Extent at GB_00775

GB_00891

4.31 The surveyed cross-section at this location is as per **Figure 4.11**.

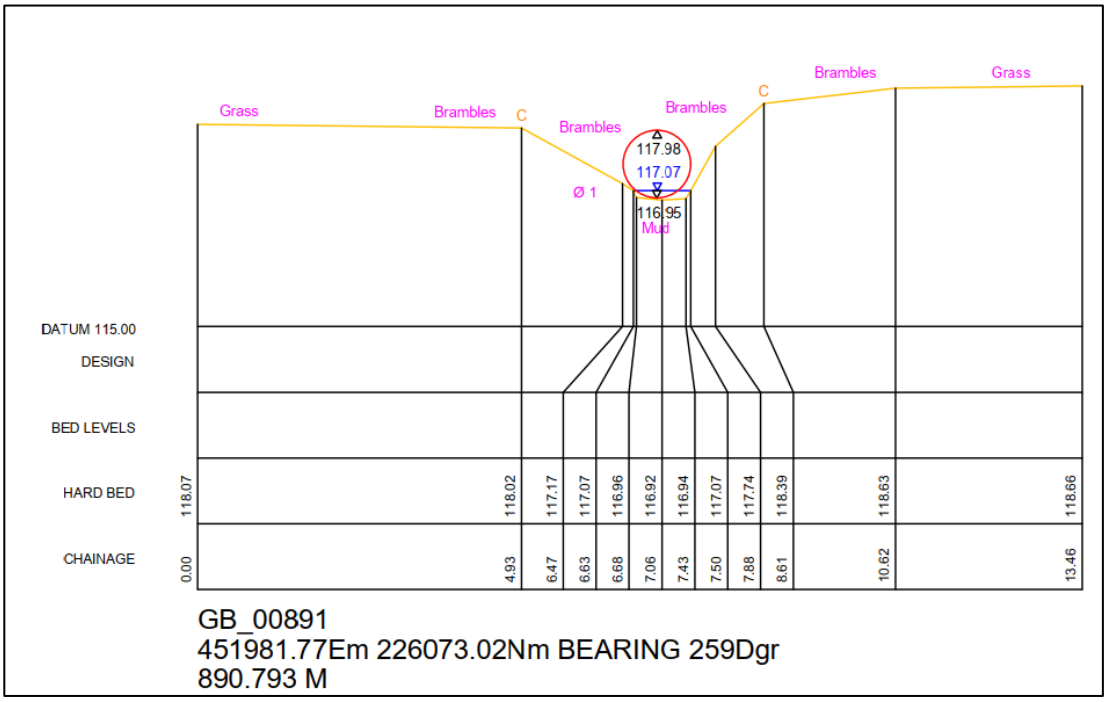

Figure 4.11: Surveyed Cross-Section of GB_00891

4.32 A 1.05m diameter pipe has been surveyed at this location and subsequently a Pipe Capacity Assessment has been undertaken. This calculation sheet, provided overleaf, displays the pipe to have a capacity of 2.066m³/s. Subsequently, based off the peak flows estimated in **Table 3.2** and **Table 3.3**, there is sufficient capacity to convey flows for all events through this structure.

4.33 The Manning's equation was also calculated at this cross-section for five intervals, based off the following assumed water levels; 117.00mAOD, 117.20mAOD, 117.40mAOD, 117.60mAOD, 117.80mAOD.

4.34 Parameters "*S*", "n" and "K" remain the same for all water levels.

4.35 Slope (*S*) has been derived as **0.003** at this location. The general gradient at the cross-section location has been calculated by determining the slope between cross sections GB_00999 and GB_00775. Over this distance of 224m, the in-channel invert level fell by 0.69m. As such, 0.69 / 224 = **0.003**.

4.36 The surface roughness (n) at this location has been assigned a value of **0.040**. This is based off the photograph provided in **Figure 4.12**. With reference to the Manning's n for Channels[1].

4.37 *K* is considered to be a constant conversion factor which adopts the value of **1**.

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BWB

Job Number: BMW3171	**Calc number: 1**	**Rev: 1**
Project: Heyford Park	**Date: 16.12.21**	**Prepared by: MB**
Title: GB_00891 Pipe Capacity		**Authorised by: CT**

Colebrook-White Formula

$$V = -2\left(2gDS\right)^{0.5} \log\left(\frac{k}{3.7D} + \frac{2.5\nu}{D\left(2gDS\right)^{0.5}}\right)$$

k = Colebrook-White roughness coefficient, in metres

V = velocity, in metres per second

D = circular cross-section pipe, inside diameter, in metres

S = slope, in metres per metre

ν = kinematic viscosity of water, in square metres per second.

g =	Gravity		9.81 m/s^2
n =	kinematic viscosity of water		1.141E-06 m^2/s
k =	Colebrook-White rougł	= 0.030 mm	= 3.000E-05 m
D =	Inside diameter	= 1050 mm	= 1.050 m
S =	Slope, in metres per metre		0.309%
=	(Hydraulic Gradient)	1:	324

Discharge:

Q = V x A

V= 2.39 m/s

A = 0.866 m^2

Q = 2.066 m^3/s = 2066.0 l/s

Figure 4.12: Photograph of Gallos Brook Channel at GB_00891

4.38 As such following parts of the Manning's equation completed. The remaining values to be determined are A and R. This will then allow for Q to be calculated.

$$Q = \frac{1\ A\ R^{2/3}\ 0.003^{1/2}}{0.040}$$

Whereby:

- *Q* = Flow rate (m^3/s)
- *A* = Cross-sectional area of flow
- *R* = Hydraulic radius (cross-sectional area divided by wetted perimeter)
- *S* = Slope of the channel at the point of measurement
- *n* = Surface roughness (based upon channel material and condition)
- *K* = Constant dependent upon units

4.39 The cross-sectional area (A) for GB_00891 was determined in AutoCAD using the AREA measure tool. The cross-sectional area was measured for five different water levels; 117.00mAOD, 117.20mAOD, 117.40mAOD, 117.60mAOD, 117.80mAOD. The channel cross-section is displayed in **Figure 4.13** for the water level of 117.40mAOD. The calculated cross-sectional area (A) values are reported in **Table 4.5.**

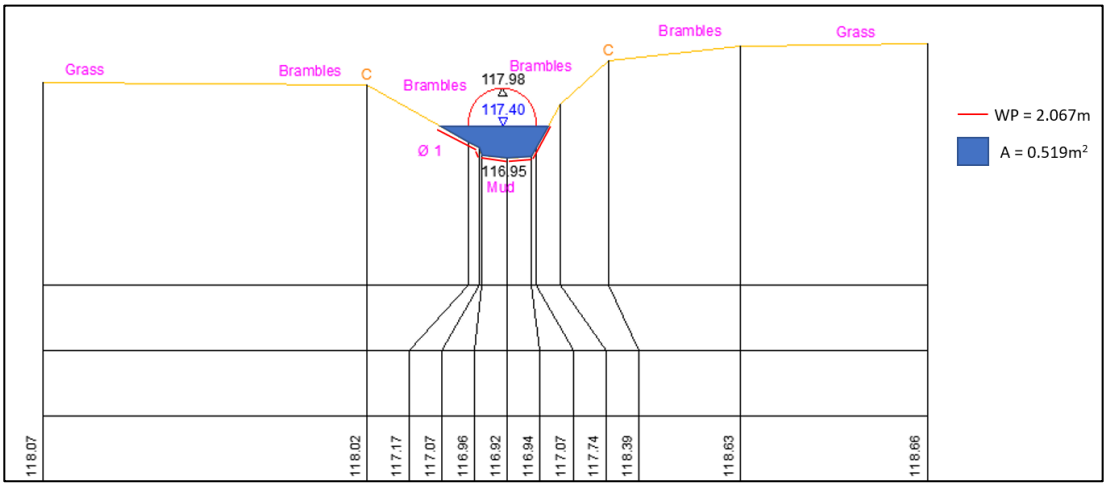


Figure 4.13: Approach to Calculating Cross-Sectional Area and Wetted Perimeter at GB_00891

4.40 Hydraulic Radius (R) is determined by dividing the cross-sectional area by the wetted perimeter for a particular water level. As such, it is first necessary to measure the wetted perimeter (WP) of the cross-section for each water level, this is also shown in **Figure 4.13** for the water level of 117.40mAOD.

4.41 With the wetted perimeter measured and the area determined, it is then possible to determine the hydraulic radius (R). Values for all parameters are therefore reported in **Table 4.5**. It is subsequently therefore possible to complete the equation to calculate the respective flow rate (Q) for each water level.

Table 4.5: Calculated Manning's Equation Values for GB_00891

Manning's Equation Parameters	Values for GB_00891 at Each Water Level				
	117.00	117.20	117.40	117.60	117.80
A	0.047	0.236	0.519	0.892	1.369
WP	0.835	1.412	2.067	2.712	3.378
R	0.056	0.167	0.251	0.329	0.405
S	0.003	0.003	0.003	0.003	0.003
n	0.040	0.040	0.040	0.040	0.040
K	1	1	1	1	1
Q	**0.009**	**0.098**	**0.283**	**0.582**	**1.027**

4.42 Given that flow rates have been calculated for a change in water level at the cross-section, it is subsequently possible to plot a rating curve that displays the relationship between flow and water level. This is displayed in **Figure 4.14**.

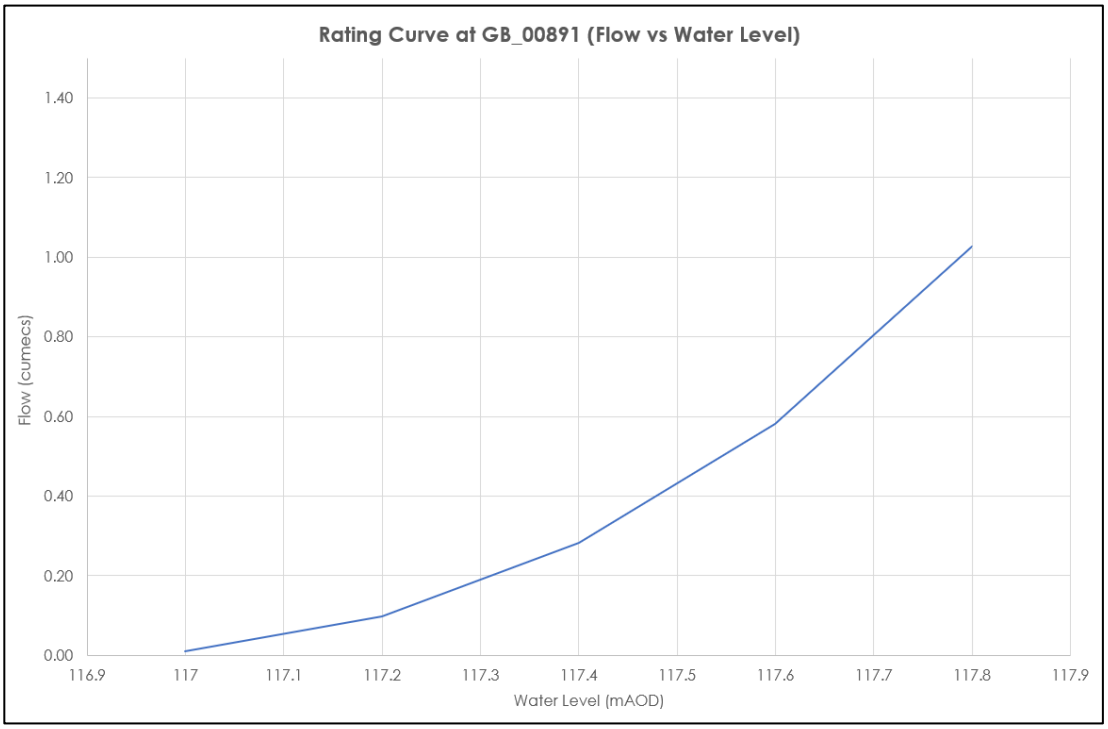


Figure 4.14: Rating Curve at GB_00891

4.43 The scaled ReFH2 peak flows, as reported in **Table 3.2** and **Table 3.3** have subsequently been applied against the rating curve in **Figure 4.14** to derive an estimated peak flood level for the respective return periods. The corresponding peak flood levels are presented in **Table 4.6**.

Table 4.6: Estimated Maximum Flood Levels at GB_00891

Return Period	GB_00891 Max Flood Level (mAOD)	+300mm Freeboard (mAOD)
2	117.21	117.51
5	117.23	117.53
10	117.27	117.57
20	117.31	117.61
50	117.34	117.64
100	117.39	117.69
100 +15%CC	117.41	117.71
100 +25%CC	117.43	117.73
100 +49%CC	117.48	117.78
200	117.42	117.72
1000	117.53	117.83

4.44 As per the cross-section drawing in **Figure 4.11**, the left bank crest height at GB_00891 has been surveyed as 118.02mAOD, whilst the right bank crest height has been surveyed as 118.39mAOD.

4.45 Subsequently, peak flows are estimated to remain in-channel for all events including the 1 in 100-year +15%CC event and 1 in 1000-year event, including a +300mm freeboard allowance.

4.46 Whilst flood levels are predicted to remain in-bank, a flood extent has been derived by projecting the design flood levels (including freeboard) for each cross-section onto the topographical survey. The estimated flood extent at GB_00891 is displayed in **Figure 4.15**.

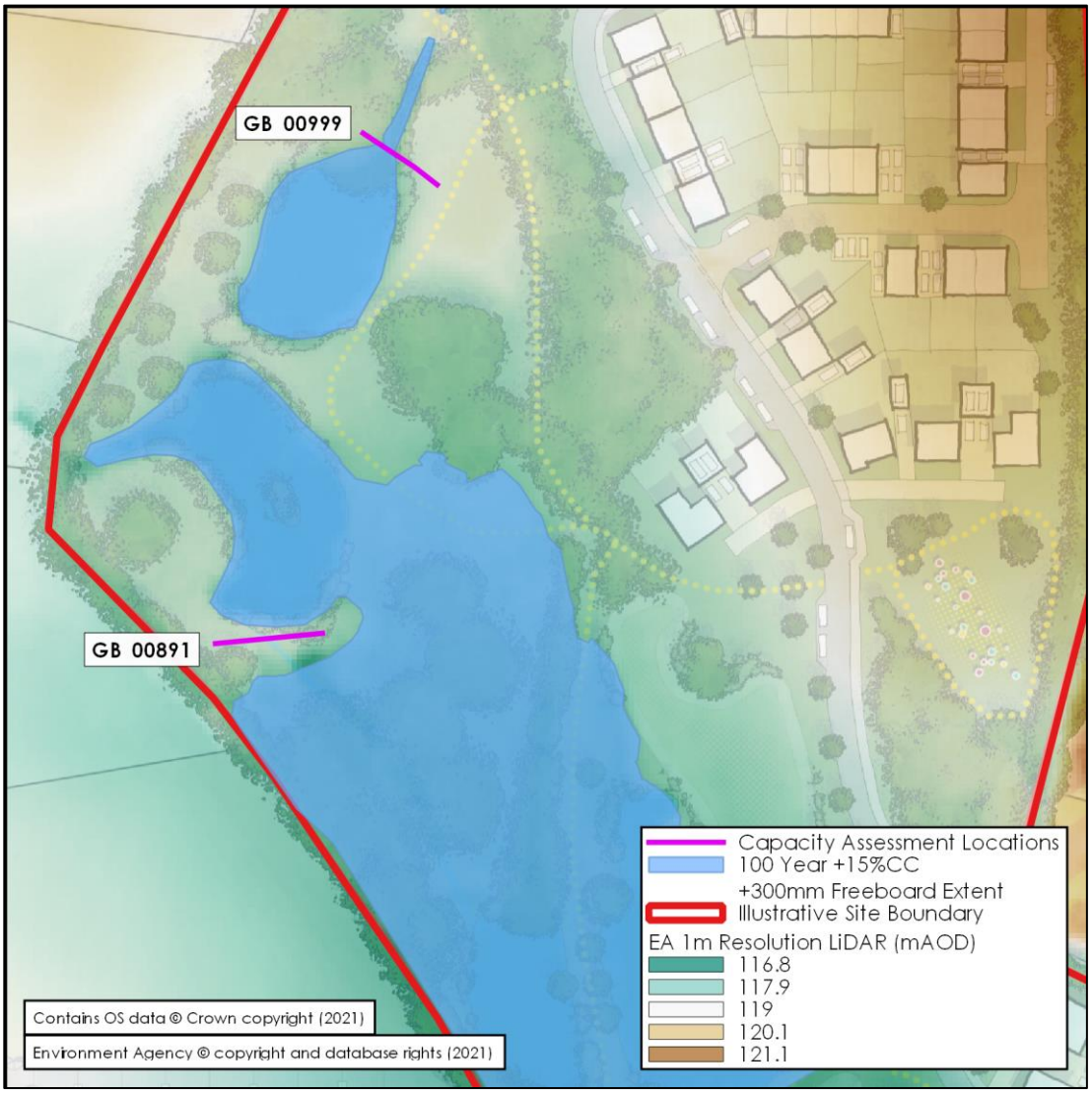


Figure 4.15: 1 in 100-Year +15%CC (Including Freeboard) Projected Flood Extent at GB_00891

GB_00999

4.47 The surveyed cross-section at this location is as per **Figure 4.16**.

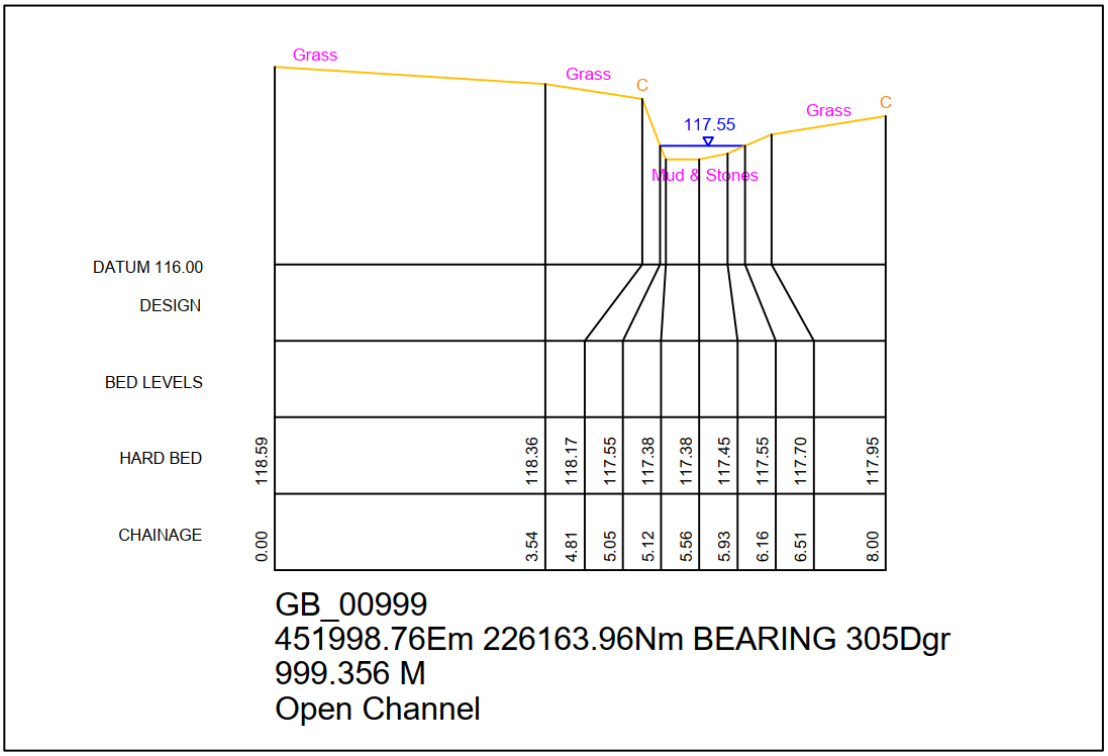


Figure 4.16: Surveyed Cross-Section of GB_00999

4.48 The Manning's equation was calculated at five intervals at this location, based off the following assumed water levels; 117.40mAOD, 117.50mAOD, 117.60mAOD, 117.70mAOD, 117.80mAOD.

4.49 Parameters "*S*", "n" and "K" remain the same for all water levels.

4.50 Slope (*S*) has been derived as **0.009** at this location. The general gradient at the cross-section location has been calculated by determining the slope between cross sections GB_01023 and GB_00891. Over this distance of 132m, the in-channel invert level fell by 1.15m. As such, 1.15 / 132 = **0.009**.

4.51 The surface roughness (n) at this location has been assigned a value of **0.040**. This is based off the photograph provided in **Figure 4.17**. With reference to the Manning's n for Channels[1].

4.52 *K* is considered to be a constant conversion factor which adopts the value of **1**.

Figure 4.17: Photograph of Gallos Brook Channel at GB_00999

4.53 As such following parts of the Manning's equation completed. The remaining values to be determined are A and R. This will then allow for Q to be calculated.

$$Q = \frac{1\ A\ R^{2/3}\ 0.009^{1/2}}{0.040}$$

Whereby:

Q = Flow rate (m^3/s)
A = Cross-sectional area of flow
R = Hydraulic radius (cross-sectional area divided by wetted perimeter)
S = Slope of the channel at the point of measurement
n = Surface roughness (based upon channel material and condition)
K = Constant dependent upon units

4.54 The cross-sectional area (A) for GB_00999 was determined in AutoCAD using the AREA measure tool. The cross-sectional area was measured for five different water levels; 117.40mAOD, 117.50mAOD, 117.60mAOD, 117.70mAOD, 117.80mAOD. The channel cross-section is displayed in **Figure 4.18** for the water level of 117.60mAOD. The calculated cross-sectional area (A) values are reported in **Table 4.7.**

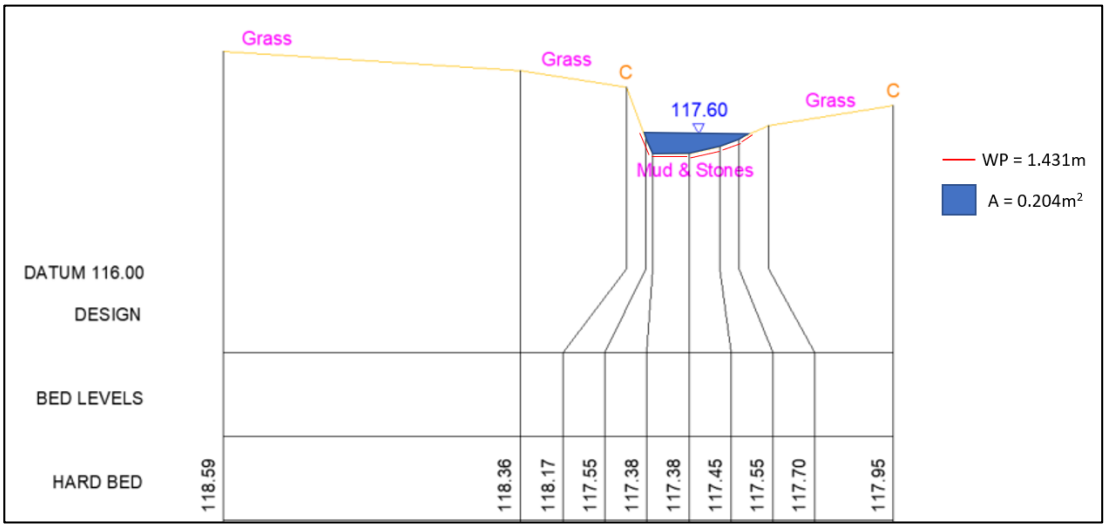


Figure 4.18: Approach to Calculating Cross-Sectional Area and Wetted Perimeter at GB_00999

4.55 Hydraulic Radius (R) is determined by dividing the cross-sectional area by the wetted perimeter for a particular water level. As such, it is first necessary to measure the wetted perimeter (WP) of the cross-section for each water level, this is also shown in **Figure 4.18** for the water level of 117.60mAOD.

4.56 With the wetted perimeter measured and the area determined, it is then possible to determine the hydraulic radius (R). Values for all parameters are therefore reported in **Table 4.7**. It is subsequently therefore possible to complete the equation to calculate the respective flow rate (Q) for each water level.

Table 4.7: Calculated Manning's Equation Values for GB_00999

Manning's Equation Parameters	Values for GB_00999 at Each Water Level				
	117.40	117.50	117.60	117.70	117.80
A	0.013	0.090	0.204	0.337	0.521
WP	0.598	1.060	1.431	1.784	2.509
R	0.022	0.085	0.143	0.189	0.208
S	0.009	0.009	0.009	0.009	0.009
n	0.040	0.040	0.040	0.040	0.040
K	1	1	1	1	1
Q	**0.002**	**0.041**	**0.132**	**0.263**	**0.433**

4.57 Given that flow rates have been calculated for a change in water level at the cross-section, it is subsequently possible to plot a rating curve that displays the relationship between flow and water level. This is displayed in **Figure 4.19**.

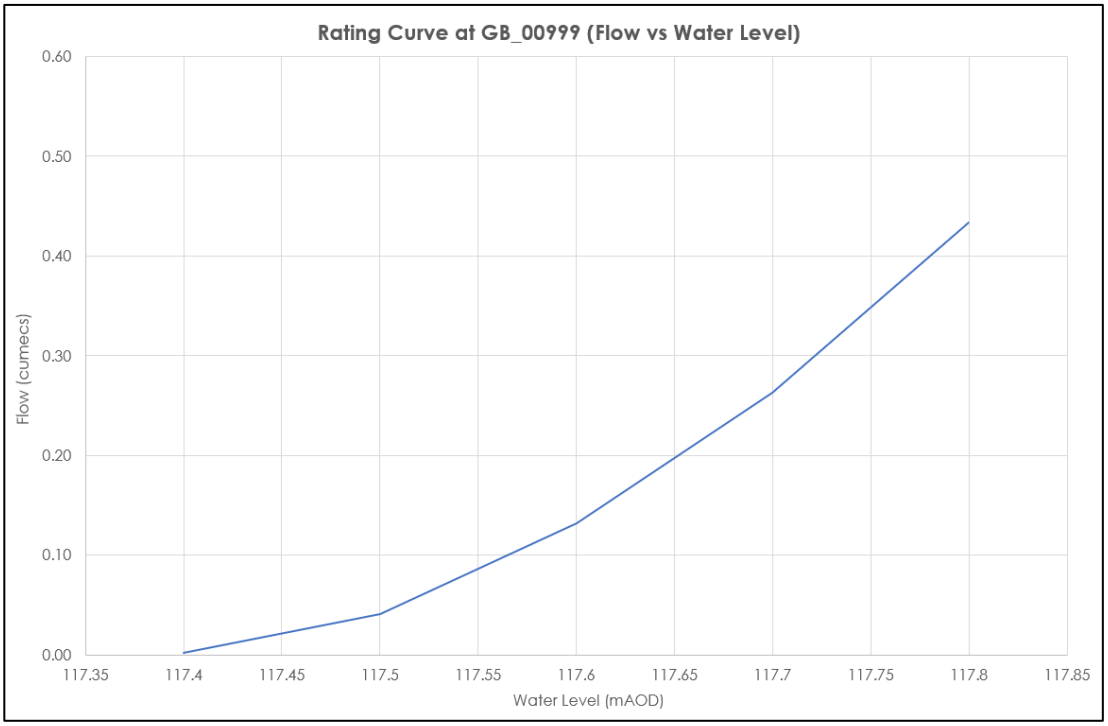


Figure 4.19: Rating Curve at GB_00999

4.58 The scaled ReFH2 peak flows, as reported in **Table 3.2** and **Table 3.3** have subsequently been applied against the rating curve in **Figure 4.19** to derive an estimated peak flood level for the respective return periods. The corresponding peak flood levels are presented in **Table 4.8**.

Table 4.8: Estimated Maximum Flood Levels at GB_00999

Return Period	GB_00999 Max Flood Level (mAOD)	+300mm Freeboard (mAOD)
2	117.50	117.80
5	117.51	117.81
10	117.52	117.82
20	117.53	117.83
50	117.56	117.86
100	117.57	117.87
100 +15%CC	117.58	117.88
100 +25%CC	117.60	117.90
100 +49%CC	117.62	117.92
200	117.58	117.88
1000	117.64	117.94

4.59 As per the cross-section drawing in **Figure 4.11**, the left bank crest height at GB_00999 has been surveyed as 118.17mAOD, whilst the right bank crest height has been surveyed as 117.95mAOD.

4.60 Subsequently, peak flows are estimated to remain in-channel for all events including the 1 in 100-year +15%CC event and 1 in 1000-year event, including a +300mm freeboard allowance.

4.61 Whilst flood levels are predicted to remain in-bank, a flood extent has been derived by projecting the design flood levels (including freeboard) for each cross-section onto the topographical survey. The estimated flood extent at GB_00999 is displayed in **Figure 4.20**.

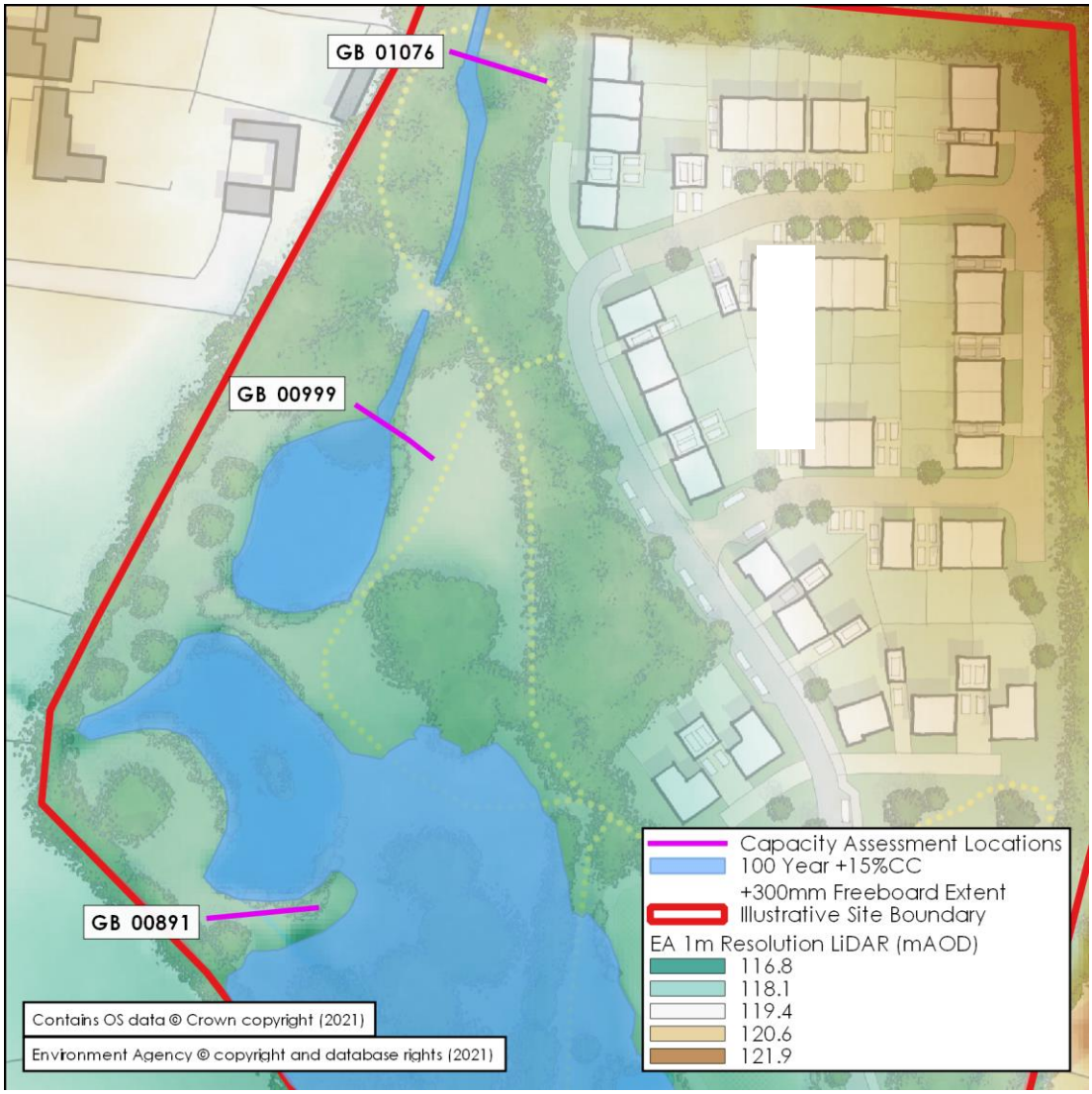


Figure 4.20: 1 in 100-Year +15%CC (Including Freeboard) Projected Flood Extent at GB_00999

GB_01076

4.62 The surveyed cross-section at this location is as per **Figure 4.21**.

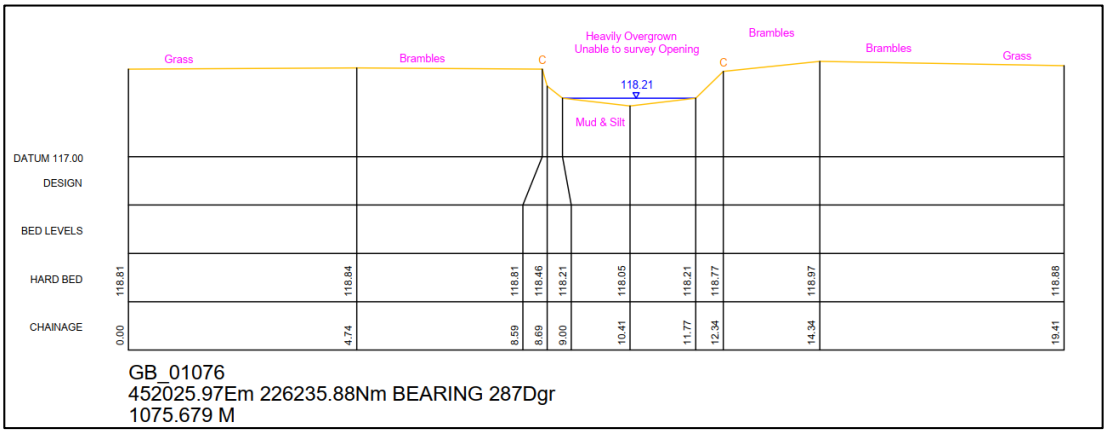


Figure 4.21: Surveyed Cross-Section of GB_01076

4.63 The Manning's equation was calculated at four intervals at this location, based off the following assumed water levels; 118.20mAOD, 118.40mAOD, 118.60mAOD, 118.80mAOD.

4.64 Parameters "*S*", "n" and "K" remain the same for all water levels.

4.65 Slope (*S*) has been derived as **0.025** at this location. The general gradient at the cross-section location has been calculated by determining the slope between cross sections GB_01176 and GB_00999. Over this distance of 177m, the in-channel invert level fell by 4.43m. As such, 4.43 / 177= **0.025**.

4.66 The surface roughness (n) at this location has been assigned a value of **0.040**. This is based off the photograph provided in **Figure 4.17**. With reference to the Manning's n for Channels[1].

4.67 *K* is considered to be a constant conversion factor which adopts the value of **1**.

Figure 4.22: Photograph of Gallos Brook Channel at GB_01076

4.68 As such following parts of the Manning's equation completed. The remaining values to be determined are A and R. This will then allow for Q to be calculated.

$$Q = \frac{1\ A\ R^{2/3}\ 0.009^{1/2}}{0.040}$$

Whereby:

- *Q* = Flow rate (m^3/s)
- *A* = Cross-sectional area of flow
- *R* = Hydraulic radius (cross-sectional area divided by wetted perimeter)
- *S* = Slope of the channel at the point of measurement
- *n* = Surface roughness (based upon channel material and condition)
- *K* = Constant dependent upon units

4.69 The cross-sectional area (A) for GB_01076 was determined in AutoCAD using the AREA measure tool. The cross-sectional area was measured for four different water levels; 118.20mAOD, 118.40mAOD, 118.60mAOD, 118.80mAOD. The channel cross-section is displayed in **Figure 4.23** for the water level of 118.60mAOD. The calculated cross sectional area (A) values are reported in **Table 4.9**.

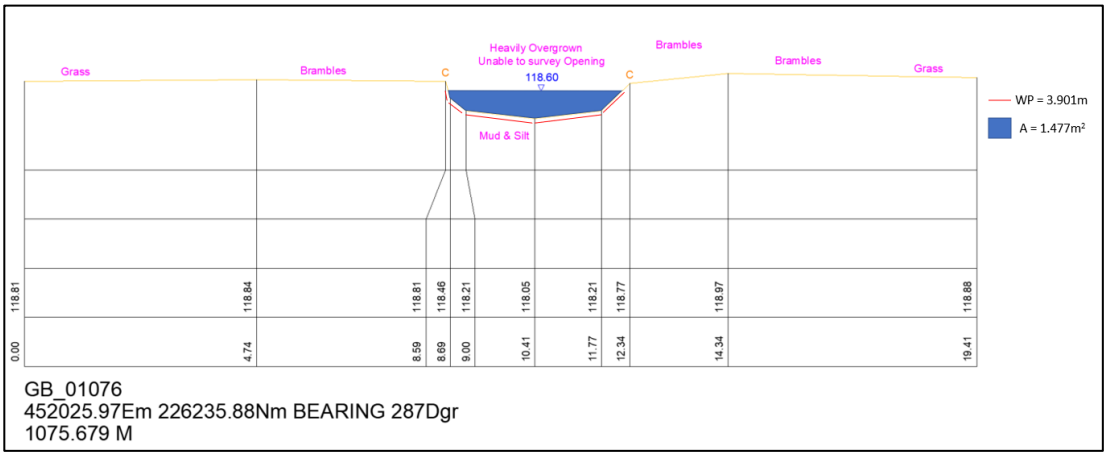


Figure 4.23: Approach to Calculating Cross-Sectional Area and Wetted Perimeter at GB_01076

4.70 Hydraulic Radius (R) is determined by dividing the cross-sectional area by the wetted perimeter for a particular water level. As such, it is first necessary to measure the wetted perimeter (WP) of the cross-section for each water level, this is also shown in **Figure 4.23** for the water level of 118.60mAOD.

4.71 With the wetted perimeter measured and the area determined, it is then possible to determine the hydraulic radius (R). Values for all parameters are therefore reported in **Table 4.9**. It is subsequently therefore possible to complete the equation to calculate the respective flow rate (Q) for each water level.

Table 4.9: Calculated Manning's Equation Values for GB_01076

Manning's Equation Parameters	Values for GB_01076 at Each Water Level			
	118.20	**118.40**	**118.60**	**118.80**
A	0.196	0.802	1.477	2.204
WP	2.61	3.378	3.901	4.681
R	0.075	0.237	0.377	0.471
S	0.025	0.025	0.025	0.025
n	0.040	0.040	0.040	0.040
K	1	1	1	1
Q	**0.138**	**1.22**	**3.056**	**5.273**

4.72 Given that flow rates have been calculated for a change in water level at the cross-section, it is subsequently possible to plot a rating curve that displays the relationship between flow and water level. This is displayed in **Figure 4.24**.

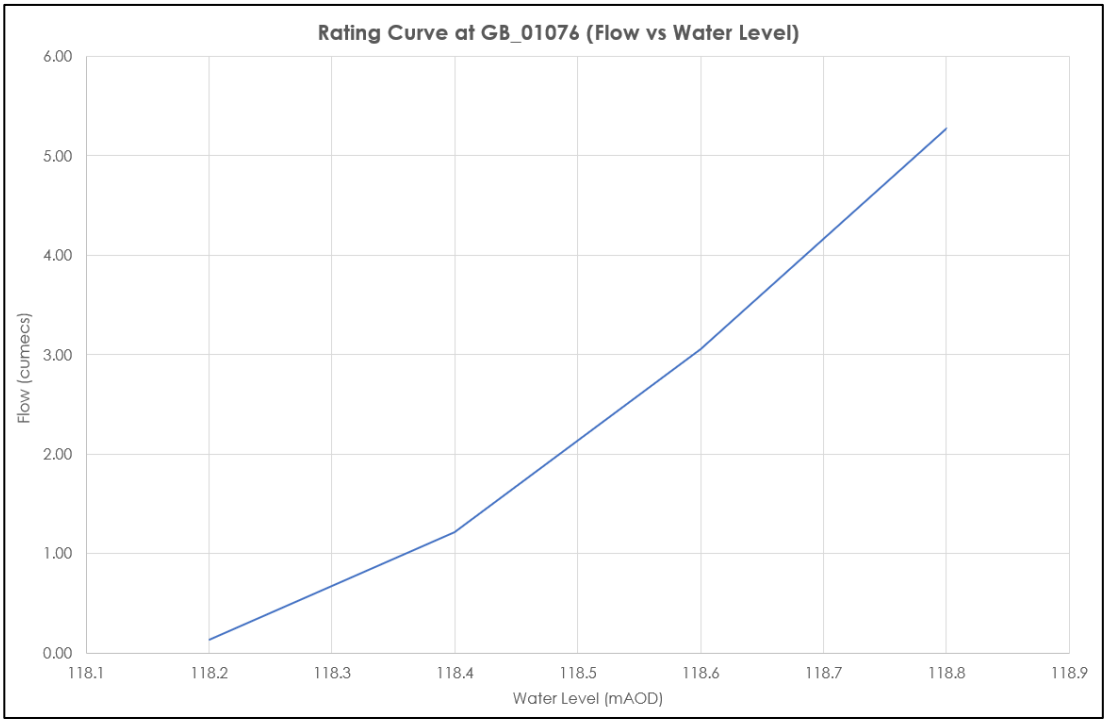


Figure 4.24: Rating Curve at GB_01076

4.73 The scaled ReFH2 peak flows, as reported in **Table 3.2** and **Table 3.3** have subsequently been applied against the rating curve in **Figure 4.25** to derive an estimated peak flood level for the respective return periods. The corresponding peak flood levels are presented in **Table 4.10**.

Table 4.10: Estimated Maximum Flood Levels at GB_01076

Return Period	GB_01076 Max Flood Level (mAOD)	+300mm Freeboard (mAOD)
2	118.18	118.48
5	118.18	118.48
10	118.18	118.48
20	118.18	118.48
50	118.18	118.48
100	118.19	118.49
100 +15%CC	118.19	118.49
100 +25%CC	118.19	118.49
100 +49%CC	118.20	118.50
200	118.19	118.49
1000	118.21	118.51

4.74 As per the cross-section drawing in **Figure 4.11**, the left bank crest height at GB_01076has been surveyed as 118.81mAOD, whilst the right bank crest height has been surveyed as 118.77mAOD.

4.75 Subsequently, peak flows are estimated to remain in-channel for all events including the 1 in 100-year +15%CC event and 1 in 1000-year event, including a +300mm freeboard allowance.

4.76 Whilst flood levels are predicted to remain in-bank, a flood extent has been derived by projecting the design flood levels (including freeboard) for each cross-section onto the topographical survey. The estimated flood extent at GB_01076 is displayed in **Figure 4.25**.

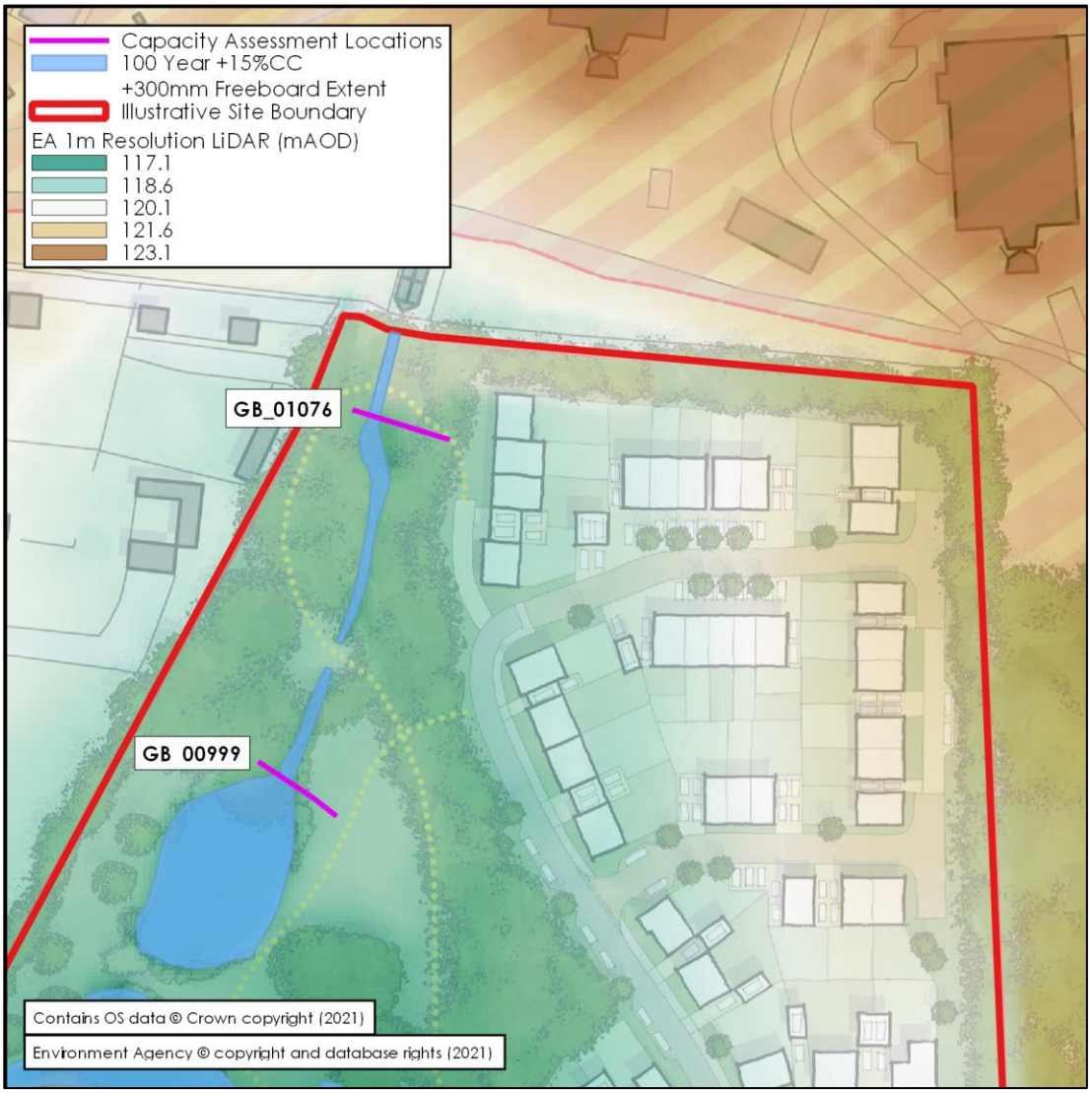


Figure 4.25: 1 in 100-Year +15%CC (Including Freeboard) Projected Flood Extent at GB_01076

Appendix 5: Thames Water Sewer Asset Records

Asset location search

Property Searches

BWB Consulting Limited
5th Floor,Waterfront House Waterfront House

NOTTINGHAM
NG2 3DQ

Search address supplied OX25 5TB

Your reference BMW3171 Upper Heyford

Our reference ALS/ALS Standard/2020_4269129

Search date 7 October 2020

Knowledge of features below the surface is essential for every development

The benefits of this knowledge not only include ensuring due diligence and avoiding risk, but also being able to ascertain the feasibility of any development.

Did you know that Thames Water Property Searches can also provide a variety of utility searches including a more comprehensive view of utility providers' assets (across up to 35-45 different providers), as well as more focused searches relating to specific major utility companies such as National Grid (gas and electric).

Contact us to find out more.

Thames Water Utilities Ltd
Property Searches, PO Box 3189, Slough SL1 4WW
DX 151280 Slough 13

searches@thameswater.co.uk
www.thameswater-propertysearches.co.uk

0845 070 9148

Asset location search

Property Searches

Search address supplied: OX25 5TB

Dear Sir / Madam

An Asset Location Search is recommended when undertaking a site development. It is essential to obtain information on the size and location of clean water and sewerage assets to safeguard against expensive damage and allow cost-effective service design.

The following records were searched in compiling this report: - the map of public sewers & the map of waterworks. Thames Water Utilities Ltd (TWUL) holds all of these.

This searchprovides maps showing the position, size of Thames Water assets close to the proposed development and also manhole cover and invert levels, where available.

Please note that none of the charges made for this report relate to the provision of Ordnance Survey mapping information. The replies contained in this letter are given following inspection of the public service records available to this company. No responsibility can be accepted for any error or omission in the replies.

You should be aware that the information contained on these plans is current only on the day that the plans are issued. The plans should only be used for the duration of the work that is being carried out at the present time. Under no circumstances should this data be copied or transmitted to parties other than those for whom the current work is being carried out.

Thames Water do update these service plans on a regular basis and failure to observe the above conditions could lead to damage arising to new or diverted services at a later date.

Contact Us

If you have any further queries regarding this enquiry please feel free to contact a member of the team on 0845 070 9148, or use the address below:

Thames Water Utilities Ltd
Property Searches
PO Box 3189
Slough
SL1 4WW

Email: searches@thameswater.co.uk
Web: www.thameswater-propertysearches.co.uk

Waste Water Services

Please provide a copy extract from the public sewer map.

Enclosed is a map showing the approximate lines of our sewers. Our plans do not show sewer connections from individual properties or any sewers not owned by Thames Water unless specifically annotated otherwise. Records such as "private" pipework are in some cases available from the Building Control Department of the relevant Local Authority.

Where the Local Authority does not hold such plans it might be advisable to consult the property deeds for the site or contact neighbouring landowners.

This report relates only to sewerage apparatus of Thames Water Utilities Ltd, it does not disclose details of cables and or communications equipment that may be running through or around such apparatus.

The sewer level information contained in this response represents all of the level data available in our existing records. Should you require any further Information, please refer to the relevant section within the 'Further Contacts' page found later in this document.

For your guidance:

- The Company is not generally responsible for rivers, watercourses, ponds, culverts or highway drains. If any of these are shown on the copy extract they are shown for information only.
- Any private sewers or lateral drains which are indicated on the extract of the public sewer map as being subject to an agreement under Section 104 of the Water Industry Act 1991 are not an ‘as constructed’ record. It is recommended these details be checked with the developer.

Clean Water Services

Please provide a copy extract from the public water main map.

Enclosed is a map showing the approximate positions of our water mains and associated apparatus. Please note that records are not kept of the positions of individual domestic supplies.

For your information, there will be a pressure of at least 10m head at the outside stop valve. If you would like to know the static pressure, please contact our Customer Centre on 0800 316 9800. The Customer Centre can also arrange for a full flow and pressure test to be carried out for a fee.

For your guidance:

- Assets other than vested water mains may be shown on the plan, for information only.
- If an extract of the public water main record is enclosed, this will show known public water mains in the vicinity of the property. It should be possible to estimate the likely length and route of any private water supply pipe connecting the property to the public water network.

Payment for this Search

A charge will be added to your suppliers account.

Further contacts:

Waste Water queries

Should you require verification of the invert levels of public sewers, by site measurement, you will need to approach the relevant Thames Water Area Network Office for permission to lift the appropriate covers. This permission will usually involve you completing a TWOSA form. For further information please contact our Customer Centre on Tel: 0845 920 0800. Alternatively, a survey can be arranged, for a fee, through our Customer Centre on the above number.

If you have any questions regarding sewer connections, budget estimates, diversions, building over issues or any other questions regarding operational issues please direct them to our service desk. Which can be contacted by writing to:

Developer Services (Waste Water)
Thames Water
Clearwater Court
Vastern Road
Reading
RG1 8DB

Tel: 0800 009 3921
Email: developer.services@thameswater.co.uk

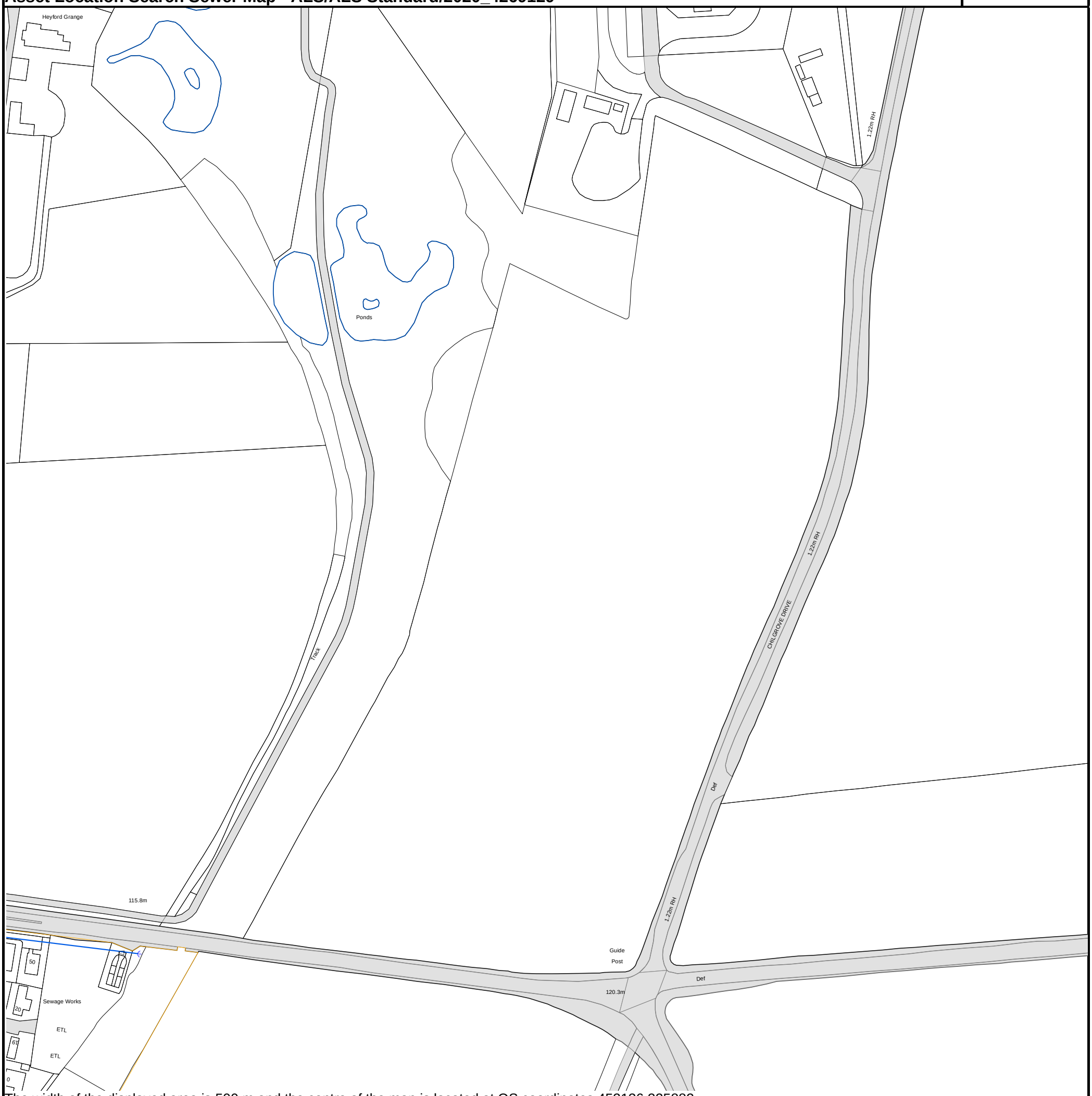
Clean Water queries

Should you require any advice concerning clean water operational issues or clean water connections, please contact:

Developer Services (Clean Water)
Thames Water
Clearwater Court
Vastern Road
Reading
RG1 8DB

Tel: 0800 009 3921
Email: developer.services@thameswater.co.uk

Asset Location Search Sewer Map - ALS/ALS Standard/2020_4269129



The width of the displayed area is 500 m and the centre of the map is located at OS coordinates 452136,225882

The position of the apparatus shown on this plan is given without obligation and warranty, and the accuracy cannot be guaranteed. Service pipes are not shown but their presence should be anticipated. No liability of any kind whatsoever is accepted by Thames Water for any error or omission. The actual position of mains and services must be verified and established on site before any works are undertaken.

Based on the Ordnance Survey Map with the Sanction of the controller of H.M. Stationery Office, License no. 100019345 Crown Copyright Reserved.

NB. Levels quoted in metres Ordnance Newlyn Datum. The value -9999.00 indicates that no survey information is available

Manhole Reference	Manhole Cover Level	Manhole Invert Level
n/a	n/a	n/a

The position of the apparatus shown on this plan is given without obligation and warranty, and the accuracy cannot be guaranteed. Service pipes are not shown but their presence should be anticipated. No liability of any kind whatsoever is accepted by Thames Water for any error or omission. The actual position of mains and services must be verified and established on site before any works are undertaken.

Based on the Ordnance Survey Map with the sanction of the Controller of H.M Stationary Office License Number 10019345

ALS/ALS Standard/2020_4269129

0 45 90 180 270 360
Meters

Scale:	1:7158
Width:	2000m
Printed By:	G1KANAGA
Print Date:	08/10/2020
Map Centre:	452135,225881
Grid Reference:	SP5225NW

Comments:

ALS Sewer Map Key

Public Sewer Types (Operated & Maintained by Thames Water)

Foul: A sewer designed to convey waste water from domestic and industrial sources to a treatment works.

Surface Water: A sewer designed to convey surface water (e.g. rain water from roofs, yards and car parks) to rivers or watercourses.

Combined: A sewer designed to convey both waste water and surface water from domestic and industrial sources to a treatment works.

Trunk Surface Water

Trunk Foul

Storm Relief

Trunk Combined

Vent Pipe

Bio-solids (Sludge)

Proposed Thames Surface Water Sewer

Proposed Thames Water Foul Sewer

Gallery

Foul Rising Main

Surface Water Rising Main

Combined Rising Main

Sludge Rising Main

Proposed Thames Water Rising Main

Vacuum

Sewer Fittings

A feature in a sewer that does not affect the flow in the pipe. Example: a vent is a fitting as the function of a vent is to release excess gas.

Air Valve

Dam Chase

Fitting

Meter

Vent Column

Operational Controls

A feature in a sewer that changes or diverts the flow in the sewer. Example: A hydrobrake limits the flow passing downstream.

Control Valve

Drop Pipe

Ancillary

Weir

End Items

End symbols appear at the start or end of a sewer pipe. Examples: an Undefined End at the start of a sewer indicates that Thames Water has no knowledge of the position of the sewer upstream of that symbol, Outfall on a surface water sewer indicates that the pipe discharges into a stream or river.

Outfall

Undefined End

Inlet

Other Symbols

Symbols used on maps which do not fall under other general categories

Public/Private Pumping Station

Change of characteristic indicator (C.O.C.I.)

Invert Level

Summit

Areas

Lines denoting areas of underground surveys, etc.

Agreement

Operational Site

Chamber

Tunnel

Conduit Bridge

Other Sewer Types (Not Operated or Maintained by Thames Water)

Foul Sewer

Surface Water Sewer

Combined Sewer

Gulley

Culverted Watercourse

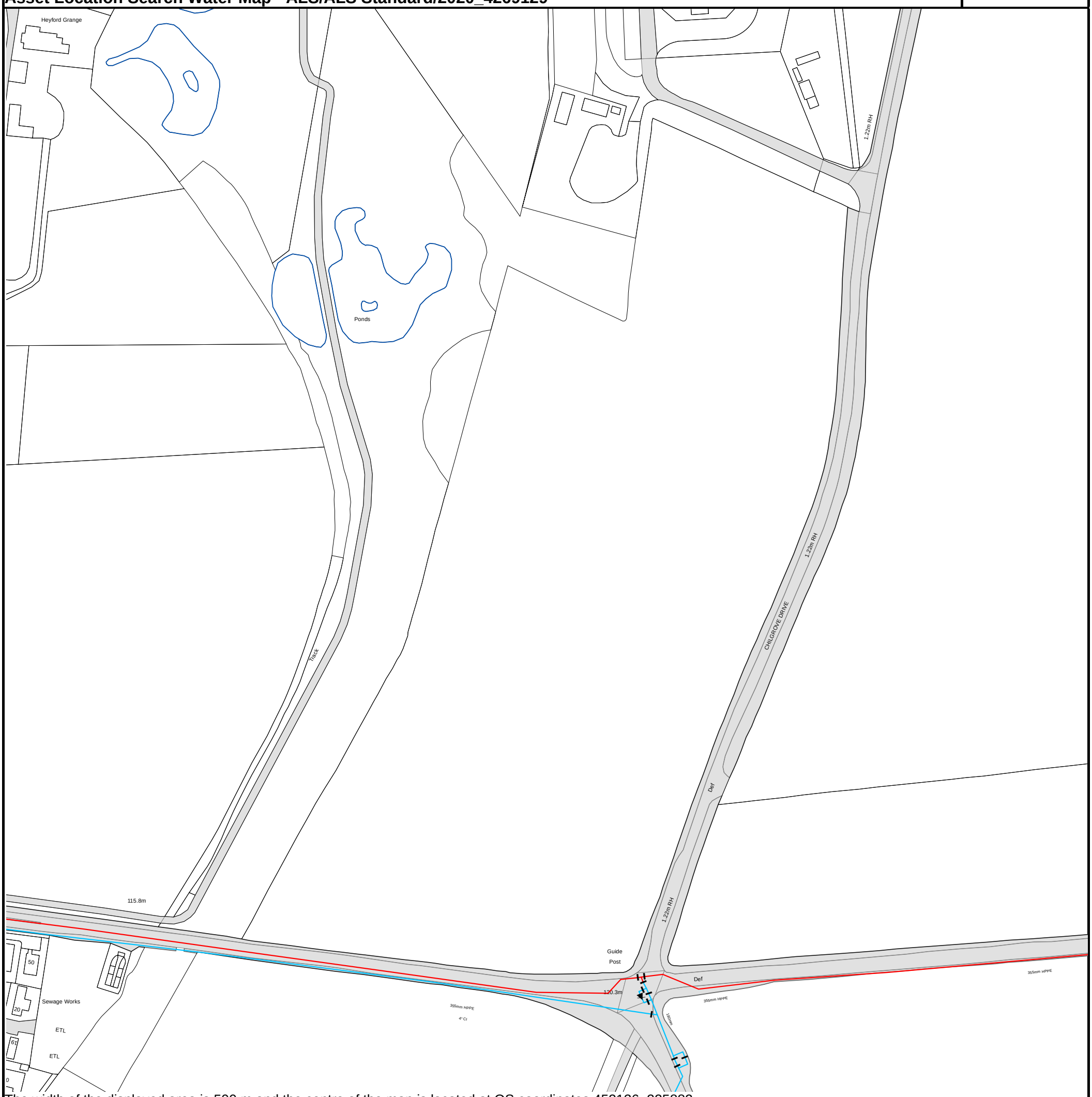
Proposed

Abandoned Sewer

Notes:

1) All levels associated with the plans are to Ordnance Datum Newlyn.
2) All measurements on the plans are metric.
3) Arrows (on gravity fed sewers) or flecks (on rising mains) indicate direction of flow.
4) Most private pipes are not shown on our plans, as in the past, this information has not been recorded.
5) 'na' or '0' on a manhole level indicates that data is unavailable.
6) The text appearing alongside a sewer line indicates the internal diameter of the pipe in milimetres. Text next to a manhole indicates the manhole reference number and should not be taken as a measurement. If you are unsure about any text or symbology present on the plan, please contact a member of Property Insight on 0845 070 9148.

Asset Location Search Water Map - ALS/ALS Standard/2020_4269129



The width of the displayed area is 500 m and the centre of the map is located at OS coordinates 452136, 225882.

The position of the apparatus shown on this plan is given without obligation and warranty, and the accuracy cannot be guaranteed. Service pipes are not shown but their presence should be anticipated. No liability of any kind whatsoever is accepted by Thames Water for any error or omission. The actual position of mains and services must be verified and established on site before any works are undertaken.

Based on the Ordnance Survey Map with the sanction of the Controller of H.M Stationary Office License Number 10019345

ALS/ALS Standard/2020_4269129

0 45 90 180 270 360
Meters

Scale:	1:7158
Width:	2000m
Printed By:	G1KANAGA
Print Date:	08/10/2020
Map Centre:	452135,225881
Grid Reference:	SP5225NW

Comments:

ALS Water Map Key

Water Pipes (Operated & Maintained by Thames Water)

4"

Distribution Main: The most common pipe shown on water maps. With few exceptions, domestic connections are only made to distribution mains.

16"

Trunk Main: A main carrying water from a source of supply to a treatment plant or reservoir, or from one treatment plant or reservoir to another. Also a main transferring water in bulk to smaller water mains used for supplying individual customers.

3" SUPPLY

Supply Main: A supply main indicates that the water main is used as a supply for a single property or group of properties.

3" FIRE

Fire Main: Where a pipe is used as a fire supply, the word FIRE will be displayed along the pipe.

3" METERED

Metered Pipe: A metered main indicates that the pipe in question supplies water for a single property or group of properties and that quantity of water passing through the pipe is metered even though there may be no meter symbol shown.

Transmission Tunnel: A very large diameter water pipe. Most tunnels are buried very deep underground. These pipes are not expected to affect the structural integrity of buildings shown on the map provided.

Proposed Main: A main that is still in the planning stages or in the process of being laid. More details of the proposed main and its reference number are generally included near the main.

Valves

- General Purpose Valve
- Air Valve
- Pressure Control Valve
- Customer Valve

Hydrants

- Single Hydrant

Meters

- Meter

End Items

Symbol indicating what happens at the end of a water main.

- Blank Flange
- Capped End
- Emptying Pit
- Undefined End
- Manifold
- Customer Supply
- Fire Supply

Operational Sites

- Booster Station
- Other
- Other (Proposed)
- Pumping Station
- Service Reservoir
- Shaft Inspection
- Treatment Works
- Unknown
- Water Tower

Other Symbols

- Data Logger

PIPE DIAMETER	DEPTH BELOW GROUND
Up to 300mm (12")	900mm (3')
300mm - 600mm (12" - 24")	1100mm (3' 8")
600mm and bigger (24" plus)	1200mm (4')

Other Water Pipes (Not Operated or Maintained by Thames Water)

Other Water Company Main: Occasionally other water company water pipes may overlap the border of our clean water coverage area. These mains are denoted in purple and in most cases have the owner of the pipe displayed along them.

Private Main: Indiates that the water main in question is not owned by Thames Water. These mains normally have text associated with them indicating the diameter and owner of the pipe.

Terms and Conditions

All sales are made in accordance with Thames Water Utilities Limited (TWUL) standard terms and conditions unless previously agreed in writing.

1. All goods remain in the property of Thames Water Utilities Ltd until full payment is received.
2. Provision of service will be in accordance with all legal requirements and published TWUL policies.
3. All invoices are strictly due for payment 14 days from due date of the invoice. Any other terms must be accepted/agreed in writing prior to provision of goods or service, or will be held to be invalid.
4. Thames Water does not accept post-dated cheques-any cheques received will be processed for payment on date of receipt.
5. In case of dispute TWUL`s terms and conditions shall apply.
6. Penalty interest may be invoked by TWUL in the event of unjustifiable payment delay. Interest charges will be in line with UK Statute Law 'The Late Payment of Commercial Debts (Interest) Act 1998'.
7. Interest will be charged in line with current Court Interest Charges, if legal action is taken.
8. A charge may be made at the discretion of the company for increased administration costs.

A copy of Thames Water's standard terms and conditions are available from the Commercial Billing Team (cashoperations@thameswater.co.uk).

We publish several Codes of Practice including a guaranteed standards scheme. You can obtain copies of these leaflets by calling us on 0800 316 9800

If you are unhappy with our service you can speak to your original goods or customer service provider. If you are not satisfied with the response, your complaint will be reviewed by the Customer Services Director. You can write to her at: Thames Water Utilities Ltd. PO Box 492, Swindon, SN38 8TU.

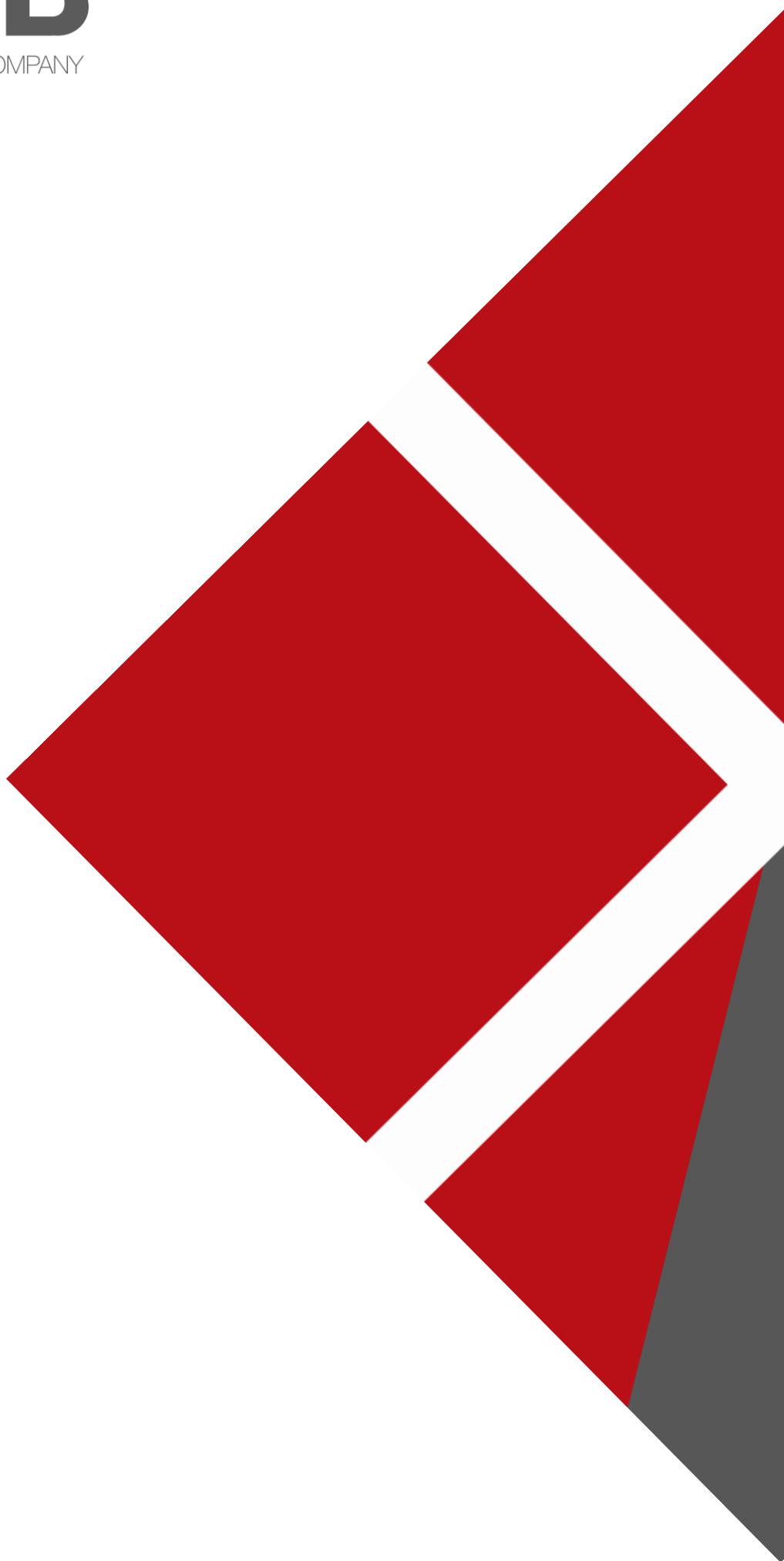
If the Goods or Services covered by this invoice falls under the regulation of the 1991 Water Industry Act, and you remain dissatisfied you can refer your complaint to Consumer Council for Water on 0121 345 1000 or write to them at Consumer Council for Water, 1st Floor, Victoria Square House, Victoria Square, Birmingham, B2 4AJ.

Ways to pay your bill

Credit Card	**BACS Payment**	**Telephone Banking**	**Cheque**
Call **0845 070 9148** quoting your invoice number starting CBA or ADS / OSS	Account number **90478703** Sort code **60-00-01** A remittance advice must be sent to: **Thames Water Utilities Ltd., PO Box 3189, Slough SL1 4WW.** or email **ps.billing@thameswater.co.uk**	By calling your bank and quoting: Account number **90478703** Sort code **60-00-01** and your invoice number	Made payable to '**Thames Water Utilities Ltd**' Write your Thames Water account number on the back. Send to: **Thames Water Utilities Ltd., PO Box 3189, Slough SL1 4WW** or by DX to **151280 Slough 13**

BWB

A CAF GROUP COMPANY



www.bwbconsulting.com