

Flood Risk Assessment Addendum

Final report

March 2025

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Revision History

Revision Ref/Date	Amendments	Issued to
S3-P01 / April 2023	Draft Report	Abigail Woods (RPS)
S3-P02 / April 2023	Draft Report	Abigail Woods (RPS)
A1-C01 / May 2023	Final Report	Abigail Woods (RPS)
A1-C02 / August 2023	Updates to Section 4	Abigail Woods (RPS)
A1-C03 / September 2023	Wording	Abigail Woods (RPS)
A1-C04 / December 2023	Map update (5-1)	Abigail Woods (RPS)
A1-C05 / March 2025	Figure update (5-1) and Table 5-1	Caitlin Daly (Stantec)

Contract

This report describes work commissioned by RPS, on behalf of RVG (Retirement Villages Group) by an email instruction dated 18/01/2023. The Client's representative for the contract was Abigail Woods of RPS. Timea Faber and Olivier Saillofest of JBA Consulting carried out this work.

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Purpose

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Executive summary

JBA Consulting (JBA) were commissioned by RPS to prepare a Flood Risk Assessment Addendum at Thamesfield, Wargrave Road, Henley-On-Thames. This follows and complements the Flood Risk Assessment completed by WSP in October 2022.

Retirement Villages Group (RVG) wish to partially redevelop their Thamesfield site and introduce 17 care home units. The proposal includes:

- To replace existing Block C and part of Block D around a remodelled central courtyard.
- Refurbishing the kitchen and adjacent plant in Block A.
- Refurbishing the laundry and plant behind the office area in Block A.

This addendum report focuses on the main sources of flooding to the site, namely:

- Flooding from the River Thames;
- Flooding from a reservoir breach, and;
- Groundwater flooding.

The proposal is for the regeneration of a Care Home scheme. As such, the development is limited to the site boundary and thus cannot be compared with alternative / more sequential preferable sites. In addition to the above, the proposal follows the sequential approach to flood risk by steering the footprints of the new builds away from the areas the most at risk of flooding. As such, it is considered that the site passes the Sequential Test.

With regards to the Exception Test, the proposal will generate the following wider community benefits:

- Contribution towards identified need for specialist housing for older people in Wokingham Borough Council (WBC).
- Contribution towards WBC's housing land supply.
- The provision of specialist housing and care for older people will free up family housing elsewhere in the Borough Council.
- The proposal will provide a wide range of health and wellbeing benefits to the residents of the scheme.
- The proposal makes efficient use of a previously developed (brownfield) site.
- The proposal will provide biodiversity net gains and landscaping benefits.
- The proposal will provide energy, economic and sustainability benefits.

When considered in conjunction with the flood mitigation measures recommended in this report, it is therefore considered that the proposal passes both parts of the Exception Test.

To assess the risk of fluvial flooding from the River Thames, hydraulic modelling was undertaken by JBA in 2022. Hydraulic modelling results indicated that:

- Water enters the site (from overtopping of the River Thames' banks) for all of the modelled flood scenarios (i.e. 30-year, 100-year, 100-year +31% CC and 1,000-year)
- Flood depths of up to 1.89m are predicted to occur within the site during the 100-year with 31% climate change 'design' flood event.

- During the 100-year with 31% climate change fluvial flood event, the peak water levels will range between 32.24 and 32.29m AOD on site and will exceed the existing floor levels of 2 existing buildings.
- During the 100-year with 31% climate change scenario, the majority of the site falls within the 'low' to 'significant' hazard categories (based on Defra's Hazard-to-People categories).
- The 'design' flood level will increase by 0.77m in the event of a 25% blockage at Henley Bridge.

A review of the Environment Agency's reservoir inundation maps indicates that the site is not at risk of flooding during the 'dry day' reservoir breach scenario (i.e. during the low flow condition within the River Thames channel) and that flood depths of up to 2.32m may occur on site during the 'wet day' reservoir breach scenario (i.e. when combined with a 1,000-year fluvial flood event from the River Thames).

According to the EA's Magic map application groundwater map, the site is considered to be at medium to high and soluble rock risk of groundwater flooding. Furthermore, borehole (SU78SE20) approx. 250m within the site's proximity, highlights that the water is present at approx. 30m below ground. It is important as ground water is likely to flood the site.

To mitigate against flood risk, it is recommended to:

For the new buildings;

- Raise the ground floor levels of the new buildings to a minimum of 600mm above the 'design' flood level.
- Install emergency generators to be used in extreme cases of flooding where the power might be affected to maintain power on site (e.g. to power medical equipment).

For the existing buildings

- Place flood barriers/doors to the doorways of buildings with a floor elevated below the 'design' flood level.
- Install emergency generators to be used in extreme cases of flooding where the power might be affected to maintain power on site (e.g. to power medical equipment).
- The external walls of the building should be inspected for any cracks or gaps, and sealed with silicone sealant or mortar as required.
- The external walls should be treated with water repellent spray.
- Internal walls of the ground floor levels should be made of easily washable materials (e.g. tiles and smooth concrete).

For the existing basement;

- Install sump pumps to the lowest point of the basement and test pumps regularly.
- Ensure that the basement is exclusively used as non-habitable floor space.
- Render the walls impervious (and seek confirmation from a structural engineer that such measures will not detrimentally impact the structural stability of the wall / i.e. that the wall is capable to withstand the increased groundwater pressure on the wet side of the wall).

- Electric wires and sockets should be set as high as possible, if cannot move electric socket and wires, then a small key switch is to be installed to isolate electricity in the basement during flood events and to switch of electricity in the basement when flood water occurs.
- Circulate a copy of the Flood Warning and Evacuation Plan by WSP (Appendix B) to the occupiers of the site and ensure it is updated accordingly.
- Place flood door barrier at the basement doorway.
- Ensure that signage of high flood risk/hazard is placed at the basement access door to notify site occupant of the hazard. Furthermore, a warning sign for not entering the basement when floodwater is present, to avoid for operators to get electric shock.
- Walls to be made of easily washable materials (e.g. tiles, smooth concrete) and appropriate venting is considered to minimise moisture damp in the basement.
- A borehole with a pressure sensor should ideally be set to monitor groundwater level near the basement and trigger alerts or alarms to the occupants of the site.
- As part of the recovery procedure, an electric certificate should be issued after flood events affecting the basement.
- The internal walls and floor of the basement should be tanked in order to prevent groundwater penetration.
- Items stored in the basement should be suitable to be easily removed following receipt of activation of 'be prepared' triggers (flood alert, on site observation). Items that cannot be removed should be suitably flood resilient in their nature to weather continued exposure to floodwater.

In addition to the above, a Flood Response Plan listing all tasks to be carried out by on-site staff and local residents prior to, during and following a flood event should be produced for the site.

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Abbreviations

1D	One Dimensional
2D	Two Dimensional
CC	Climate Change
DTM	Digital Terrain Model
EA	Environment Agency
FFL	Finished Floor Levels
GCS	Grantham Coates Surveyors
Ha	Hectares
JBA	Jeremy Benn Associates
LiDAR	Light Detection and Ranging
m AOD	Metres Above Ordnance Datum
QT	Flow-Time
TUFLOW	2D Hydraulic Modelling Software

1 Introduction

1.1 Terms of reference

JBA Consulting (JBA) were commissioned by RPS to undertake an FRA Addendum study at Thamesfield, Wargrave Road, Henley-On-Thames.

This follows and complements the Flood Risk Assessment completed by WSP in October 2022.

1.2 Context

The FRA Addendum addresses the flood risk requirements received from Wokingham Borough Council in their pre-planning advice letter (dated 29 November 2022) following the work completed by WSP dated 2022 which includes:

- FRA report (see Appendix A)
- Flood Warning and Evacuation Plan (see Appendix B)

It also refers to the latest development proposal for the site (see Appendix C) and to hydraulic modelling work (see Appendix D) undertaken by JBA in 2022 and subsequently approved by the Environment Agency (see Appendix E) in 2023.

This Addendum also expands on reservoir flooding, and on flood risk mitigation required on site. When/if in contradiction, the content of this Addendum supersedes the content of WSP's FRA.

1.3 The Proposal

Retirement Villages Group has identified that there is an opportunity to redevelop the existing site at Thamesfield, Henley-on-Thames to provide several amenity benefits to existing residents, to improve the functioning of the site and to provide new extra care accommodation. This will ensure vitality and viability of the site over the longer term.

The piecemeal development of buildings and extensions on site has resulted in the compromised functionality of the existing site, principally in terms of circulation. The proposed re-development of the buildings and spaces in the northern part of the site therefore seeks to better utilise this area which currently accommodates single storey residential units, inefficient circulation and 'left over' external spaces. The Design and Access statement submitted as part of the planning application contains full details of the existing site constraints and opportunities for improvement through the redevelopment of this part of the site.

Thamesfield is an established and operational Integrated Retirement Community (IRC) providing extra care retirement accommodation and associated communal facilities. The Site currently comprises 37 extra care units (use class C2).

Following the planning application there will be 50 extra-care units on the site (net gain of 14 extra care units).

A copy of the latest site layout plans is provided in Appendix C.

2 Planning Policy and Flood Risk

2.1 National Planning Policy Framework

It is a requirement for development applications to consider the potential risk of flooding from various sources to a proposed development over its expected lifetime and any possible impacts on flood risk elsewhere as a result of the development.

This FRA has been prepared in line with the revised National Planning Policy Framework (NPPF) December 2023.

Where appropriate the following aspects of flood risk should be addressed in all planning applications in flood risk areas:

- The nature and expected lifetime of the development and the extent to which the development is designed to deal with flood risk.
- The area liable to flooding from various sources.
- The probability of the current and future flood risk.
- The extent and standard of existing flood defences and their effectiveness over time.
- The likely depth of flooding.
- The rates of predicted flows.
- The likelihood to impacts on other areas, properties, and habitats.
- The effects of climate change (as per NPPF Chapter 14).
- The proposed development site is over 1ha. Therefore, a site-specific Flood Risk Assessment is required. This document shall consider the risk to the proposal from all sources of flooding including fluvial (river), tidal, coastal, pluvial (Surface Runoff / Surcharging Sewers), flooding from reservoirs and groundwater.
- The NPPF advocates a risk-based approach to flood risk management in terms of appraising, managing and reducing the consequences of flooding both to and from a development site. The primary objectives of this FRA to determine the following:
 - Whether the site is at significant risk from any form of flooding;
 - If the site is at risk of flooding determine if safe access to and from the site can be achieved and maintained;
 - Mitigation measures to alleviate flood risk on site.

2.2 Local Planning Guidance

In addition to the Planning guidance and requirements listed in WSP's reports (which refer to Wokingham Strategic Flood Risk Assessment), the following local policies were reviewed:

- Policy CC09 - Development and Flood Risk (from all sources)
- Policy CC10 - Sustainable Drainage - Wokingham Borough Managing Development Delivery Document (adopted 2014)

This Flood Risk Assessment report was prepared in compliance with the above policies ensuring that:

- 1 All sources of flood risk, including historic flooding, must be taken into account at all stages and to the appropriate degree at all levels in the planning application process to avoid inappropriate development in areas at risk of flooding.

Proposals must be consistent with the guidance in paragraphs 99-104 of the National Planning Policy Framework (NPPF); the Technical Guidance to the NPPF and demonstrate how they have used the Strategic Flood Risk Assessment (SFRA) to determine the suitability of the proposal.

- 2 Development proposals in Flood Zones 2 or 3 must take into account the vulnerability of proposed development.
- 3 Development must be guided to areas of lowest flood risk by applying the sequential approach taking into account flooding from all sources and shall ensure flood risk is not worsened for the application site and elsewhere, and ideally that betterment of existing conditions is achieved. The sequential test will not be required if at least one of the following applies:
 - a. Replacement of an existing single residential property. However, the replacement property should, where possible, be located on the part of the site at lowest risk
 - b. Conversions and change of use unless it involves a change to a more vulnerable class
 - c. Minor development, as defined in footnote 10 of the Technical Guidance Note to the NPPF.
- 4 In exceptional circumstances, new development in areas of flood risk will be supported where it can be demonstrated that:
 - a. The development provides wider sustainability benefits to the community that outweigh flood risk
 - b. The development will:
 - i. Be safe for its lifetime, taking account of the vulnerability of its users
 - ii. Not increase flood risk in any form elsewhere and, where possible, will reduce flood risk overall
 - iii. Incorporate flood resilient and resistant measures into the design
 - c. Appropriate evacuation and flood response procedures are in place to manage the residual risk associated with an extreme flood event.
- 5 Where required, suitable and appropriately detailed flood risk information will need to accompany a planning application. A Flood Risk Assessment (FRA) is required for:
 - a. All proposals in areas of known historic flooding from all sources
 - b. Where there is evidence of a risk from all sources of flooding identified in the Strategic Flood Risk Assessment
 - c. Those proposals set out in footnote 20 to paragraph 103 of the NPPF

In line with Policy CC10, evidence that the “development proposals [will] ensure surface water arising from the proposed development including taking into account climate change is managed in a sustainable manner [will] be demonstrated through a Surface Water Drainage Strategy.” Relevant information confirming compliance with this policy is documented in separate Drainage Strategy report.

2.2.1 Wokingham Borough Council Level 1 Strategic Flood Risk Assessment (2023)

A Strategic Flood Risk Assessment (SFRA) is undertaken by the Local Planning Authority to assess the current and future flood risk within their administrative boundary and, to determine the impact development may have on flood risk. This informs the allocation of land within the Local Plan, through the application of the Sequential Test and, if necessary,

the Exception Test. The current version of the Wokingham Borough Council Level 1 Strategic Flood Risk Assessment was published in May 2023.

The recommendations relating to flood risk are summarised below:

- To locate new development in areas of lowest risk, in line with the sequential test, by steering sites to Flood Zone 1 from the Flood Map for Planning and avoiding where possible areas with a higher risk of surface water flooding. If a sequential test is undertaken and a site at flood risk is identified as the only appropriate site for the development, the exception test shall be undertaken. If development can't be avoided in the higher risk surface water Zone (Zone B), then part "b" of the exception test should be satisfied.
- Planning applications for phased developments should be accompanied by a drainage strategy, which takes a strategic approach to drainage provision across the entire site and incorporates adequate provision for SuDS within each phase.
- Identify opportunities to maintain and enhance permeable surfaces and greenspaces to help reduce surface water runoff whilst promoting other benefits, including biodiversity and wellbeing.
- There should be no built development within 8m from the top of a watercourse or main river for the preservation of the watercourse corridor, wildlife habitat, flood flow conveyance and future watercourse maintenance or improvement.

2.3 Sequential and Exception Tests

The NPPF requires that the Sequential and Exception Test should be applied to identify the location of new development and the layouts of the development site. The Sequential Test aims to promote development in low flood risk areas. The exception test is used where no suitable development areas can be found in low flood risk zones.

The Sequential Test should be applied to identify suitable sites which are at low risk from all sources of flooding, avoiding medium and high-risk areas where possible. If no suitable areas for the development proposal can be identified in low-risk areas, then sites with the lowest flood risk should be considered next. If development is necessary within a medium-high risk zone an exception test may be required to demonstrate the need for the development in that location and how the development will mitigate the flood risk.

The NPPF classifies care home developments as 'More Vulnerable' and, according to Table 2-1:

- Their construction is not incompatible with Flood Zone 2 and 3¹.
- The Exception Test is required.

Table 2-1: Flood risk and flood zone 'incompatibility'

Vulnerability Classification (Table 2)		Essential Infrastructure	Highly Vulnerable	More Vulnerable	Less Vulnerable	Water Compatibility
Flood Zone (Table 1)	Zone 1	✓	✓	✓	✓	✓
	Zone 2	✓	Exception Test	✓	✓	✓
	Zone 3a	Exception Test	✗	Exception Test	✓	✓
	Zone 3b	Exception Test	✗	✗	✗	✓

1 Flood risk and coastal change - GOV.UK (www.gov.uk)

- ✓ Exception test not required
- X Development should not be permitted

The proposal is for the regeneration of a Care Home scheme. As such, the development is limited to the site boundary and thus cannot be compared with alternative / more sequential preferable sites. In addition to the above, the proposal follows the sequential approach to flood risk by steering the footprints of the new builds away from the areas the most at risk of flooding (as shown in Figure 5-1). As such, it is considered that the site passes the Sequential Test.

With regards to the Exception Test, the proposal will generate the following wider community benefits:

- Contribution towards identified need for specialist housing for older people in Wokingham Borough Council (WBC).
- Contribution towards WBC's housing land supply.
- The provision of specialist housing and care for older people will free up family housing elsewhere in the Borough Council.
- The proposal will provide a wide range of health and wellbeing benefits to the residents of the scheme.
- The proposal makes efficient use of a previously developed (brownfield) site.
- The proposal will provide biodiversity net gains and landscaping benefits.
- The proposal will provide energy, economic and sustainability benefits.

When combined with the flood mitigation measures listed under Section 5 (which will be implemented as part of the proposal), it is therefore considered that the proposal passes both parts of the Exception Test.

3 Fluvial flood risk

3.1 Flood extents

Baseline fluvial flood extents for the 30-year, 100-year and 1,000-year fluvial events are shown in Figure 3-1. This indicates that the site is at risk of fluvial flooding during all modelled return periods.

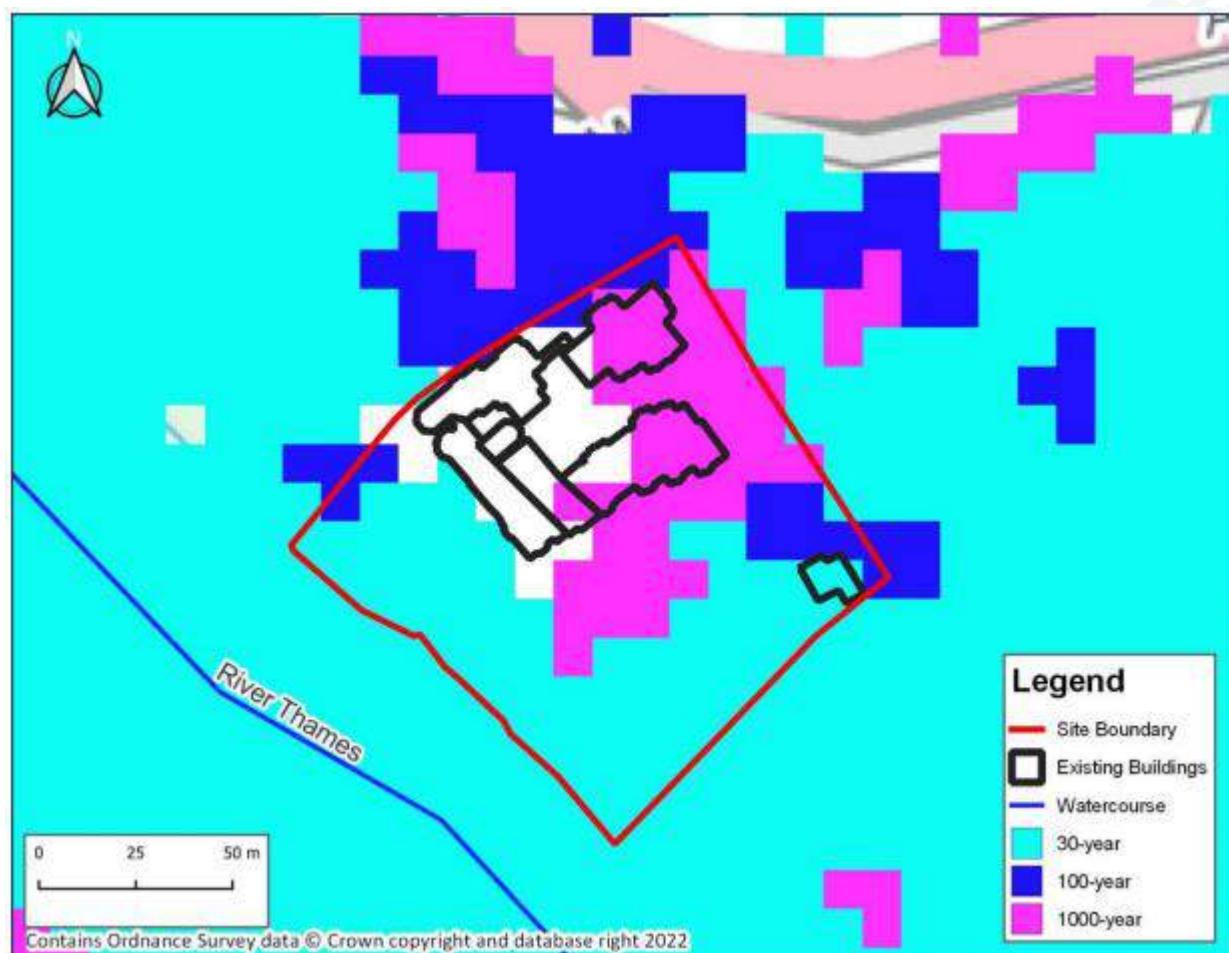


Figure 3-1: Baseline flood extents (30-year, 100-year and 1,000-year)

Figure 3-1 shows that the capacity of River Thames exceeds during all the modelled events. The river water that enters the site for the 30-year return period are significant and mainly affects the south and south-west areas of the site. During the 100-year return period, the flood extents completely surround the site although is unlikely to affect the existing buildings. During the 1,000-year flood event, the existing buildings are likely to flood, including the car parks and private apartments near the car parks.

The proposed building footprint will be steered away from the edge of the 100-year with climate change flood extent.

3.2 Flood levels

The baseline fluvial flood levels during the 100-year plus 31% climate change allowance at the site are shown in Figure 3-2.

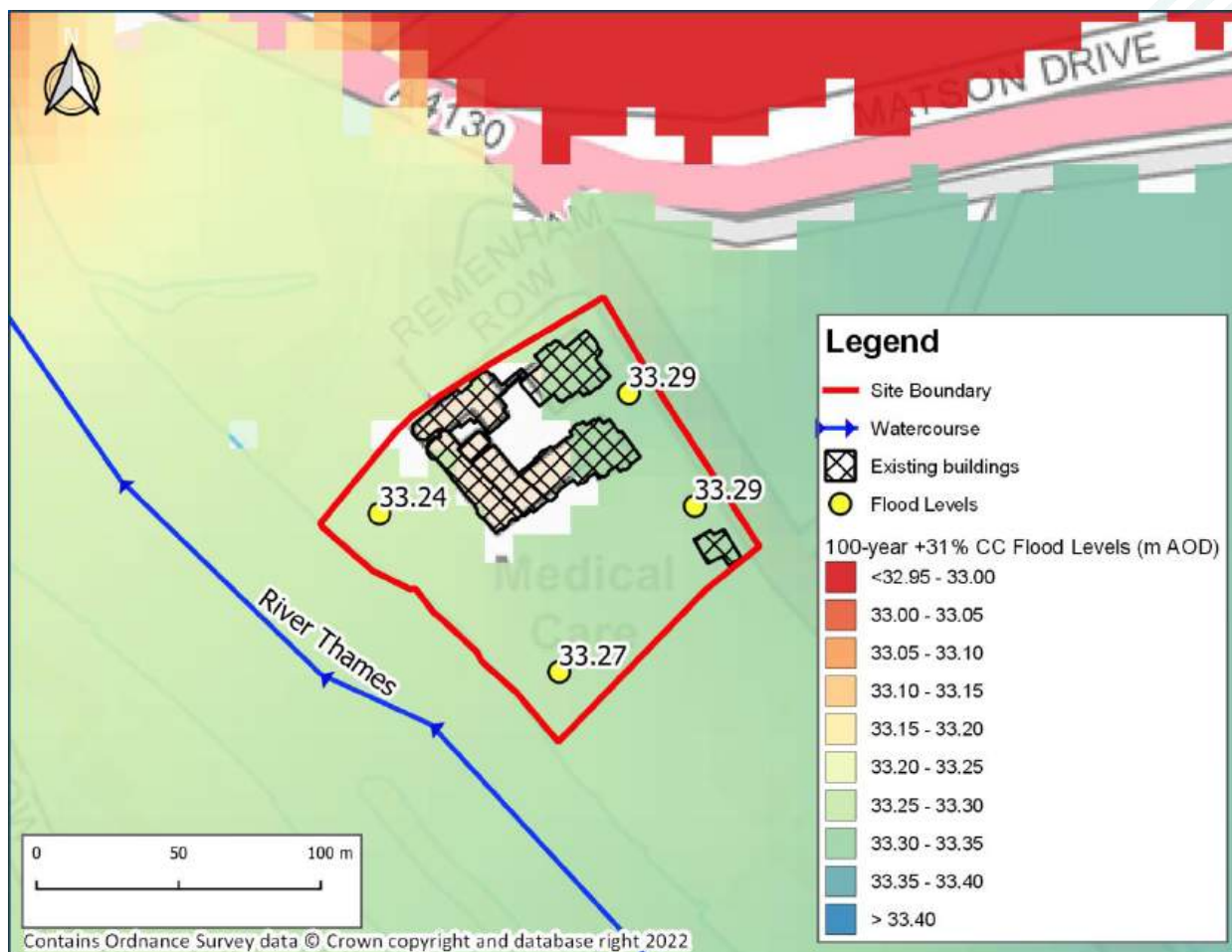


Figure 3-2: Baseline fluvial flood levels during 100-year event plus 31% climate change allowance

Figure 3-2 shows that during the 100-year plus 31% climate change fluvial flood event, the peak water levels will range between 33.24 and 33.29m AOD on site. This will exceed the existing floor levels of two existing buildings on site.

3.3 Flood depths

The baseline flood depths have been reviewed for the design flood event (100-year plus 31% allowance for climate change) and are shown in Figure 3-3.

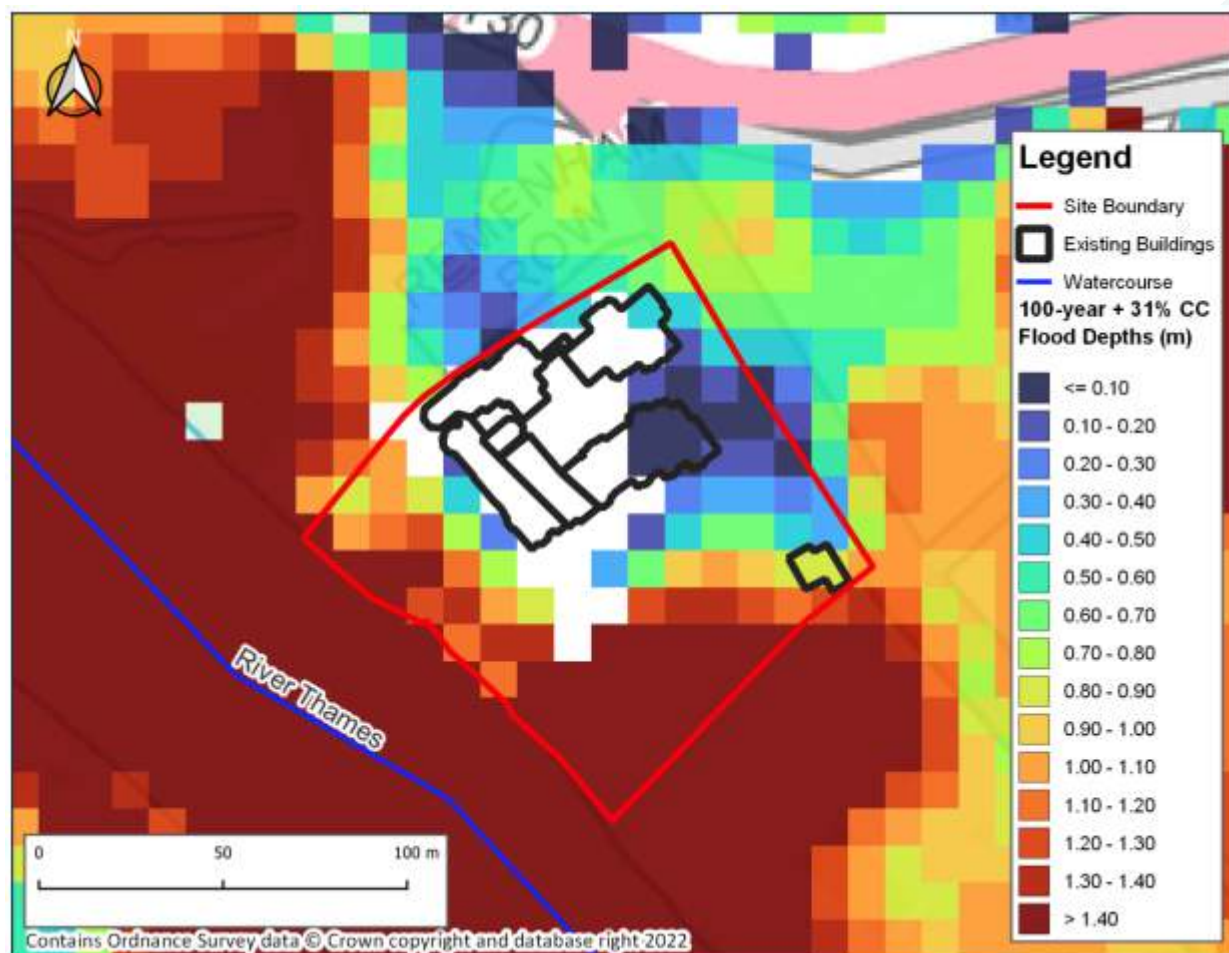


Figure 3-3: Baseline 100-year flood depths with 31% climate change scenario

Figure 3-3 shows the maximum predicted flood depths within the site during the 100-year with 31% climate change event. The flood depths at Block D (See building location in Appendix C) typically range from 0.40 - 0.50m, although this is much lower for Block E with depths of typically ≤ 0.10 m. Flood depths at the site access to the north of the site are most commonly between 0.60 - 0.80m which would likely have implications for access and egress.

3.4 Flood hazard

The 100-year with (+31%) climate change fluvial flood hazard-to-people classifications in relation to the proposed site are represented in Table 3.1. The hazard-to-people classification used in the modelled fluvial flooding maps are based on the formula suggested in Defra's FD2321/TR2 "Flood Risks to People" is shown below. The hazard categories are described in Table 1.

$$HR = d \times (v + 0.5) + DF$$

where,

HR = (flood) hazard rating;

d = depth of flooding (m);

v = velocity of floodwaters (m/sec); and

DF = debris factor (= 1, conservative estimate of DF as largely urban

Table 3.1 Defra's FD2321/TR2 "Flood Risks to People" classifications		
Flood hazard rating depth x (velocity+0.5)+DF	Level of Flood Hazard Description	Description
<0.75	Low	Caution "Flood zone with shallow flowing water or deep standing water"
0.75 - 1.25	Moderate	Dangerous for some (i.e. Children) "Danger: flood zone with deep or fast flowing water"
1.25 - 2.0	Significant	Dangerous for most "Danger: flood zone with deep fast flowing water"
>2.0	Extreme	Dangerous for all "Extreme danger: flood zone with deep fast flowing water"

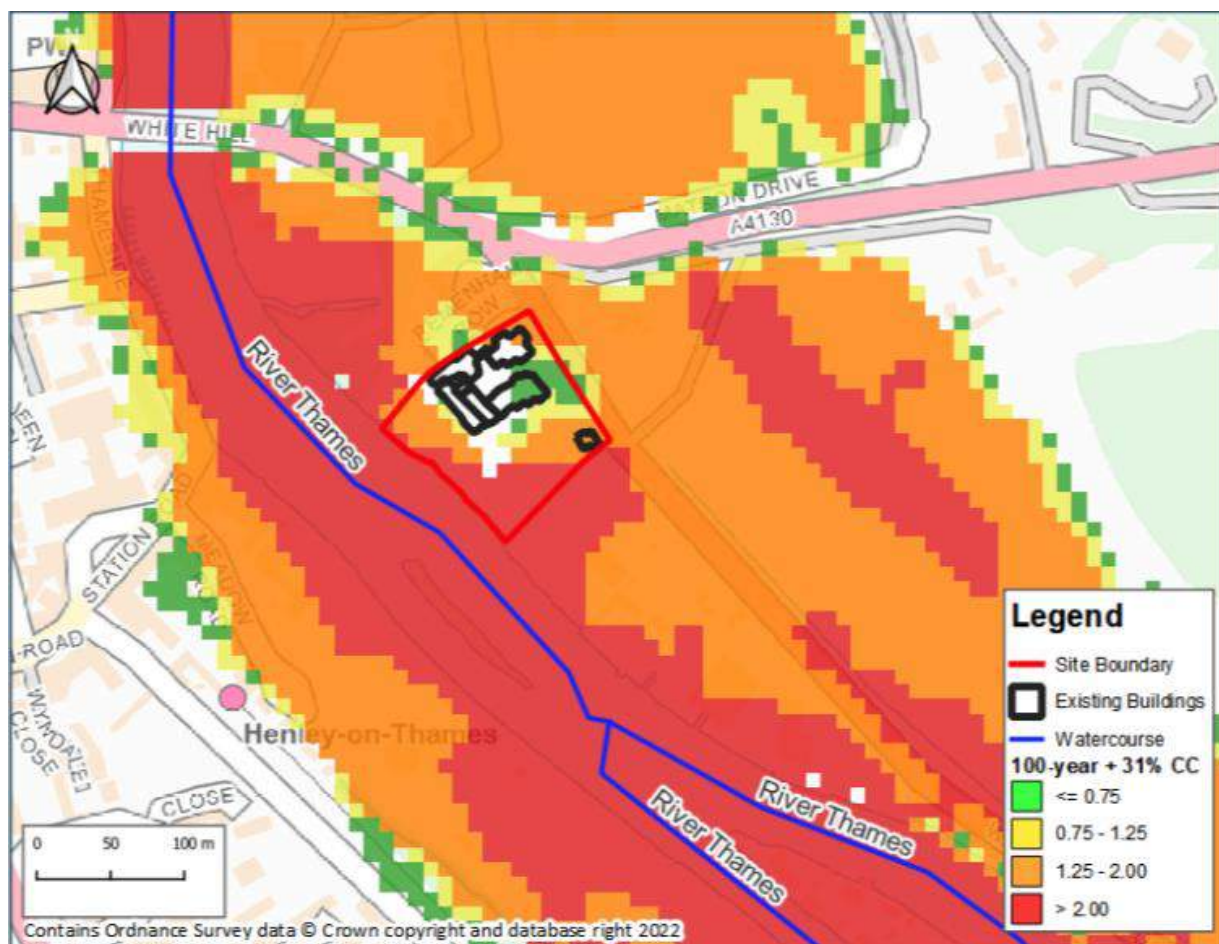


Figure 3-4: Flood Hazard to people

Figure 3-4 shows that the majority of the site and along the A321 falls within the 'very low risk - caution' (≤ 0.75) to 'danger for most' (> 2.00) hazard categories. On the western side along the site the southwest side of the site is classified as 'danger for all' and on the far south corner of the site is in 'danger for all'. Near the main entrance and car park the hazard to people falls under 'very low - caution' and 'danger for some', which could provide safe access for emergency vehicles and those rescuing teams on foot but would be a danger for the elderly to walk past by that flood water.

3.5 Blockage scenario

The site is located near Henley Bridge, which is subject to a potential blockage during a flood event. Therefore, blockage risk analysis was undertaken.



Figure 3-5: Blockage risk analysis in 100-year and 31% climate change with 25% blockage at Henley Bridge

Figure 3-5 shows that during a 1 in 100-year flood event plus 31% climate change allowance, with a 25% blockage at Henley Bridge, flood depths would increase to 0.77m at the site. A blockage of the Henley Bridge would result in a 'significant increase' in flood risk onsite. It is therefore important that the main river beneath the bridge is regularly maintained and cleared to allow the water to flow freely.

4 Other sources of flood risk

4.1 Groundwater flood risk

According to EA's MAGIC map², the geology of the site mainly consists of sedimentary bedrock formations such as chalk, sand and gravel. Based on the borehole record and the geology of the site, it is considered to be in high risk of groundwater flooding. This correlates with anecdotal evidence whereby flood waters were previously observed in the basement by members of the Retirement Village.

Existing basements in the buildings are mainly used for storage and the more vulnerable aspects of the development will not be situated in the basements due to the risk of flooding. There is an approximate of difference in elevation of 2.5m between the floor level of the basement and ground level. There have been instances of flooding in the past within the basements resulting in the installation of sump pumps.

4.2 Reservoir flood risk

Nearby reservoirs need to be considered with regard to flood risk, in the unlikely event a reservoir was to fail. A breach in the reservoir would result in a sudden and large amount of water flowing with high velocity. Two reservoirs, the Farmoor reservoirs, located approximately 25 miles north to site are considered to pose a risk of flooding to the area should they breach during normal river levels and/or during flood conditions.

The Black Swan reservoir, that is located south to the site approximately 10 miles away could also pose a risk of flooding to the site. In the event of a breach, this could lead to flooding downstream along the River Thames.

Figure 3.1 provides an indication of worst-case scenarios of reservoir flooding during a 'dry day' and 'wet day' at the site. The 'fluvial contribution' layer illustrates the baseline flood extents used to generate the 'wet day' breach extents.

² Magic Map Application (defra.gov.uk)

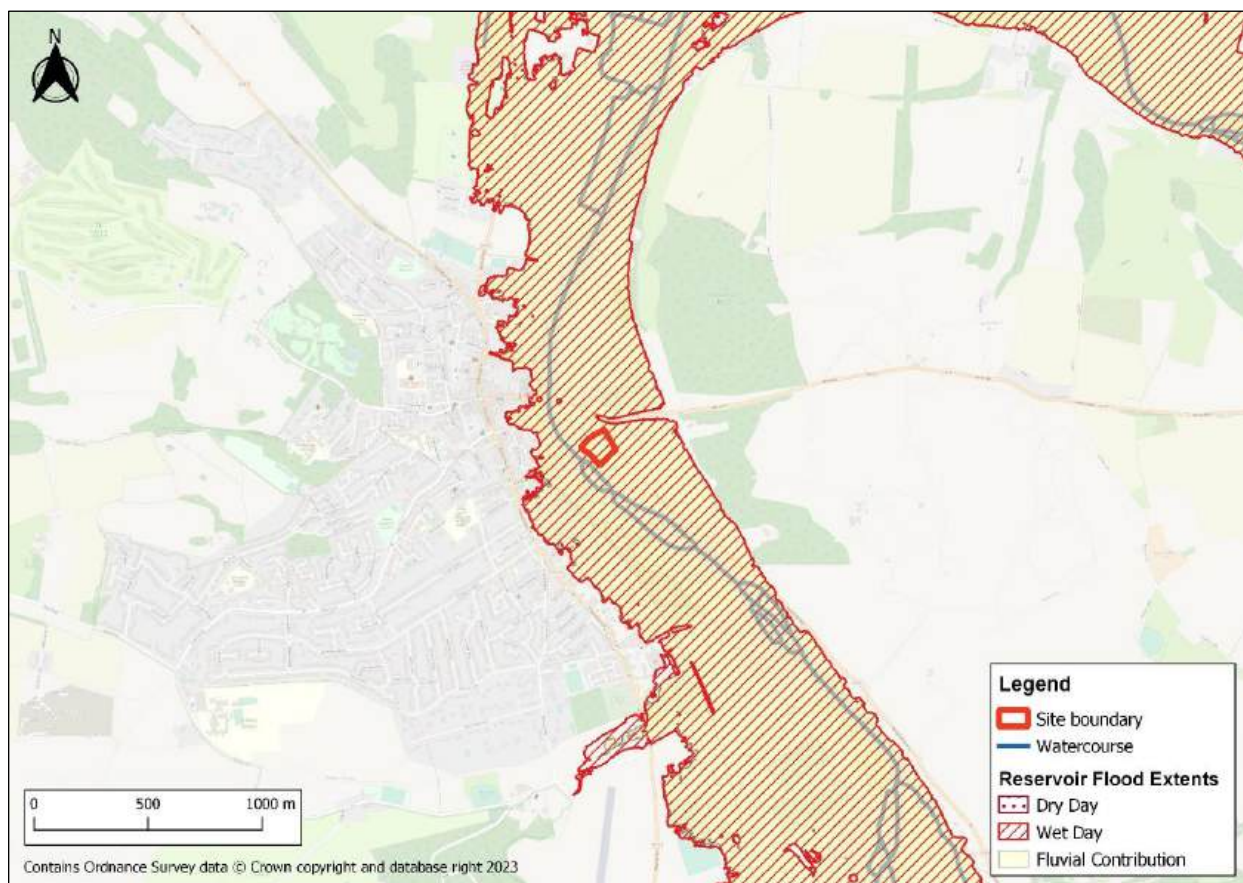


Figure 4-1: Reservoir Flood Extents during 'Wet Day', 'Dry Day' and 'Fluvial Contribution'

Figure 4-1 shows that the site is not affected by reservoir flood extents during the 'dry day' scenario. Flooding may occur during the 'wet day' reservoir breach scenario when i.e. combined with a 1,000-year fluvial flood event from the River Thames. A comparison of the 'wet day' flood extent with LiDAR data indicates flood level of 34.39m AOD could be reached on site during this scenario. This would result in flood depths of up to 2.32m on site.

5 Flood mitigation

5.1 Finished Floor Levels

It is recommended to increase the floor levels of existing buildings, where possible (i.e. subject to headroom constraints) in order to improve their resistance to flooding. With regards to the new building, their finished floor levels will be raised to a minimum of 600mm above the 'design' (100-year with climate change) flood level, i.e. to a minimum of 33.86mAOD.

5.2 Emergency planning

The buildings are at high risk of fluvial flooding due to the proximity to the River Thames, with no permanent safe access and egress route available during the peak of the 'design' 100-year with climate change fluvial flood event. As a result, flood warning and evacuation procedures at this site will be essential.

In 2022, the WSP produced a Flood Warning and Evacuation Plan (see Appendix B) which includes safe exit and access routes during a flood event. The assembly point is located at the courtyard in the centre of the site, where the occupants will need to gather following receipt of a flood warning and make their way out to Wargrave Road if it is safe to do so.

Further to WSP's recommendations, and following consideration of their latest site design, flood boards indicating flood depths along the evacuation route will be provided to confirm when safe access and egress is no longer possible and when confinement/safe refuge on site need to be considered.

5.3 Safe access and egress

Safe egress for the site occupants will be through the main entrance and along Wargrave Road, heading north towards the A4130. The surface water flood risk is lower near the car park and entrance which could be used for safe access and egress. Furthermore, the fluvial flood hazard is lower ('danger for some') at the main entrance, which means emergency vehicles will still be able to access the site. In the event of a flood emergency, the site occupants will be required to evacuate the site. For evacuation plan see Appendix B, Flood Warning and Evacuation Plan by WSP.

As safe access and egress will not be possible during the peak of the 'design' flood event, the Flood Response Plan will be updated accordingly and learnt by staff members. Furthermore, emergency procedure/evacuation plan practices will be regularly undertaken by all site occupants, to learn the process and the muster points of the evacuation plan. Prior to a flood event it is important to plan for the evacuation of the people in the building. The building should only be used as a safe refuge as a last resort.

5.4 Confinement/safe refuge

Given that the whole site is surrounded by flood water during a 100-year with climate change flood event, it is recommended that the residents are evacuated from the building using the safe access/egress routes and following the evacuation plan procedures. In the case of residents are not able to be evacuated, they will have to stay in their rooms if located in upper floor levels (or otherwise in the upper floor levels), for example in Block A, B and E. If the weather conditions are bad during a flood event, it is not recommended for the residents to exit the building (unless instructed by emergency services) as there is no safe access/exit points of the site for the pedestrians.

If the weather conditions are mild and it is safe to leave the buildings, the northern outside area of the site is appropriate for evacuation procedures. For example, the residents can gather to the courtyard in the centre the buildings and move towards the car park where vehicles can enter and exit safely to transport and evacuate the residents.

In extreme cases of flooding when the power can be affected, it is highly recommended to install emergency generators for the buildings. It is also recommended to circulate a copy of the Flood Warning and Evacuation Plan to the residents.

5.5 Basement solutions

The basement is understood to be approximately 2m in depth and by placing new steel beams on the soffit of the ground floor slab, will restrict the headroom locally. The basement height will vary between 1.800m and 2.175m. To mitigate against flood risk in the basement, the space will be used exclusively as non-habitable floor space and for storage only. It is recommended to reinforce the basement and render the walls and floor impervious to ground water (seek confirmation from a structural engineer that such measures will not detrimentally impact the structural stability of the wall / i.e. that the wall is capable to withstand the increased groundwater pressure on the wet side of the wall). Furthermore, the walls should be sprayed with water repellent material and ventilation of the basement should be considered to mitigate damp. The installation of sump pumps at the lowest point in the basement is essential to extract flood water, prevent water pooling in the basement. It is important to ensure that these pumps are tested regularly.

Electrical wires will also be run from the ceiling and electrical appliances will be raised from the floor, if possible. If not, it is recommended that a key switch is installed to isolate electricity in the basement in emergency flooding. A key switch is low cost and will provide efficient solution for electrical mechanisms in the basement. Should it fail to operate and should it require manual interventions, it is highly recommended that operators not to enter in flood water in the basement as there is a high risk of electric shock and switch of main electrical panel. Therefore, it is recommended to place a warning site of the flood water risks/hazards in the basement and to notify site occupant not to enter the basement.

The inspections of the internal walls and floor of the basement is essential to recognise any cracks or gaps which then needs to be fill-in with silicone sealant or mortar to prevent water ingress into the basement.

It is highly recommended that a borehole with sensor is set up to regularly monitor the groundwater levels at the site as permeable bedrock lays beneath the site.

5.6 Flood mitigation against reservoir flooding

Reservoir flooding is considered a residual risk for the site. It will not occur during the 'dry day' scenario and, during a 'wet day' scenario, the site will already be subject to flooding from the River Thames (fluvial contribution).

As a result, no additional flood mitigation measures on top of the flood warning and evacuation procedures already considered against fluvial flood risk are deemed required.

5.7 Floodplain compensation

Figure 5-1 shows the existing and proposed building footprints in relation to the 100-year with climate change floodplain.

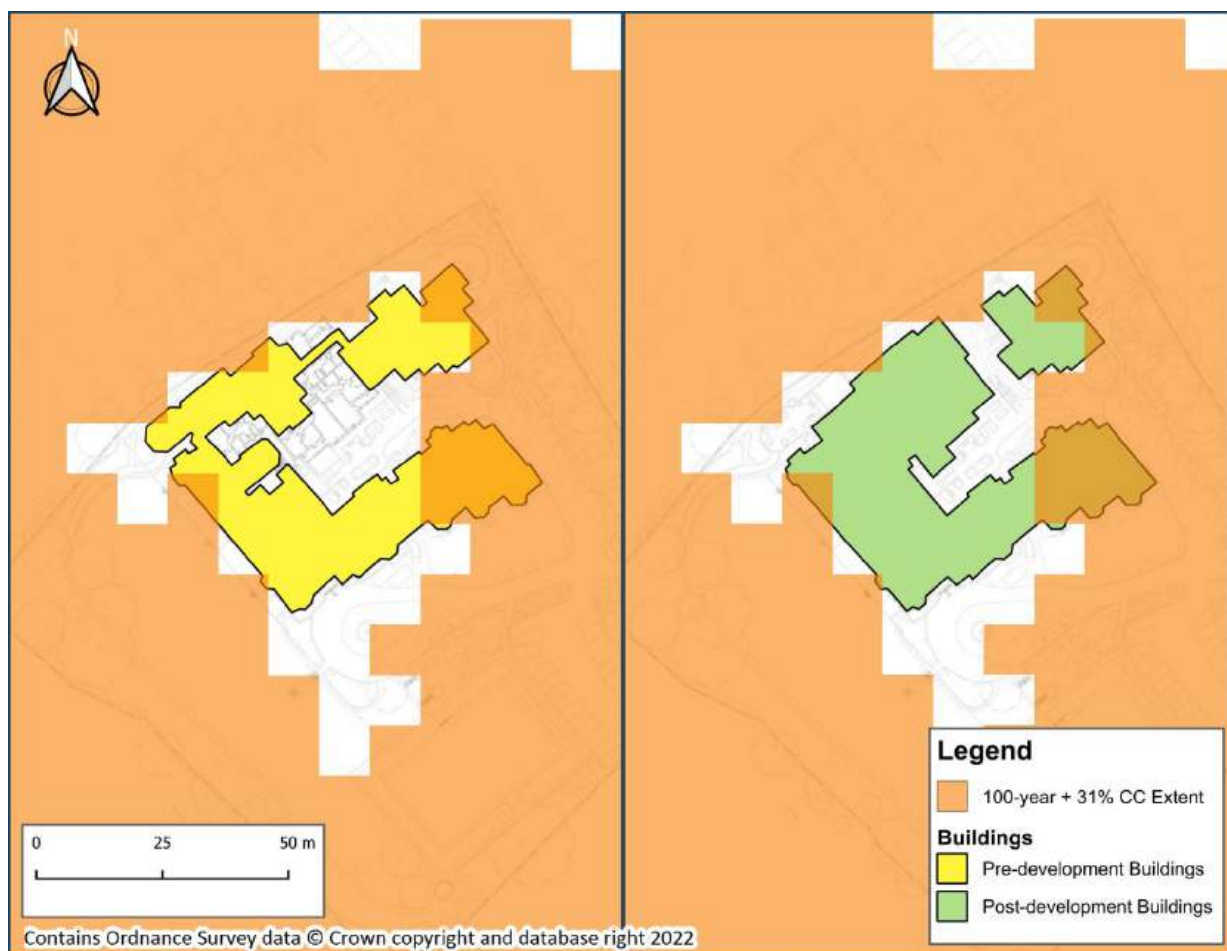


Figure 5-1: Pre-development and post-development buildings with 100-year plus 31% climate change event

A GIS query was run to calculate the total building footprint area encroaching within the 1 in 100-year plus 31% climate change floodplain for both the pre- (existing/baseline) and post-development (proposed) scenarios. Results are shown in Table 5-1. Table 5-1 indicates that the cumulative building footprint area within the floodplain will reduce by approximately 15.4m² following the proposed development. As a result, floodplain compensation is not required for the site.

Table 5-1: Pre-development and post-development area within 100- year plus 31% climate change extent (m2)

Pre-development	Post-development
515.4	499.0

6 Conclusions

- JBA Consulting were commissioned by RPS to undertake a fluvial hydraulic modelling study.
- This report highlights the risks of flooding to site and the necessary implementations.
- The model has been run for the 30-year, 100-year and 1,000-year with 31% climate change scenarios. It is predicted that the capacity of the River Thames is exceeded during all modelled events and will flood the site.
- Fluvial flood risk is 'high' within the site boundary which is mainly affected by the adjacent River Thames.
- Groundwater flood risk is considered medium to high within the site. It is possible that groundwater floods the basement of the site.
- Reservoir flooding is shown to affect the site should a breach coincide with 'wet day' conditions, however the likelihood of reservoir breach is low. Reservoir flooding does not affect the site during 'dry day' conditions and directly.
- During the modelled fluvial 1 in 100 year plus climate change event, the majority of the site and along the A321 falls within the 'caution' to 'danger for most' hazard categories.
- Blockage at Henley Bridge is projected with the 25% blockage to cause significant increase of flooding the site, with a maximum flood depth of 0.77m.
- A copy of the Flood Warning and Evacuation Plan by WSP (Appendix B) should be provided to the occupiers of the site along with a Flood Response Plan that lists the tasks to undertake should a flood event occur.
- The proposal will reduce the cumulative building footprint falling within the 100-year with climate change floodplain by approximately 15.4m².

To mitigate against flood risk, it is recommended to:

For the new buildings;

- Raise the ground floor levels of the new buildings to a minimum of 600mm above the 'design' flood level.
- Install emergency generators to be used in extreme cases of flooding where the power might be affected to maintain power on site (e.g. to power medical equipment).

For the existing buildings

- Place flood barriers/doors to the doorways of buildings with a floor elevated below the 'design' flood level.
- Install emergency generators to be used in extreme cases of flooding where the power might be affected to maintain power on site (e.g. to power medical equipment).
- The external walls of the building should be inspected for any cracks or gaps, and sealed with silicone sealant or mortar as required.
- The external walls should be treated with water repellent spray.
- Internal walls of the ground floor levels should be made of easily washable materials (e.g. tiles and smooth concrete).
- For the existing basement;
- Install sump pumps to the lowest point of the basement and test pumps regularly.
- Ensure that the basement is exclusively used as non-habitable floor space.

- Render the walls impervious (and seek confirmation from a structural engineer that such measures will not detrimentally impact the structural stability of the wall / i.e. that the wall is capable to withstand the increased groundwater pressure on the wet side of the wall).
- Electric wires and sockets should be set as high as possible, if cannot move electric socket and wires, then a small key switch is to be installed to isolate electricity in the basement during flood events and to switch of electricity in the basement when flood water occurs.
- Circulate a copy of the Flood Warning and Evacuation Plan by WSP (Appendix B) to the occupiers of the site and ensure it is updated accordingly.
- Place flood door barrier at the basement doorway.
- Ensure that signage of high flood risk/hazard is placed at the basement access door to notify site occupant of the hazard. Furthermore, a warning sign for not entering the basement when floodwater is present, to avoid for operators to get electric shock.
- Walls to be made of easily washable materials (e.g. tiles, smooth concrete) and appropriate venting is considered to minimise moisture damp in the basement.
- A borehole with a pressure sensor should ideally be set to monitor groundwater level near the basement and trigger alerts or alarms to the occupants of the site.
- As part of the recovery procedure, an electric certificate should be issued after flood events affecting the basement.
- The internal walls and floor of the basement should be tanked in order to prevent groundwater penetration.
- Items stored in the basement should be suitable to be easily removed following receipt of activation of 'be prepared' triggers (flood alert, on site observation). Items that cannot be removed should be suitably flood resilient in their nature to weather continued exposure to floodwater.

In addition to the above, a Flood Response Plan listing all tasks to be carried out by on-site staff and local residents prior to, during and following a flood event should be produced for the site.

Appendices

A FRA report (WSP October 2022)



Technical Note – Flood Risk Assessment and Outline Drainage Strategy

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CHECKED:	QW	APPROVED:	TK

INTRODUCTION

This pre-application technical note has been prepared by WSP on behalf of Retirement Village Group, to identify the risks of flooding associated with partial redevelopment of the Thamesfield Retirement Village, which will henceforth be referred to as ‘the Site’. The Site is located on Wargrave Road, Henley-on-Thames, RG9 2LX within Wokingham Borough Council (WBC), Berkshire. A Site location plan is shown in Appendix A.

This initial flood risk investigation has been informed by:

- Data provided by the Environment Agency (EA);
- EA online mapping data (via the GOV.UK website);
- Hydraulic Modelling Study at Thamesfield, Wargrave Road, Henley-On-Thames, (2022), by JBA Consulting.

In addition to the consultation with the above parties, the report has been informed by assessing and reviewing the following available data, local policy documents and policies:

- National Planning Policy Framework (NPPF), 2021
- South Oxfordshire District Council (SODC) Strategic Flood Risk Assessment (SFRA), (2017)
- WBC Draft Local Plan, (2020)
- WBC Preliminary Flood Risk Assessment (PFRA), (2011)
- WBC Local Flood Risk Management Strategy, (2015)
- WBC Strategic Flood Risk Assessment (SFRA), (2019)

Relevant maps from the above documents are attached in Appendix C.

BASELINE INFORMATION

The Site is located at Wargrave Road and bound by the River Thames to the west, the A321 Wargrave Road to the east, Remenham Row to the north and greenspace to the south. The Site is located within the district of Wokingham Borough Council (WBC), and on the border of South Oxfordshire District Council (SODC).

The Site is situated at:

- National Grid Reference: SU 76583 82479
- Easting, Northing: 476583, 182479
- Nearest Postcode: RG9 2LX

Please refer to Figure 1 and Appendix A.

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Figure 1 - Indicative Site Location

EXISTING WATERCOURSE

The River Thames, a main river, directly borders the west of the Site. There are no other watercourses in proximity to the Site.

EXISTING DRAINAGE

There is an existing surface water rising main in the northeast corner of the Site travelling north along the A321. There are no other existing on-site connections to the Thames Water network. Please refer to Appendix B for Thames Water Asset Records. There is no existing foul drainage network onsite and a CCTV drainage surveys will be required at a later stage to inform the drainage design.

TOPOGRAPHY AND SITE LEVELS

Based on the topographical survey provided to WSP by Thamesfield Retirement Villages, the levels survey show that the Site slopes down from its eastern boundary to the west, towards the River Thames. The Site fall from approximately +33.50 mAOD to +31.71 mAOD respectively. Please refer to Appendix B for a detailed topographic survey.



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PROPOSED DEVELOPMENT

The development proposals for the Site is comprised of:

The erection of a three-storey extension to provide 14 no. extra-care units, following associated demolition works, along with the potential expansion of the car parking facilities.

POTENTIAL SOURCES OF FLOODING

Reference to gov.uk 'Flood Map for Planning' and 'long term flood risk information' maps (which makes use of EA data) is made where appropriate, along with reference to the WBC documents and SODC documents.

Using the available information, the following assessment has been made:

TIDAL FLOODING

There is no risk of tidal flooding at the Site. Therefore, the risk of tidal flooding is considered **negligible**.

RESERVOIR FLOODING

Based on the online GOV.UK 'Long Term Flood Risk Information', the Site has been identified as within the extent of flooding from reservoirs, however only when there is flooding from rivers. Based on the information available, WSP have deemed this flood risk as **low**.

SURFACE WATER FLOODING

Based on the online GOV.UK 'Long Term Flood Risk Information', the Site is identified to have 'Very Low' risk of flooding from surface water. Therefore, the risk of flooding from surface water is considered **negligible**.

SEWER FLOODING

The SODC SFRA mapping of sewer flooding incidences in the district shows there has been 16-24 incidents of sewer flooding in the vicinity of the Site, however there is no information stating where these sewer floodings have occurred specifically. The WBC PFRA shows there to be no historic incidences of flooding from local flooding incidences at the Site or in the nearby vicinity. Please refer Appendix C.

Based on the available information the risk of flooding from sewers is considered **low**.

GROUNDWATER FLOODING

The 'Susceptibility to Groundwater Flooding Map', Figure 6 of WBC Appendix A.9 SFRA, shows the Site to be in an area described as 'Not considered to be prone to groundwater flooding'. Please refer to Appendix C. Therefore, the risk of groundwater flooding at the Site has been assessed as **low**.

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FLUVIAL FLOODING

Based on the online GOV.UK Flood Map for Planning, majority of the building areas of the Site are located in Flood Zone 2 and external areas has been identified to lie within Flood Zone 3 (please refer to Figure 2).

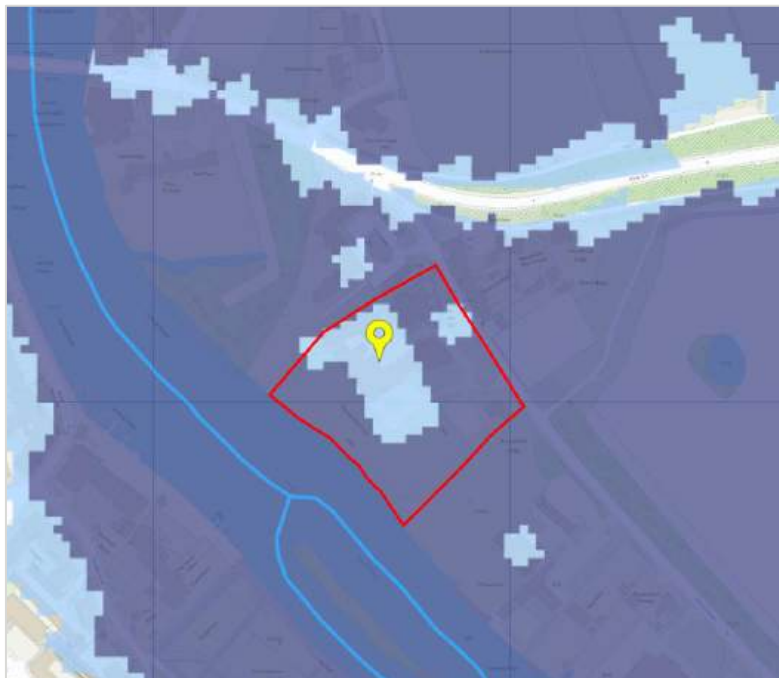


Figure 2 - GOV.UK Flood Map for Planning

Further evidence in the WBC SFRA shows that the Site is located in Flood Zone 3b (Appendix C). According to the EA's definition of flood Zone 3b, the functional floodplain is land where water is required to flow or be stored in times of flooding. As the buildings were built prior to the flood modelling carried out by the EA to determine the flood zone definition, the existing building area should not be deemed as land required to store flood water from the river or sea in a flood event as it would not have been available to provide storage at the time of the modelling. As a result, the whole Site will be deemed to be in Flood Zone 3a and all assessments moving forward will analyse the Site in line with Flood Zone 3a methodology.

Due to the lack of EA product 4 (Detailed Flood Risk Assessment Map, including flood zones, defences and storage areas, areas benefiting from defences, statutory main river designations, historic flood event outlines and more detailed information from the computer river models), JBA Consulting undertook a fluvial water hydraulic modelling study at Thamesfield Retirement Village (Appendix D).

The 'design flood' used for assessment in the JBA report is defined by the EA as river flooding likely to occur with a 1% annual probability (a 1 in 100 chance each year) with an appropriate climate change allowance.

The climate change allowance added is in line with EA guidance that 'More vulnerable' developments in Flood Zone 3a should consider the 'Central' projection. For the 2080s, for the stretch of the River Thames

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the Site sits alongside, the central climate change uplift is 31%. It should be noted that for stretches of the Thames both upstream and downstream, lower climate change uplifts are applied, and therefore it is unlikely a higher value will be requested by the EA. Assessment of the ‘Higher’ or ‘Upper’ projections may be requested as part of a sensitivity analysis.

Figure 3 generated by the JBA hydraulic model shows that only a small part of existing Building 1, Building 5 and the whole of Building 6 are located within the flooding extents when subjected to the design flood (1 in 100-year rainfall event, with a 31% climate change allowance).

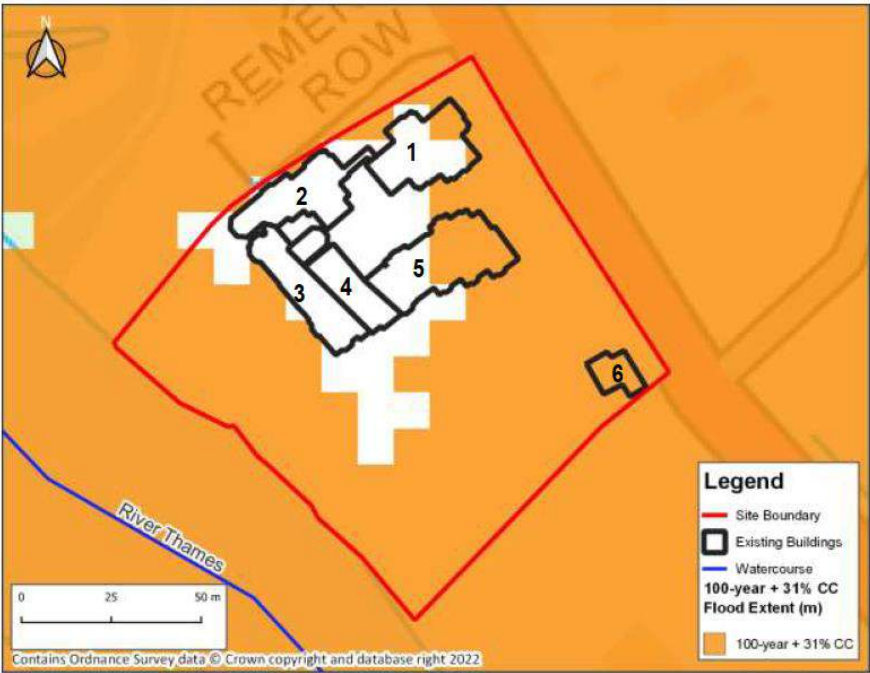


Figure 3 Baseline 100- Year flood extents with 31% climate change scenario
(Source: Hydraulic Modelling Study at Thamesfield, Wargrave Road, Henley-On-Thames, (2022), by JBA Consulting.)

Figure 4, along with Table 1, indicates that for the 100-year event with a 31% climate change allowance, peak flood levels are not expected to exceed the existing floor level in any of the main buildings where redevelopment is proposed, with the exception of Building 1 which will undergo a partial demolition of a unit outside the footprint and in a higher flood zone. For Building 1 flood levels exceed existing floor level by 0.01m. The only other existing building where flood levels exceed existing floor level is Building 6, where an exceedance of 0.66m is predicted.

There are however no proposed demolition or re-development works for Buildings 5 & 6, areas within the modelled flood extents and therefore, no increased risk is associated with these buildings. For the areas where the development is proposed, fluvial flooding will not materially affect building areas and central courtyard / gardens as shown by the modelled flooding extents below.

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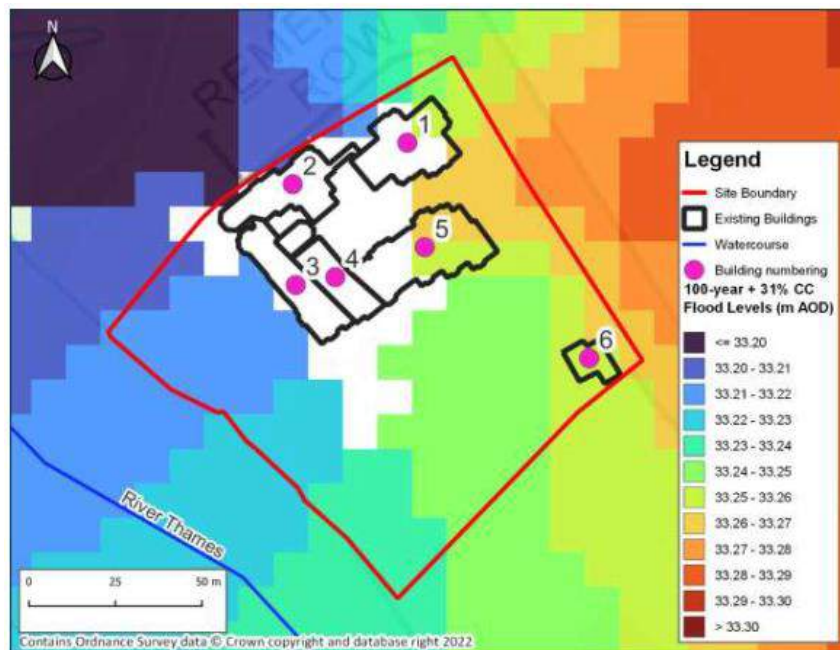


Figure 4 Baseline 100-year water levels with 31% climate change
(Source: Hydraulic Modelling Study at Thamesfield, Wargrave Road, Henley-On-Thames, (2022), by JBA Consulting.)

Table 1: Peak Water Levels Related to Buildings Floor Levels

Building No.	Existing Floor Levels (mAOD)*	Peak water level within existing building(mAOD)
1	33.26	33.27
2	33.83	33.20
3	33.84	33.22
4	33.48	No flooding
5	33.26	33.26
6	32.60	33.26

*: Estimated from Point 2 Surveyors Limited topographical survey dated June 2021

(Source: Hydraulic Modelling Study at Thamesfield, Wargrave Road, Henley-On-Thames, (2022), by JBA Consulting.)

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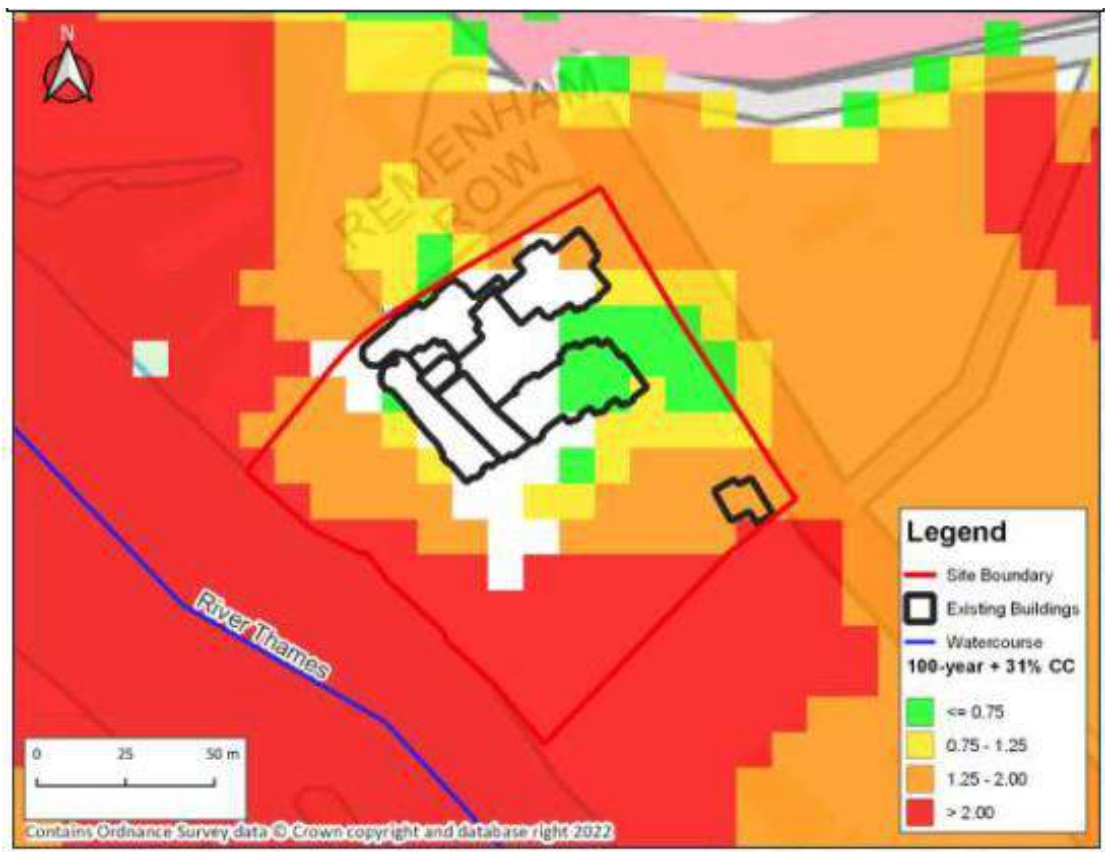


Figure 5: Hazard to People
(Source: Hydraulic Modelling Study at Thamesfield, Wargrave Road, Henley-On-Thames, (2022), by JBA Consulting.)

The fluvial hazard-to-people rating during a 100-year with 31% climate change flood scenario has been mapped by JBA consulting using the formula as suggested in Defra’s FE2321/TR2 “Flood Risk to People”. As shown in Figure 5, the Hazard to People rating for the majority of the building and central garden area (more vulnerable areas) falls within the “no risk” to “low” (≤ 0.75) hazard categories. Only the external areas (water compatible areas) south and east of the Site, where there are no proposals for development fall within significant (1.25-2) and extreme (>2).

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SEQUENTIAL AND EXCEPTION TEST

VULNERABILITY CLASSIFICATION

As stated in the NPPF, a sequential risk-based approach to determine the suitability of land for development in flood risk areas should be applied at all stages of the planning process giving precedence to low flood risk areas wherever possible.

Table 2 - Flood Risk Vulnerability and Flood Zone 'Compatibility'

FLOOD RISK VULNERABILITY CLASSIFICATION		ESSENTIAL INFRASTRUCTURE	WATER COMPATIBLE	HIGHLY VULNERABLE	MORE VULNERABLE	LESS VULNERABLE
Flood Zone	Zone 1	✓	✓	✓	✓	✓
	Zone 2	✓	✓	Exception Test Required	✓	✓
	Zone 3a	Exception Test Required	✓	✗	Exception Test Required	✓
	Zone 3b	Exception Test Required	✓	✗	✗	✗

- ✓ Development is appropriate
- ✗ Development should not be permitted

As discussed in the previous section, the building areas are located in Flood Zone 2 and the external areas are located in Flood Zone 3a. In accordance with the NPPF, the sequential and exception test must be applied.

SEQUENTIAL TEST

The Sequential Test should be applied to major developments located in areas at risk of flooding. However, a pragmatic approach needs to be taken where proposals involve comparatively small extensions to existing premises (relative to their existing size), where it may be impractical to accommodate the additional space in an alternative location (PPG paragraph 027 Reference ID: 7-027-20220825). We note that the proposal's size, scale and footprint would be modest when seen on the context of the existing building form on site. Furthermore, the proposal seeks to increase the existing provision of extra-care units on site. As such, it would not be practical or reasonable to accommodate the proposed units elsewhere. For these reasons, we consider it would not be necessary to undertake a Sequential Test.

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EXCEPTION TEST

To pass the exception test two criteria must be satisfied:

- It must be demonstrated that the development provides wider sustainability benefits to the community that outweigh the flood risk; and
- Demonstrate that the development will be safe for its lifetime taking account of the vulnerability of its users, without increasing flood risk elsewhere, and which possible, reduce flood risk overall.

The WBC Local Plan policy TB09 states the following:

“The council will in principal support proposals which provide for the following types of accommodation to provide people’ need over a lifetime:

- *Extra care homes [...]*

Proposals that allow the elderly and those with disability to remain in their own homes or purpose-built accommodation.”

With reference to the first point, the Site will provide 14 no. extra-care units to ensure appropriate support is available to the elderly and therefore makes a significant contribution to the community, aligning with the WBC Local Plan Policy TB09. In addition, the proposed development will reduce the existing impermeable areas and the proposed drainage strategy will introduce a sustainable drainage system to improve the current surface water management and enhance the biodiversity and amenity values.

With reference to the second point, the redevelopments will include the residential apartments on the first floor. Based on the Hydraulic Modelling Study 2022, the proposed redevelopment is located outside the Hazard to People areas (Figure 5). The modelled flood level during the 1 in 100 years with 31% climate change in Building 2, where the proposed redevelopment is located, is below the existing floor level. The proposed development will ensure the residential area (more vulnerable) is situated above the estimated flood levels. A dry route of escape and safe access and egress will be provided above the estimated flood levels for occupants so that occupants can escape to a place of safe refuge. It is worth mentioning that only the proposed potential car park extension is located in Flood Zone 3. Car park areas are less sensitive and can be usually used to manage the exceedance flows. In addition, a Flood Warning and Evacuation Plan will be put in place. It is recommended that the Site signs up to receive Flood Alerts issued by the EA to aid with the early evaluation, helping to reduce the consequence of flooding by removing the receptor before flood waters from fluvial sources surround the Site. Any residual risk will be safely managed as part of the Flood Evacuation Plan.

Furthermore, the proposed redevelopment will not increase the impervious area at the Site. It will instead provide a reduction in the permeable area by replacing the vehicle access area with a new green courtyard and introducing Sustainable Urban Drainage Systems (SuDS) features. These will also improve biodiversity

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and sustainability at the Site. Additional measures outlined as part of the FRA and Outline Drainage Strategy (ODS) detailed below further demonstrate how the development satisfies the second point of the Exception Test.

OUTLINE DRAINAGE STRATEGY

The proposed drainage strategy at the Site is to include the following measures:

- The proposed drainage arrangement for the Site will comprise of appropriate SuDS system to deliver source control, water quality treatment and biodiversity enhancement and attenuation. The attenuation will be sized to hold the critical 1 in 100 year rainfall event plus 40% Climate change;
- Proposals for the application include the replacement of the existing impermeable driveway with a green courtyard. This will naturally provide a reduction of surface water runoff by increasing the permeability of the construction surfaces on the Site. This can be further developed at later design stages to be incorporated into the Sustainable Drainage System;
- A permeable paving system without infiltration will be proposed in the potential car park extension areas to manage surface water runoff close to its source and prevent groundwater contamination. The permeable paving cleans the surface water runoffs through filtration, absorption, biodegradation and sedimentation processes that occurs within the surface structure, subsurface matrix and geotextile layer. Overflow will be connected to the surface water drainage network.
- To ensure the effectiveness of the drainage strategy, a drainage maintenance schedule will be in place to ensure the future permeance of all the SuDS and drainage devices for its lifetime;
- Provision of additional flood protection design safety measures such as setting finished floor levels to provide established freeboard for the buildings above the flood levels; and
- Managing any residual risk by providing a safe access and escape route as detailed within an agreed Flood Evacuation Plan.

CONCLUSION

The above FRA & ODS report has been put together by WSP in support of the application for the erection of a three-storey extension to provide 14 no. extra-care units, following associated demolition works, along with the potential expansion of the car parking facilities.

All flood sources in the vicinity of the Site have been reviewed in line with the NPPF guidelines. The most significant source of flooding has been identified as fluvial flooding.

Based on the EA Flood Map for Planning, the building areas of the Site are located in Flood Zone 2 and the external areas of the Site are located in Flood Zone 3. However, according to the Hydraulic Modelling study 2022, the proposed redevelopment of the existing buildings is located outside the Hazard to People areas

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(Figure 5) and the modelled flood level during the 1 in 100 year with 31% climate change is lower than the existing floor levels, in all the areas where redevelopment are proposed.

The proposed redevelopment does not increase the building footprint and instead reduces the existing impervious area through the introduction of a new green courtyard. The proposed drainage strategy will introduce a sustainable drainage system to improve the current surface water management and enhance the biodiversity and amenity values. Because of this, the redevelopment will not increase the flood risk at the Site. Any residual risk will be mitigated by design measures introduced to ensure no impact on third-party land and vulnerable users are protected.

For the reasons mentioned above, the current flood risk at the Site will be mainly unaltered by the proposed development.

NEXT STEPS

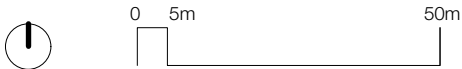
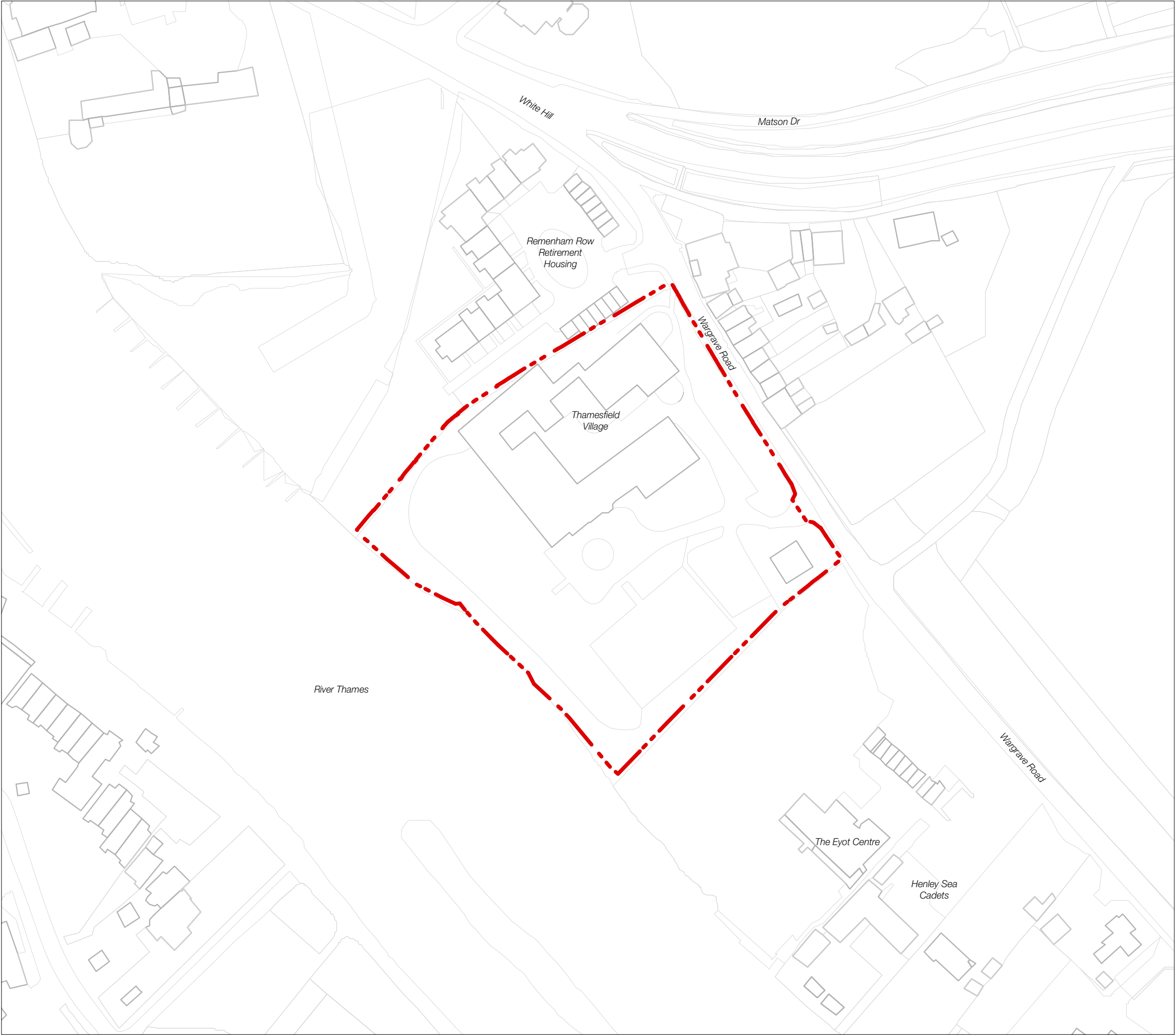
A detailed Flood Risk Assessment and Drainage Strategy should be devised for further assessment of the Site.



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APPENDIX A -SITE LOCATION PLAN



Notes

Do not scale for this drawing. Use written levels and dimensions only.

This drawing is to be read in conjunction with all other relevant documentation produced by Design Engine Architects Consultants and Sub-Contractors drawings, schedules and Specifications.

Key:

Site Boundary — · — · — ·

00	28/09/22	Preliminary Issue	TTr	RE
rev	date	notes	drawn	chkd

DESIGNENGINE
ARCHITECTS

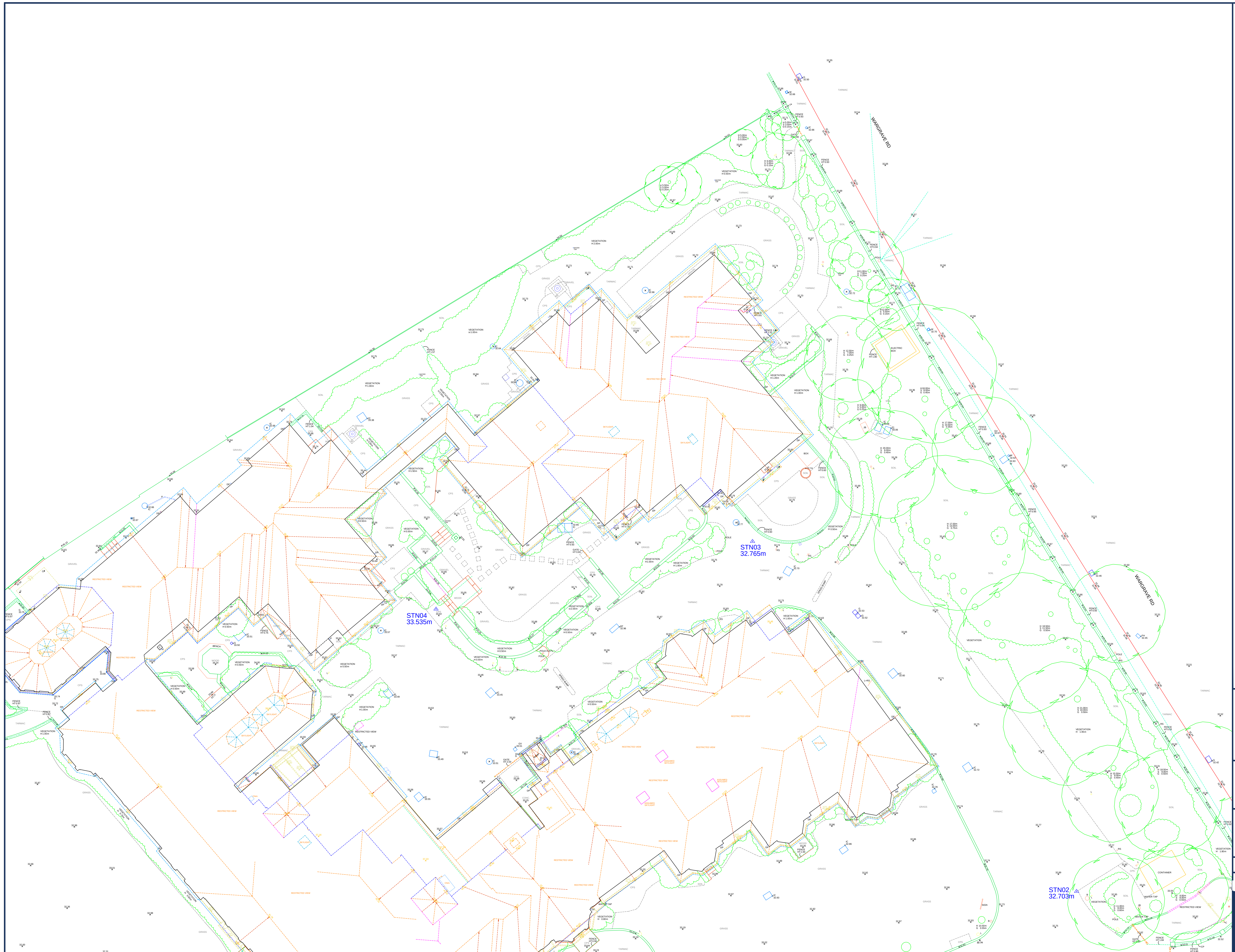
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client	drawing title	
u	Site Location Plan	
status	drawing reference	revision
PRELIMINARY	2212-001	00



Technical Note – Flood Risk Assessment and Outline Drainage Strategy

DATE:	12 October 2022	CONFIDENTIALITY:	Confidential
SUBJECT:	Technical Note – Flood Risk Assessment and Outline Drainage Strategy		
PROJECT:	70094722	AUTHOR:	KW
CHECKED:	QW	APPROVED:	TK

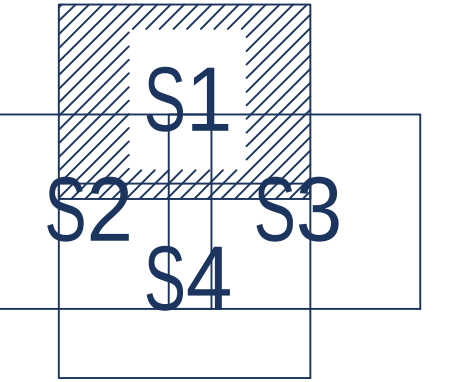
APPENDIX B – TOPOGRAPHICAL SURVEY AND ASSET MAP



Key		
A/C	Air Conditioning Unit	IC Inspection Cover
Bo	Boiler	JB Junction Box
BP	Brick paving	LP Lamp Post
BT	BT Inspection Cover	MH Man Hole Cover
CATV	Cable Television Inspection Cover	PO Post
CH	Coal Hole	PL Pavement Light
CK	Concrete Paving Slab	PO Post
DS	Dropped kerb	RF Ridge Level
DP	Down Pipe	S/O Smoke Outlet
EL	Electricity	SFC Surface Charge
FH	Fuel Hydrant	SV Stop Valve
G	Gully	T/CB Telephone Call Box
GS	Gate Post	TP Tactile Paving
ILS	Illuminated Road Sign	W Water Inspection Cover
IR	Illuminated Road Sign	WM Water Meter



Sheet Layout



Control Stations

TN01, 476580.281, 182423.656, 33.270
TN02, 476633.690, 182453.841, 32.703
TN03, 476606.079, 182483.662, 32.765
TN04, 476579.108, 182477.894, 33.535

Notes:

Survey location is related to Ordnance Survey Grid via GPS Observations.

All information contained in this drawing
(including digital data) should be checked and
verified prior to any fabrication or construction.

Project: Thamesfield Retirement Village
Wargrave Road
Henley-on-Thames
RG9 2LX

Title: Topographic Survey
Sheet 1

Drawn By: SB	Scale: 1:100	Date: June 2021
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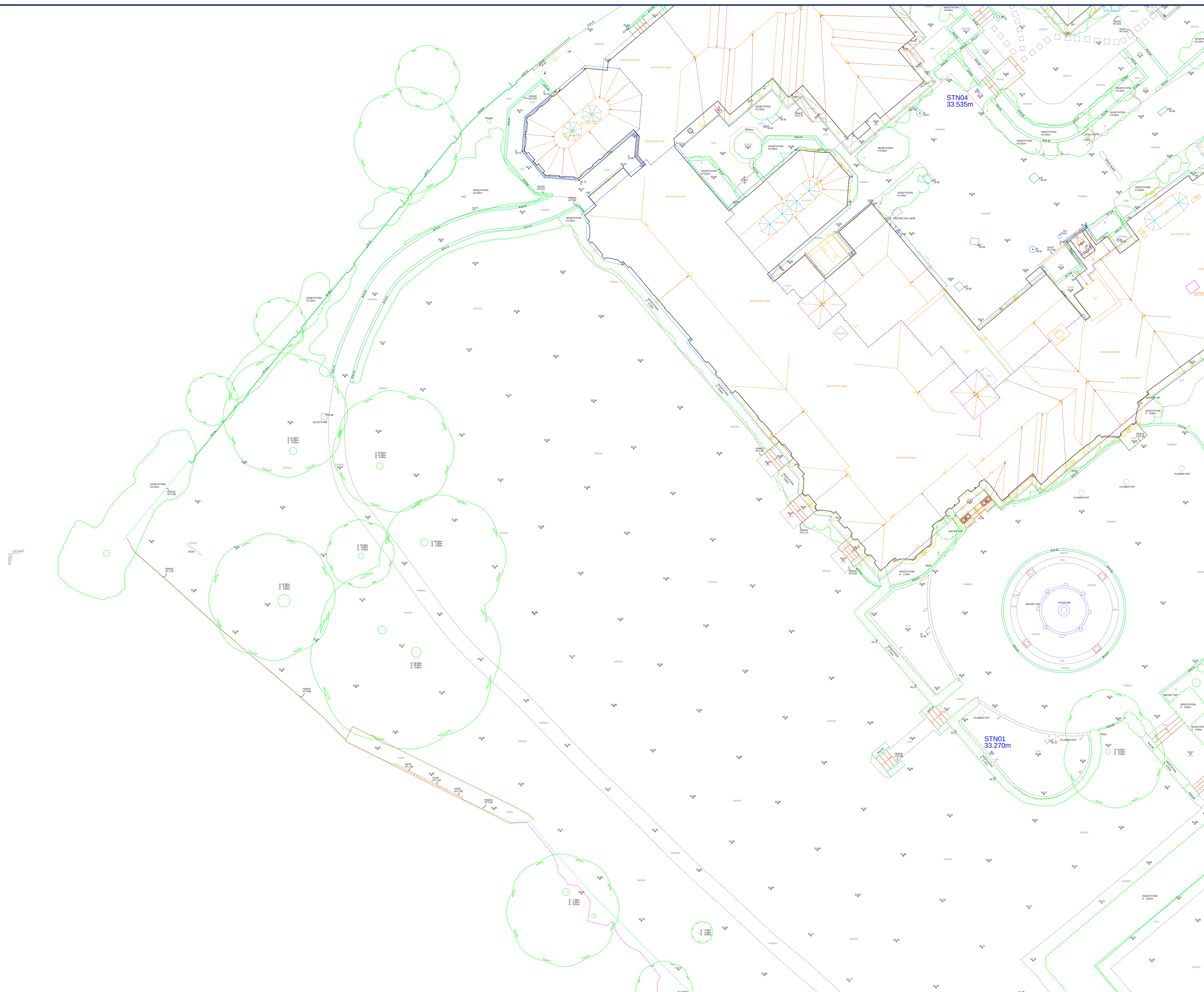
Dwg No: **LS2498/T**

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17 Slingsby Place
London
WC2E 9AB

0207 836 5828

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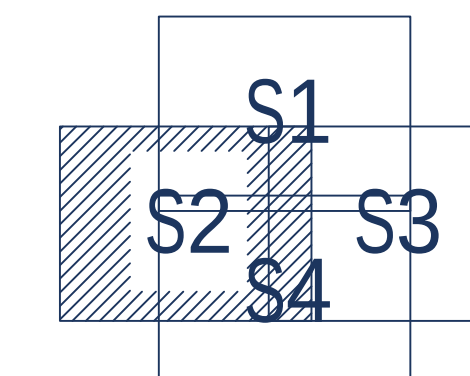
POINT



Key:		
A/C	Air Conditioning Unit	IC Inspection Cover
B	Bollard	JB Junction Box
BP	Bike parking	LP Lamp Post
BT	BT Inspection Cover	MH Man Hole Cover
CATV	Cable Television Inspection Cover	PI Post Inspection Box
CH	Chute	PL Pavement Light
CPS	Concrete Paving Slab	PO Pot
DK	Drainage	R Ridge Line
DP	Down Pipe	S/O Smoke Outlet
EL	Elbows Level	SRFC Stop Valve
FI	Fire Hydrant	T Stop Valve
ILB	Illegal	TCL Telephone Call Box
GL	Gate Post	TP Traffic Paving
IB	Insulated Bollard	W Water Inspection Cover
IRS	Illuminated Road Sign	WM Water Meter



Sheet Layout



Control Stations

STN01, 476580.281, 182423.656, 33.270
STN02, 476633.690, 182453.841, 32.703
STN03, 476606.079, 182483.662, 32.765
STN04, 476579.108, 182477.894, 33.535

Notes:

Notes:

- Levels are related to Ordnance Survey Datum via GPS Observations.
- Survey location is related to Ordnance Survey Grid via GPS Observations.

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Project: Thamesfield Retirement Village
Wargrave Road
Henley-on-Thames
RG9 2LX

Title: Topographic Survey
Sheet 2

Drawn By:

Scale: 1:100

Date: June 2021

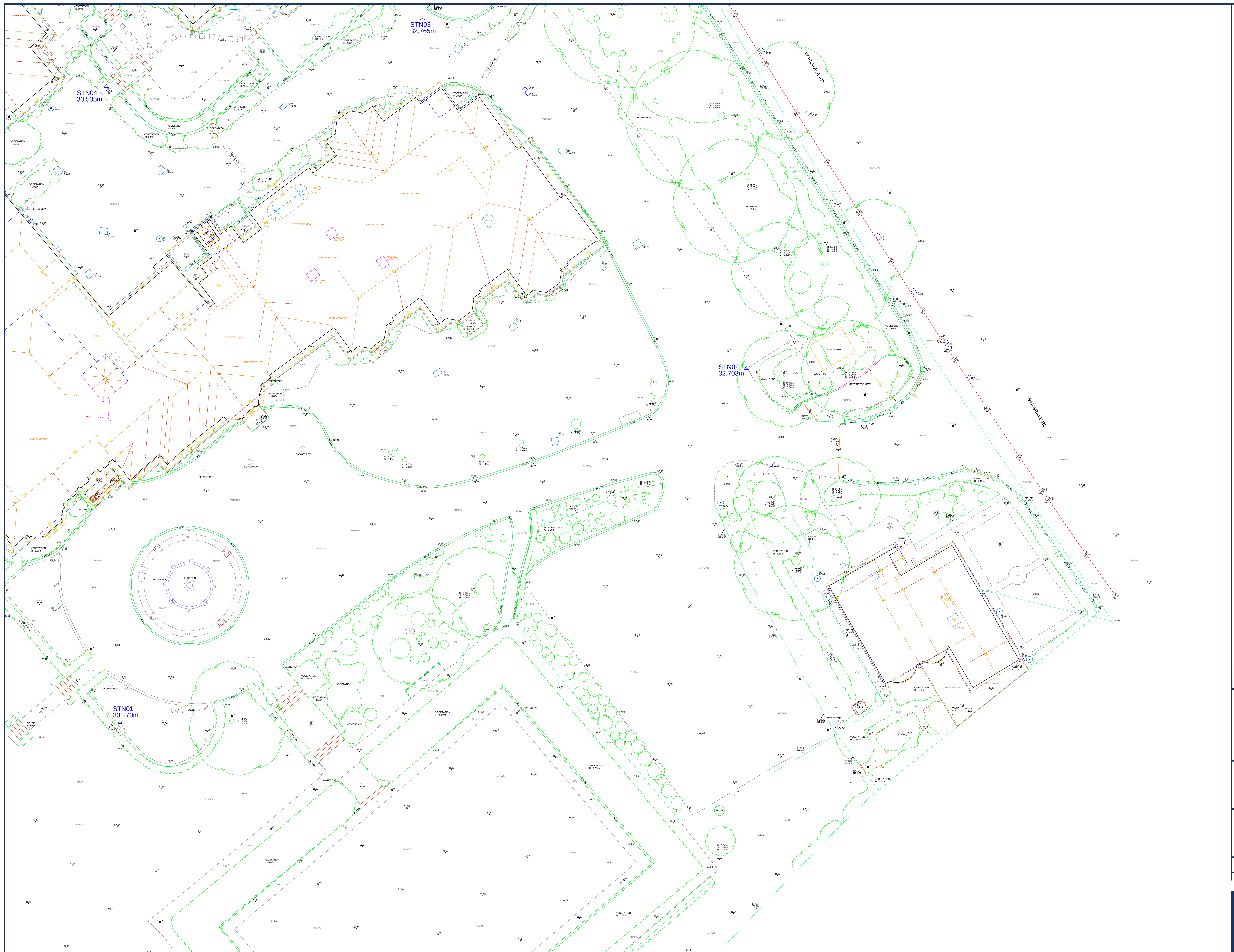
Dwg No: LS2498/T

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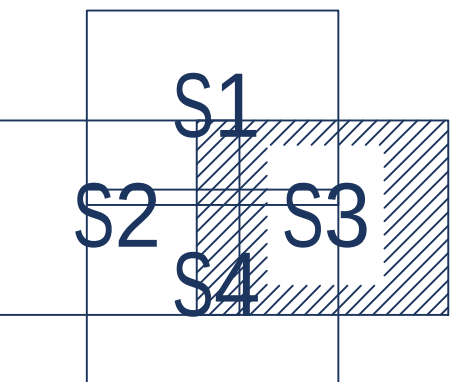




Key:			
A/C	Air Conditioning Unit	IC	Inspection Cover
B	Boillard	JB	Junction Box
BP	Brick Paving	LP	Lamp Post
BT	Brick Television Cover	MB	Man Hole Cover
CAV	Cable Television Inspection Cover	PH	Post Box
CH	Coal Hole	PL	Pavement Light
CS	Concrete Paving Slab	PO	Post
CKS	Dropped Kerb	RL	Ridge Level
DE	Down Pipe	SFO	Smoke Outlet
EL	Eaves Level	SFC	Surface Change
FH	Fire Hydrant	SV	Stop Valve
G	Gully	TCP	Telephone Call Box
GP	Gate Post	TB	Tactile Paving
ILB	Illuminated Boillard	WM	Water Inspection Cover
ILS	Illuminated Road Sign	WM	Water Meter



Sheet Layout



Control Stations

STN01, 476580.281, 182423.656, 33.270
STN02, 476633.690, 182453.841, 32.703
STN03, 476606.079, 182483.662, 32.765
STN04, 476579.108, 182477.894, 33.535

Notes:

Survey location is related to Ordnance Survey Grid via GPS Observations.

All information contained in this drawing
(including digital data) should be checked and
verified prior to any fabrication or construction.

Project: Thamesfield Retirement Village
Wargrave Road
Henley-on-Thames
RG9 2LX

Title: Topographic Survey
Sheet 3

Drawn By: SP

No:

Scale: 1:100

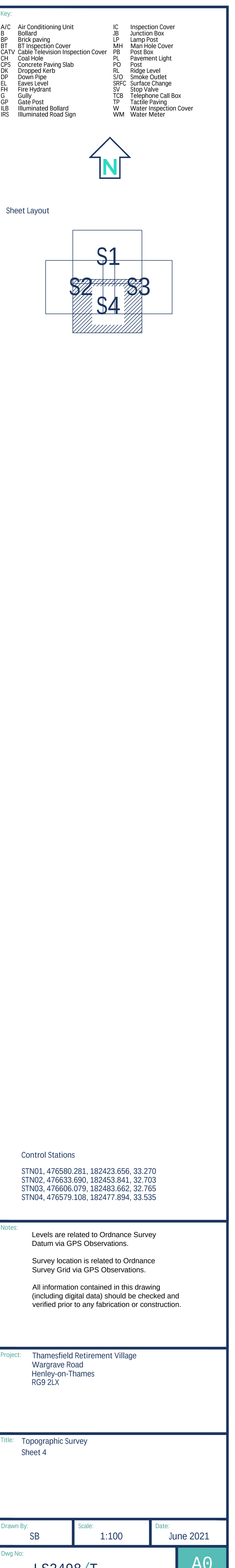
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Date: June 2021

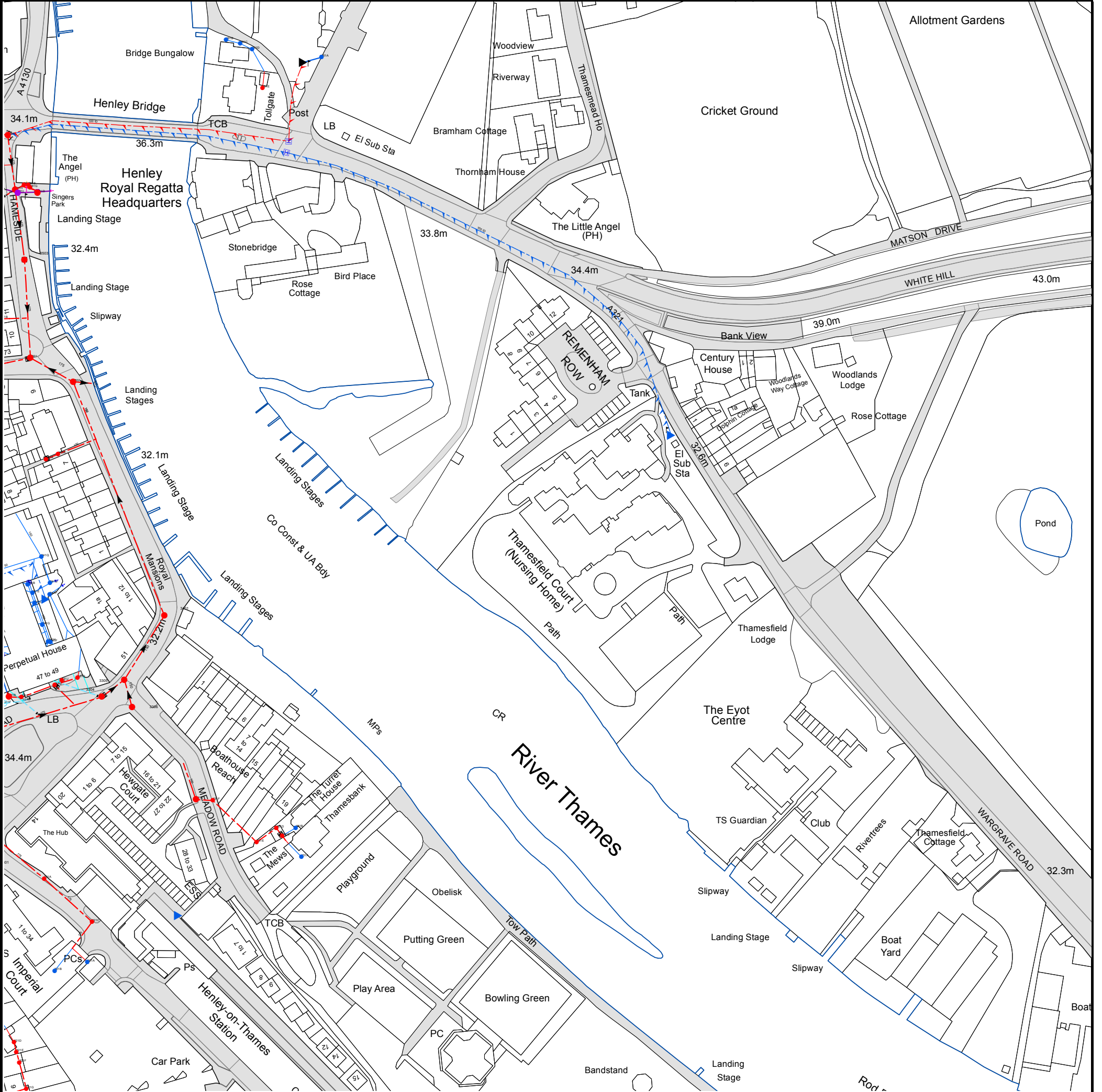
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Asset Location Search Sewer Map - ALS/ALS Standard/2021_4517652



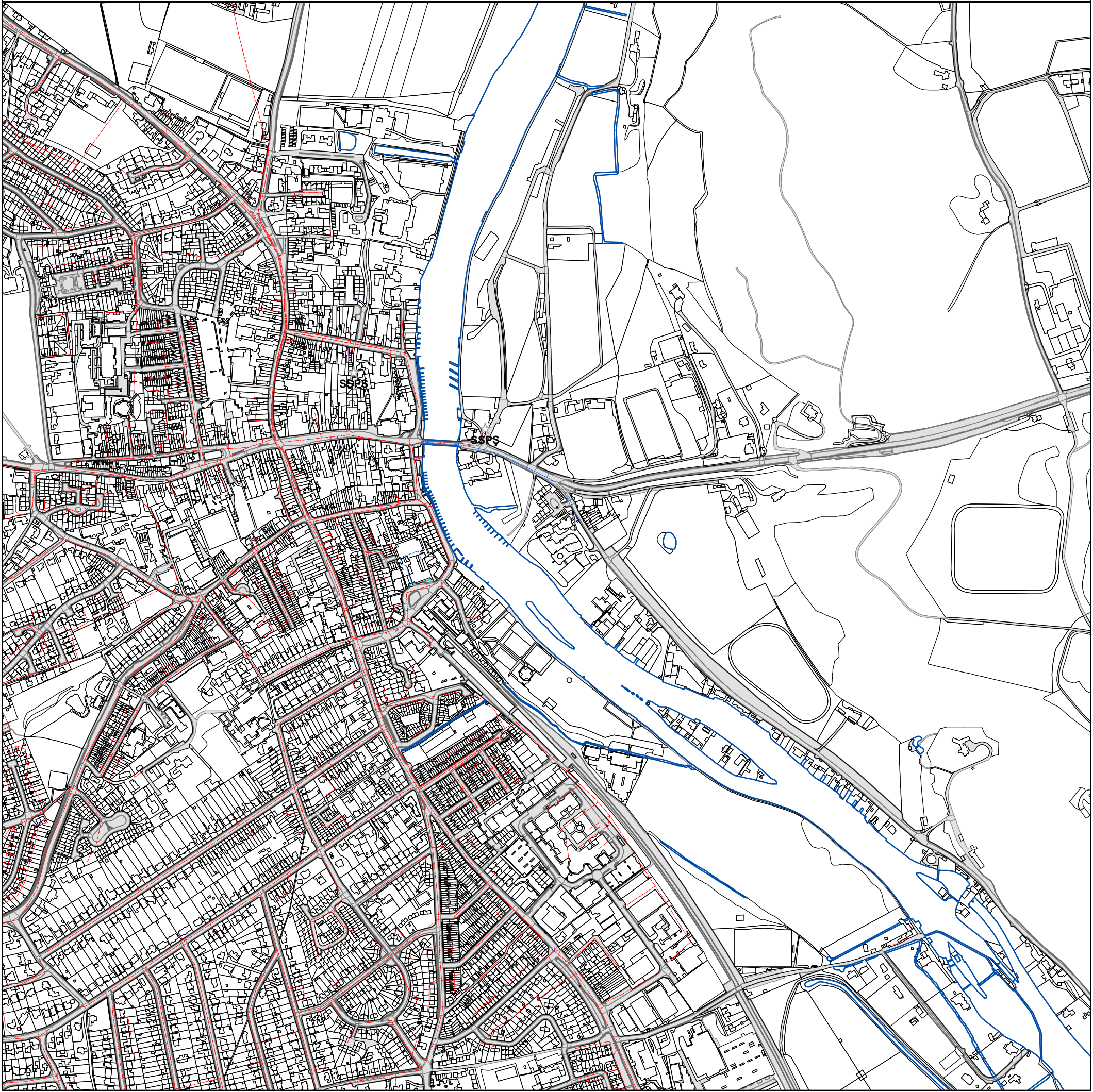
The width of the displayed area is 500 m and the centre of the map is located at OS coordinates 476561,182453

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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
3601	34.1	31.72
361H	32.71	31.46
361I	n/a	n/a
361F	32.42	31.8
3503	32.43	31.06
361E	32.31	31.72
361G	n/a	n/a
3501	32.55	30.41
361D	31.97	29.4
341A	n/a	n/a
331B	n/a	n/a
341B	32.17	31.67
341E	32.17	31.03
341C	32.17	31.33
341Q	n/a	n/a
341G	32.17	31.47
331F	n/a	n/a
331C	n/a	n/a
331H	n/a	n/a
331A	n/a	n/a
341H	n/a	31.47
341P	n/a	31.53
341D	34.1	30.6
341F	32.17	31.35
331E	n/a	n/a
341R	n/a	n/a
331I	n/a	n/a
331J	n/a	n/a
3502	32.33	30.46
331D	n/a	n/a
321A	n/a	n/a
321C	n/a	n/a
3304	32.91	31.4
3305	32.73	31.33
3306	32.64	31.6
3401	32.2	31.2
331K	n/a	n/a
431F	n/a	n/a
461B	n/a	n/a
461C	n/a	n/a
461D	n/a	n/a
431E	n/a	n/a
461E	n/a	n/a
431D	n/a	n/a
431C	n/a	n/a
431B	n/a	n/a
431A	n/a	n/a
461A	n/a	n/a
321B	n/a	n/a
321D	n/a	n/a
321E	n/a	n/a
321F	n/a	n/a
321G	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.		



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Scale: 1:7161
Width: 2000m
Printed By: Rveldhur
Print Date: 06/10/2021
Map Centre: 476560,182453
Grid Reference: SU7682SE

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

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 'D' on a manhole level indicates that data is unavailable.

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		Gully
	Culverted Watercourse		Proposed
			Abandoned Sewer

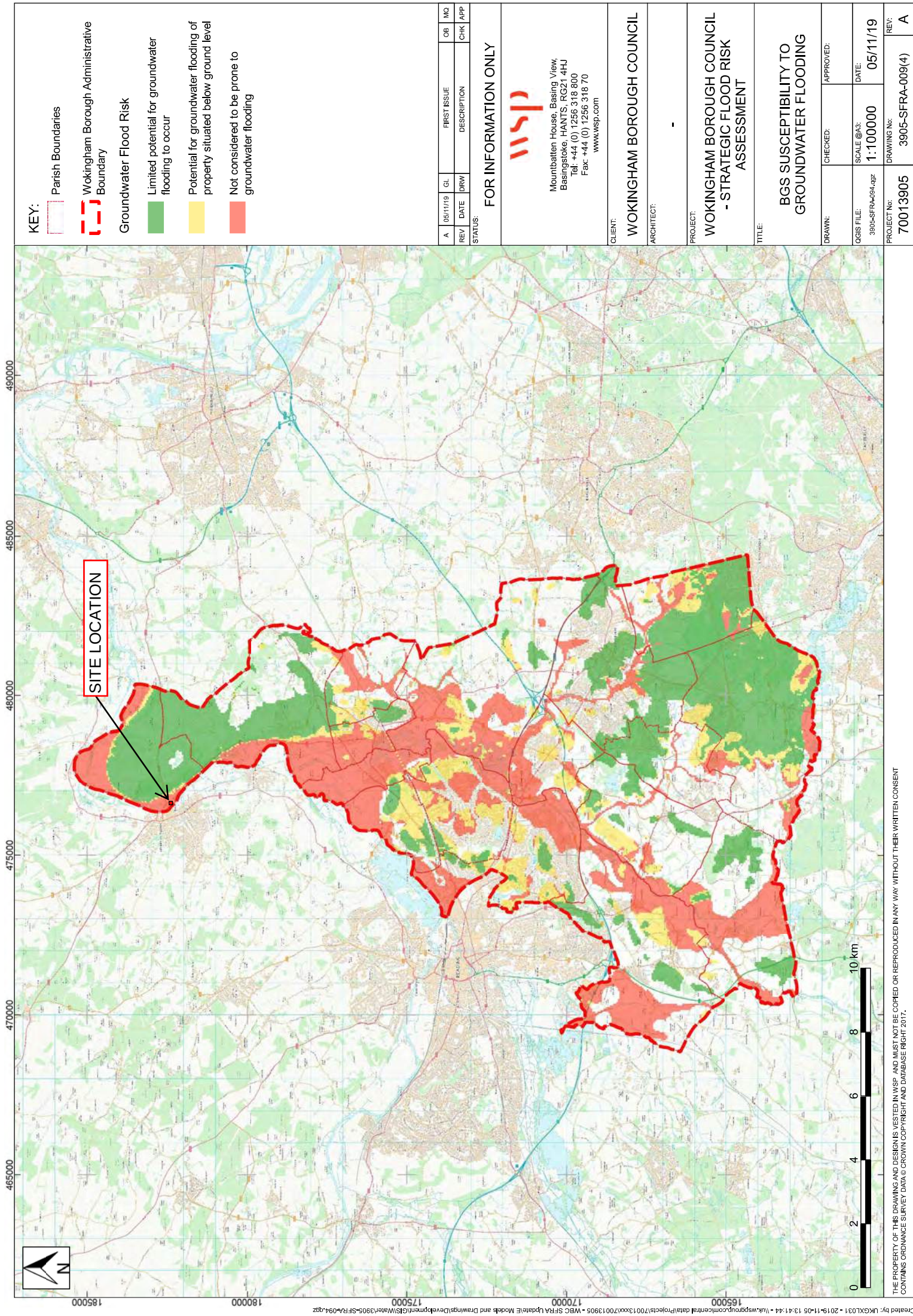
- 6) The text appearing alongside a sewer line indicates the internal diameter of the pipe in millimetres. Text next to a manhole indicates the manhole reference number and should not be taken as a measurement. If you are unsure about any text or symbology present on the plan, please contact a member of Property Searches on 0800 009 4540.



Technical Note – Flood Risk Assessment and Outline Drainage Strategy

DATE:	12 October 2022	CONFIDENTIALITY:	Confidential
SUBJECT:	Technical Note – Flood Risk Assessment and Outline Drainage Strategy		
PROJECT:	70094722	AUTHOR:	KW
CHECKED:	QW	APPROVED:	TK

APPENDIX C – FLOOD MAPPING



KEY:

- Parish Boundaries
- Wokingham Borough Administrative Boundary
- Groundwater Flood Risk
 - Limited potential for groundwater flooding to occur
 - Potential for groundwater flooding of property situated below ground level
 - Not considered to be prone to groundwater flooding

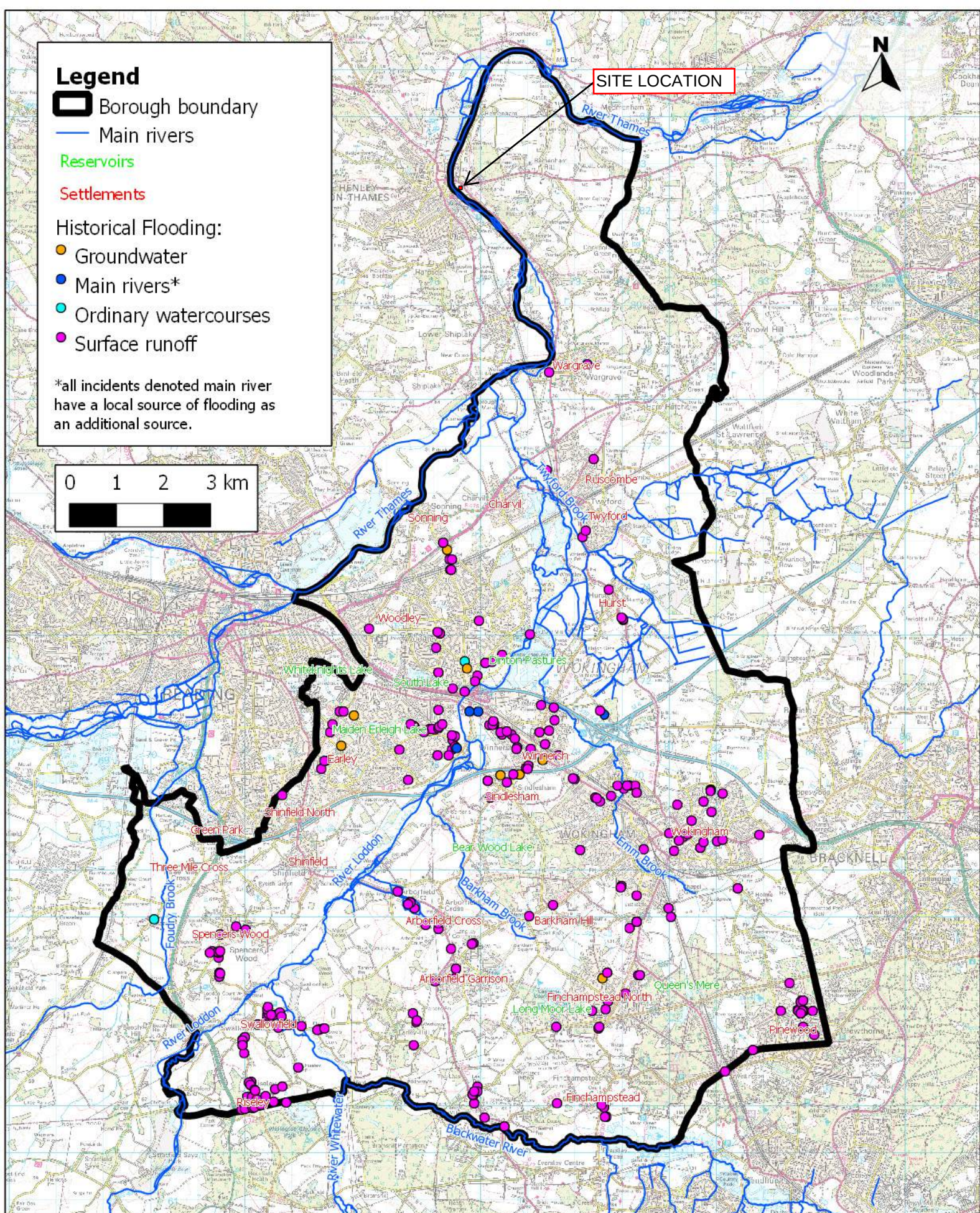
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A		05/11/19							
STATUS:									

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CLIENT:	WOKINGHAM BOROUGH COUNCIL								
ARCHITECT:	-								
PROJECT:	WOKINGHAM BOROUGH COUNCIL - STRATEGIC FLOOD RISK ASSESSMENT								
TITLE:	BGS SUSCEPTIBILITY TO GROUNDWATER FLOODING								
DRAWN:	CHECKED:	APPROVED:							
OSIS FILE:	SCALE @A3:	DATE:							
3905-SFRA-094-qbz	1:100000	05/11/19							
PROJECT No:	DRAWING No:	REV:							
70013905	3905-SFRA-009(4)	A							



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Wokingham Preliminary Flood Risk Assessment

Figure 5-1: Historical flooding incidents from local sources of flooding

Drawn by: AS
Checked by: BV

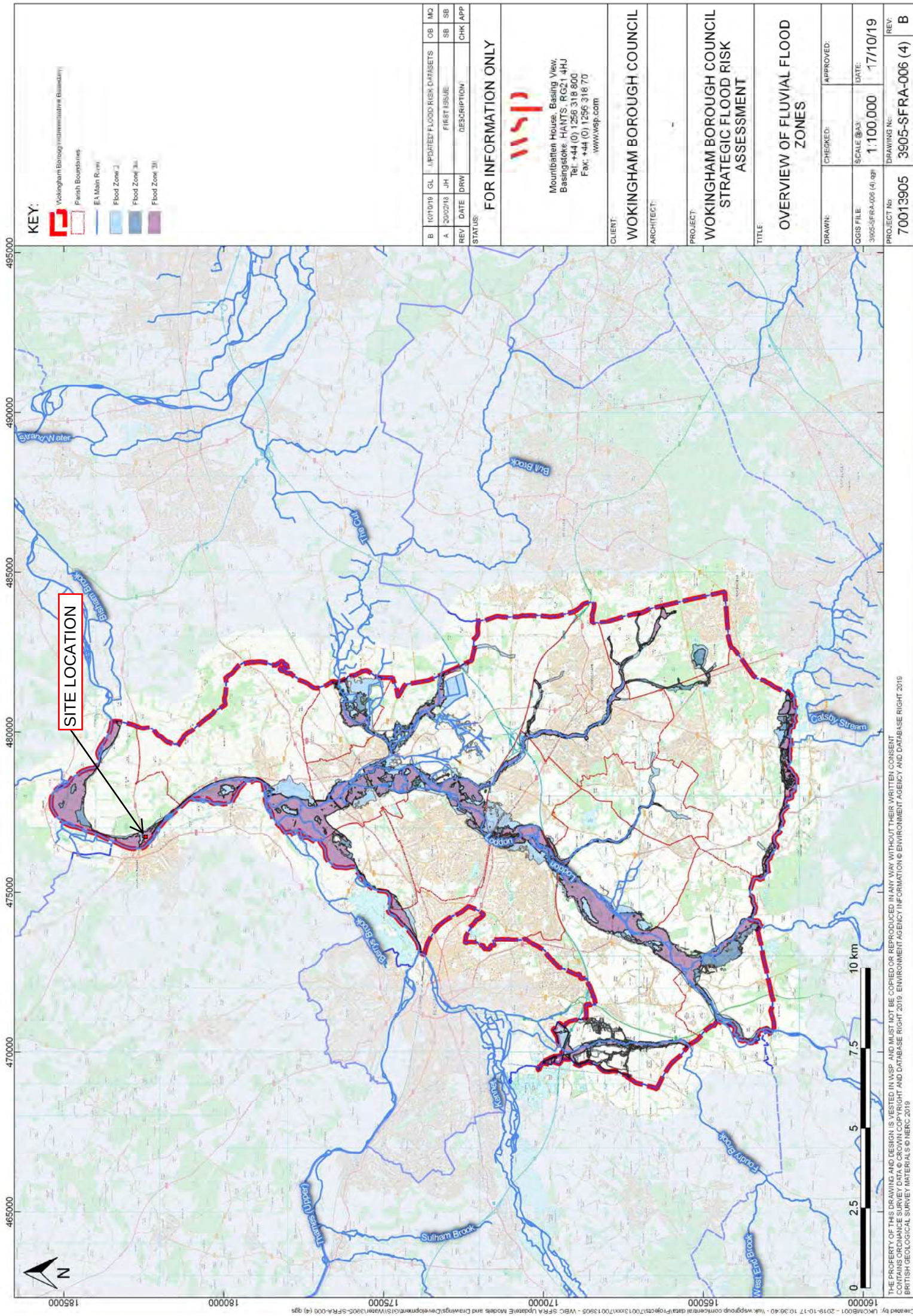
Revision: 3
Date: 10/06/11



Wokingham Borough Council
Civic Offices
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Wokingham RG40 1BN



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West Sussex RH10 1DQ
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Technical Note – Flood Risk Assessment and Outline Drainage Strategy

DATE:	12 October 2022	CONFIDENTIALITY:	Confidential
SUBJECT:	Technical Note – Flood Risk Assessment and Outline Drainage Strategy		
PROJECT:	70094722	AUTHOR:	KW
CHECKED:	QW	APPROVED:	TK

APPENDIX D HYDRAULIC MODELLING STUDY

Hydraulic Modelling Study at Thamesfield, Wargrave Road, Henley-On-Thames

Draft report

May 2022

www.jbaconsulting.com



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JBA Project Manager

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UNITED KINGDOM
B46 3AD

Revision History

Revision Ref/Date	Amendments	Issued to
S03-P01 / May 2022	Draft Report	Caroline Keiller (RV Services Limited)

Contract

JBA were contacted on 8/12/2021 by Niall Greenan of WSP on behalf of RV Services Limited to commission this report. This report describes work commissioned by RV Services Limited. RV Services Limited representative for the contract was Caroline Keiller. Emelie Persson and Olivier Saillofest of JBA Consulting carried out this work.

Prepared by Emelie Persson BSc PgCert

Assistant Analyst

Reviewed by Olivier Saillofest BEng MSc CEng MCIWEM
C.WEM

Technical Director

Purpose

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Executive summary

JBA Consulting were commissioned by RV Services Limited to undertake a fluvial water hydraulic modelling study at Thamesfield, Wargrave Road, Henley-On-Thames.

The proposed development located off Wargrave Road, Henley-On-Thames. The surrounding area is a mix of residential and greenfield land. The site is located adjacent to the River Thames (which flows in a northerly direction southwest of the site).

To assess the risk of fluvial flooding at the site, a license has been obtained from the Environment Agency (EA) to re-use the existing 1D-2D Thames Mapledurham to Hurley hydraulic model (2019) of the River Thames. The existing model has been re-run with an updated version of Flood Modeller – TUFLOW, site-specific topographic survey data and cross-sectional data of Henley Bridge.

The model has been run for the baseline scenario for 20-year, 100-year, 100-year with 31% climate change and 1,000-year events in order to determine the existing fluvial flood risk to the site.

In line with the new guidance on Climate Change issued by the Environment Agency in July 2021¹, the effect of climate change was assessed by increasing 100-year peak flows by 31% for the fluvial model (higher central climate change allowance for essential infrastructure developments within the Thames and Chilterns South management catchment).

Results from the hydraulic model were tested for their sensitivity to changes in Manning's roughness, downstream boundary conditions, and flows. A blockage risk scenario was undertaken for Henley Bridge during the 100-year with climate change flood event. Results from the sensitivity analysis indicate that the model results within the site are relatively insensitive to changes in roughness, downstream boundary or changed flow conditions.

Results from the updated model runs show that:

- Water enters the site from overtopping of the River Thames from all of the modelled 20-year, 100-year, 100-year +31% CC and 100-year fluvial flood events, as illustrated in Figure 0-1.
- The peak flood depth predicted within the site during the 100-year with 31% climate change event is 1.89m.
- During the 100-year with 31% climate change event, peak water levels are predicted exceed the existing flood levels in 2 off the existing buildings within the site boundary.
- During the 100-year with 31% climate change scenario the majority of the site falls 'low' to 'significant' hazard categories on the Defra Hazard to People map.
- The blockage risk analysis undertaken at Henley Bridge (node 32.078BU) during the 100-year with climate change flood event indicates that when a 25% blockage is applied, a significant increase in maximum flood depths of up to 0.77m is predicted within the site.

¹ <https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances>



Figure 0-1: Baseline fluvial flood extents

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Abbreviations

1D	One Dimensional
2D	Two Dimensional
CC	Climate Change
DTM	Digital Terrain Model
EA	Environment Agency
ESTRY	Primary 1D engine used by TUFLOW
FEH	Flood Estimation Handbook
FFL	Finished Floor Levels
GCS	Grantham Coates Surveyors
Ha	Hectares
HQ	Head-Flow
JBA	Jeremy Benn Associates
LiDAR	Light Detection and Ranging
m AOD	Metres Above Ordnance Datum
QT	Flow-Time
ReFH	Revitalised Flood Hydrograph
RoFSW	Risk of Flooding from Surface Water
TUFLOW	2D Hydraulic Modelling Software

1 Introduction

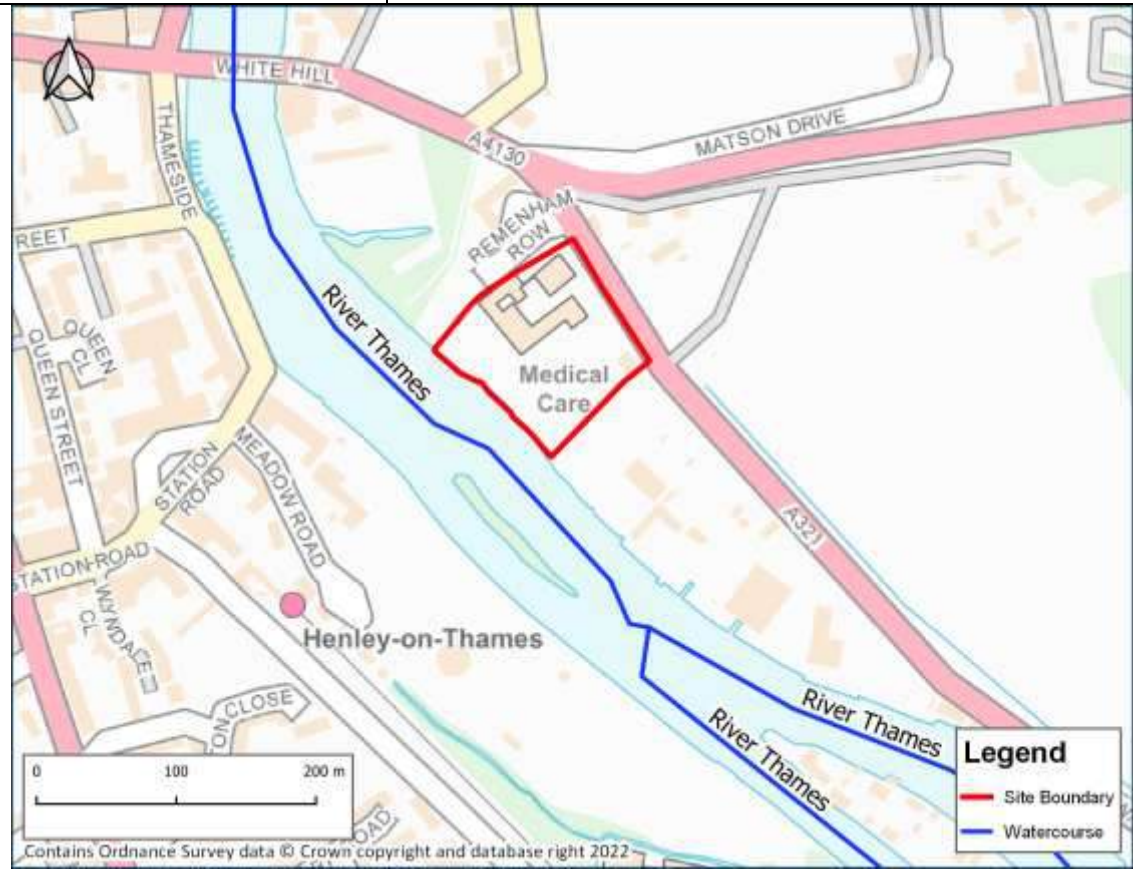
1.1 Terms of reference

JBA Consulting (JBA) were commissioned by RV Services Limited to undertake a fluvial hydraulic modelling study at Thamesfield, Wargrave Road, Henley-On-Thames.

To support this assessment, the 2019 Thames Mapledurham to Hurley 1D-2D hydraulic model was re-used and re-run with the latest versions of Flood Modeller – TUFLOW and with inclusion of new site-specific topographic survey data to allow accurate representation of the fluvial flood levels, extents and hazards within the site boundary.

1.2 Site details

Table 1-1: Site details	
Site name	Thamesfield, Wargrave Road, Henley-On-Thames, RG9 2LX
Site area	1.24ha
Existing land-use	Residential (retirement living accommodations)
OS NGR	SU765824
County	Oxfordshire
Country	England



1.3 Site description

The proposed development site is located off Wargrave Road, Henley-On-Thames. The surrounding area is a mix of residential and greenfield land. The site is currently occupied by an existing retirement village with 35 apartments and a 12-bed care home. The proposal is looking at potential redevelopment opportunities for the site to deliver additional homes and improved facilities.

The River Thames is located immediately adjacent to the site and flows in a northerly direction.

1.4 Existing flood data

It is understood that the Environment Agency's fluvial flood zones currently represents the best source of flood risk information in relation to the site.

To refine flood risk in relation to the site, JBA Consulting was commissioned to carry out an updated version of the detailed fluvial hydraulic modelling study in relation to the proposed development site.

1.5 General approach

The existing 1D-2D Thames Mapledurham to Hurley Hydraulic model was obtained from the EA and re-used as part of this project.

The existing model has been updated with new survey data of Henley Bridge and the flood relief culverts located approximately 100 m east of the bridge / 120m northwest of the site. The model is using LiDAR data from the Defra website (flown in 2018 with a 1m grid resolution) and site topographic survey data collected in June 2021 by Point 2 Surveyors Limited, provided in Appendix A.

Given the age of the latest EA model update, flow estimates are deemed representative of current conditions and thus do not need updating. The model has been run for the baseline defended scenario for the 20-year, 100-year, 100-year with 31% climate change and 1000-year flood events in order to determine the existing flood risk to the site.

1.6 Limitations

The 1D-2D Thames Mapledurham uses a 2D grid cell size of 20m within the site area. Given the model run times (i.e. between 1 day and 20hrs) and the prominent location of the site in the Thames floodplain, no attempts were made to refine the model grid cell size. Where results show partial flooding of a building in the model, a comparison of the modelled peak water level with the building floor level was carried and, when relevant, the building was filtered away from the mapped flood extent.

2 Model build phase

2.1 Model geometry

2.1.1 Data availability

The LiDAR used to represent the ground levels within the floodplain has a grid resolution 1m and was last flown in 2018.

Site topographic survey collected by Point 2 Surveyors Limited in June 2021 was provided by the client and used to represent ground levels within the site (see Appendix A). Survey of Henley bridge and the 6 flood relief culverts located approximately 100 m east of the bridge was collected by Grantham Coates Surveys Ltd in March 2022 (see Appendix B).

2.1.2 Model extent and build

2.1.2.1 Fluvial model

To understand fluvial flood risk to the site, the 1D-2D Mapledurham to Hurley 2019 model was obtained from the Environment Agency and re-used as part of this study. The hydraulic model represents the River Thames, and the floodplain in the vicinity of the proposed site. The extent of the fluvial model developed for this study is shown in Figure 2-1.

The channels were represented as 1-dimensional (1D) features using Flood Modeller (version 4.6.0). The 1D model begins approximately 24.6km upstream of the proposed development site and the model extends approximately 7.3km downstream of the site.

The 2D domain was represented using TUFLOW (2020-01-AB-iSP-w64) with floodplain topography represented using LiDAR data. The 2D domain for the fluvial model has an area of 8.27km² and a 5m grid resolution.

The orientation of the grid is southeast to northwest, representing the main direction of floodplain flows. The 1D and 2D domains can be seen in Figure 2-1.

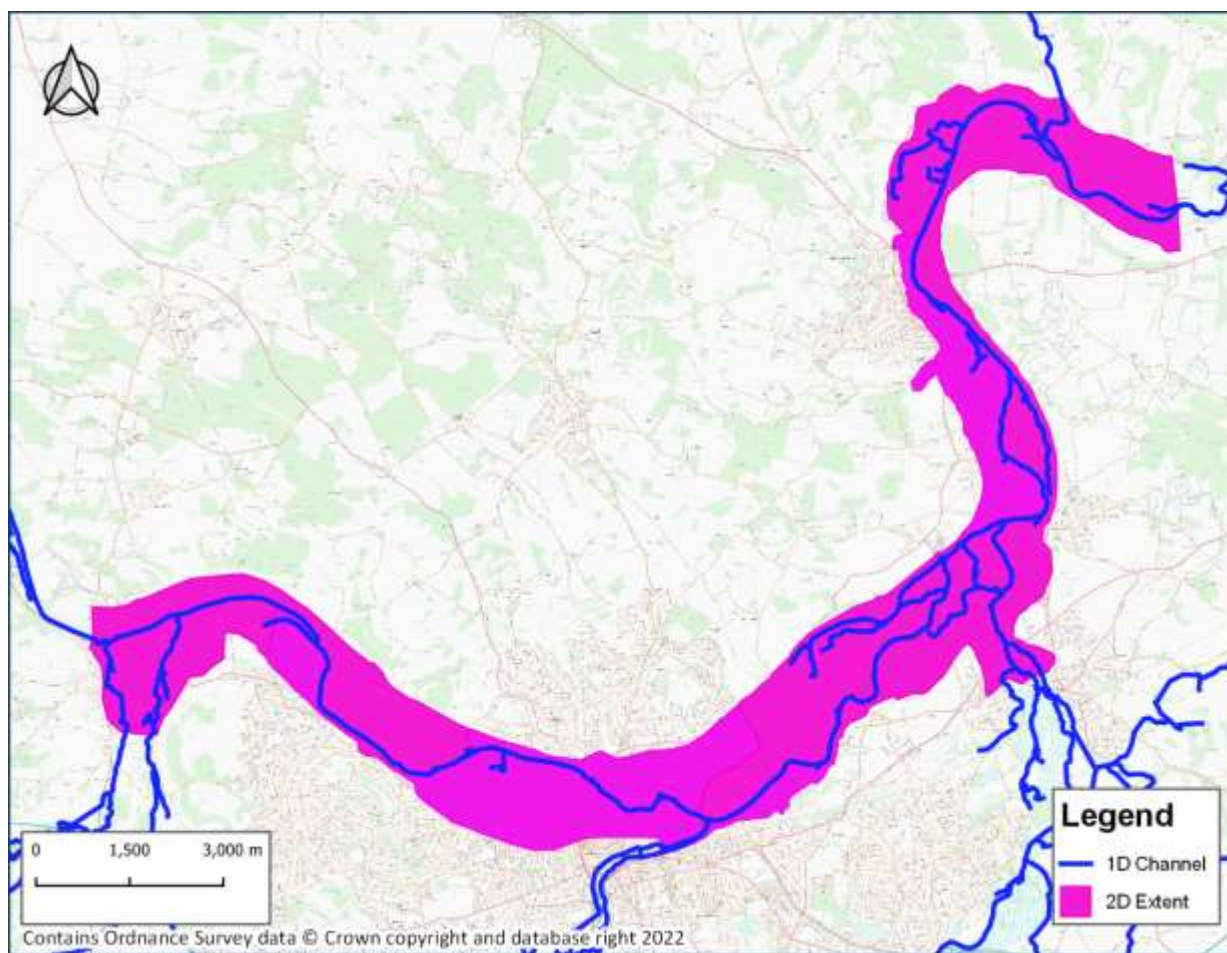


Figure 2-1: Model extent

2.1.3 Model roughness parameters

Manning's n values from the 2019 Thames Mapledurham to Hurley model was re-used to represent roughness values for the channel and floodplain. Table 2-1 gives the range of Manning's n values used in the 1D and 2D domains.

Table 2-1: Manning's n range within the hydraulic model	
1D Channel	0.025 – 0.05 (in channel) 0.075 (banks)
Buildings	0.300
General surface	0.050 – 0.060
Glasshouse	0.200
Inland water	0.045
Landform	0.060
Boulders	0.065
Trees	0.012 – 0.060
Rail	0.045
Roads	0.035

2.2 Model boundary conditions

2.2.1 Model inflows

Flow estimates from 2019 Thames to Mapledurham to Hurley hydraulic model was updated in line with the new guidance on Climate Change issued by the Environment Agency in July 2021², the effect of climate change was assessed by increasing 100-year peak flows by 31% for the model (higher central climate change allowance for essential infrastructure developments within the Thames and Chilterns South management catchment).

2.2.2 Downstream boundary conditions

The original downstream boundary conditions used in the 2019 Thames to Mapledurham to Hurley hydraulic model was kept in this study. *A rating curve extracted from the Lower Thames modelling was used to derive boundary conditions the model. This characterises the flow vs stage relationship upstream of Hurley Lock for both the channel and the floodplain. The downstream boundary condition was informed by plotting stage vs discharge pairings for the rising limb from each of the design events simulated for the Lower Thames flood risk modelling (20%, 10%, 5%, 3.33%, 4%, 2%, 1.33%, 1%, 0.5% and 0.1% AEP events). Given the close proximity of the downstream boundary location to the Lower Thames model inflow (at Hambleden Lock) the flow data informing the stage vs discharge pairings is based on the Lower Thames model inflow to remove complexity of extracting 1D channel and 2D floodplain flows from the Lower Thames model³.*

² <https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances>

³ JBA Consulting for Environment Agency. Thames Mapledurham – Final Model Report (v2 Mar 2019)

2.3 Calibration

The 2019 Thames Mapledurham to Hurley hydraulic model was calibrated to historic flood events. As a result, new calibration has not been carried out on the model results, however sensitivity testing has been carried out to provide confidence in the model parameters, see Appendix C.

2.4 Model Runs

2.4.1 Modelled scenarios

The following flood scenarios were simulated by the model:

Baseline scenarios

- 20-year (5% AEP) fluvial flood event;
- 100-year (1% AEP) fluvial flood event;
- 100-year (1% AEP) plus Climate Change (31%) fluvial flood event;
- 1000-year (0.1% AEP) fluvial flood event.

Blockage scenario

- 100-year (1% AEP) plus Climate Change (31%) fluvial flood event – Henley Bridge (32.078BU) downstream of the site blocked by 25%.

Sensitivity analysis

- 100-year (1% AEP) flood event with +20% increase in peak flows;
- 100-year (1% AEP) flood event with +20% increase in roughness value;
- 100-year (1% AEP) flood event with -20% decrease in roughness value;
- 100-year (1% AEP) flood event with +250mm increase in peak water level at the downstream model boundary.

The results of the baseline and blockage scenarios are discussed in the following section with sensitivity analysis included in Appendix C of this report.

3 Hydraulic model results

3.1 Baseline flood extents

Flood extents for the 20-year, 100-year and 1,000-year fluvial flood events are shown in Figure 3-1.



Figure 3-1: Baseline flood extents (20-year, 100-year and 1,000-year)

Figure 3-1 shows that the capacity of the River Thames is exceeded during all of the modelled events and flooding occurs on the site for all of the three modelled events. Flood extent for the 100-year with (+31%) climate change is represented in Figure 3-2.

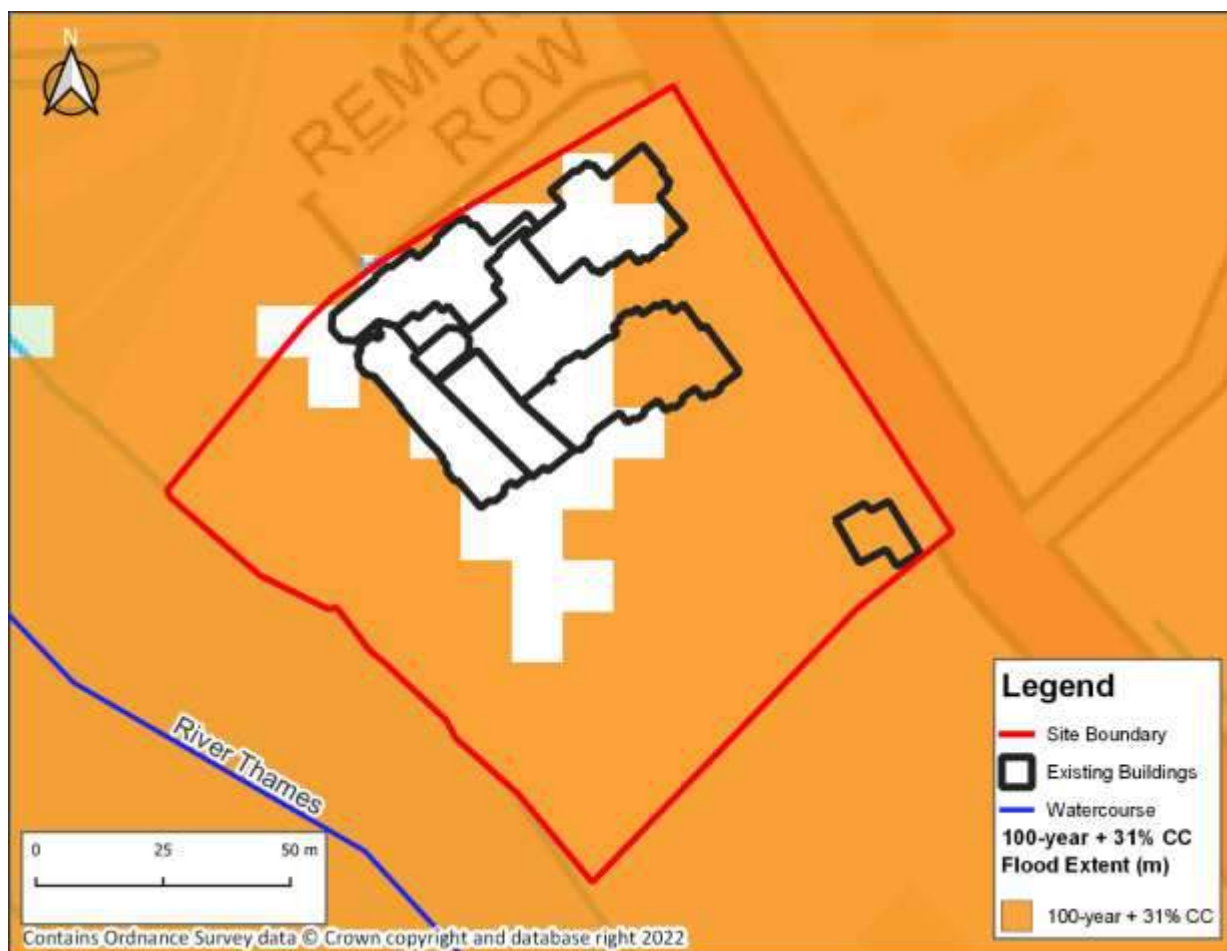


Figure 3-2: Baseline 100-Year flood extents with 31% climate change scenario

Figure 3-2 shows that the extent of flooding during the 100-year with 31% climate change scenario.

3.2 Baseline flood depths

The baseline flood depths during the 100-year with 31% climate change event in the vicinity of the site are shown in Figure 3-3.

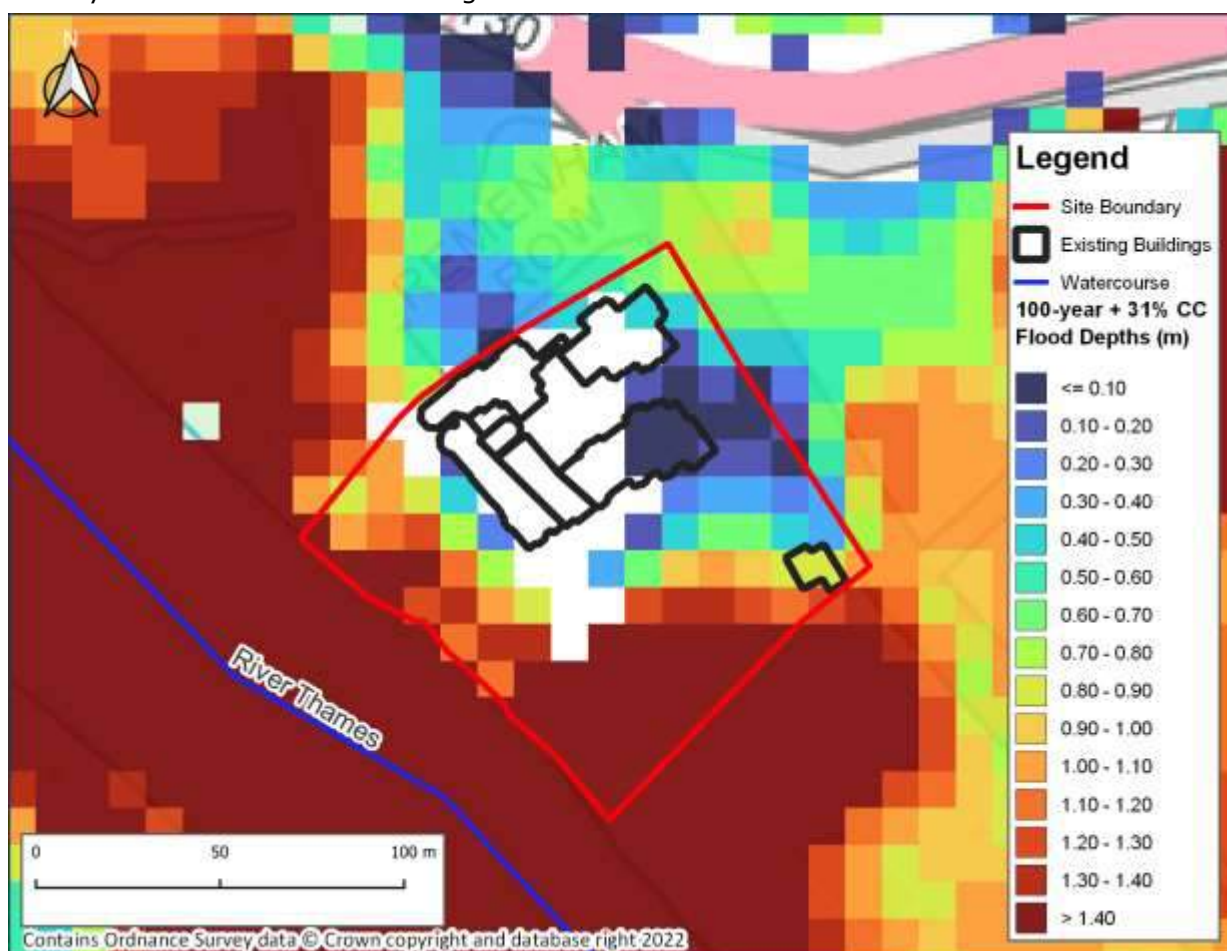


Figure 3-3: Baseline 100-year flood depths with 31% climate change scenario

Figure 3-3 shows the maximum predicted flood depths within the site during the 100-year with 31% climate change event. An approximate maximum depth of 1.89m is predicted within the southern part of the site.

3.3 Baseline flood levels

The baseline flood levels during the 100-year with 31% climate change return period are shown within Figure 3-4 below.

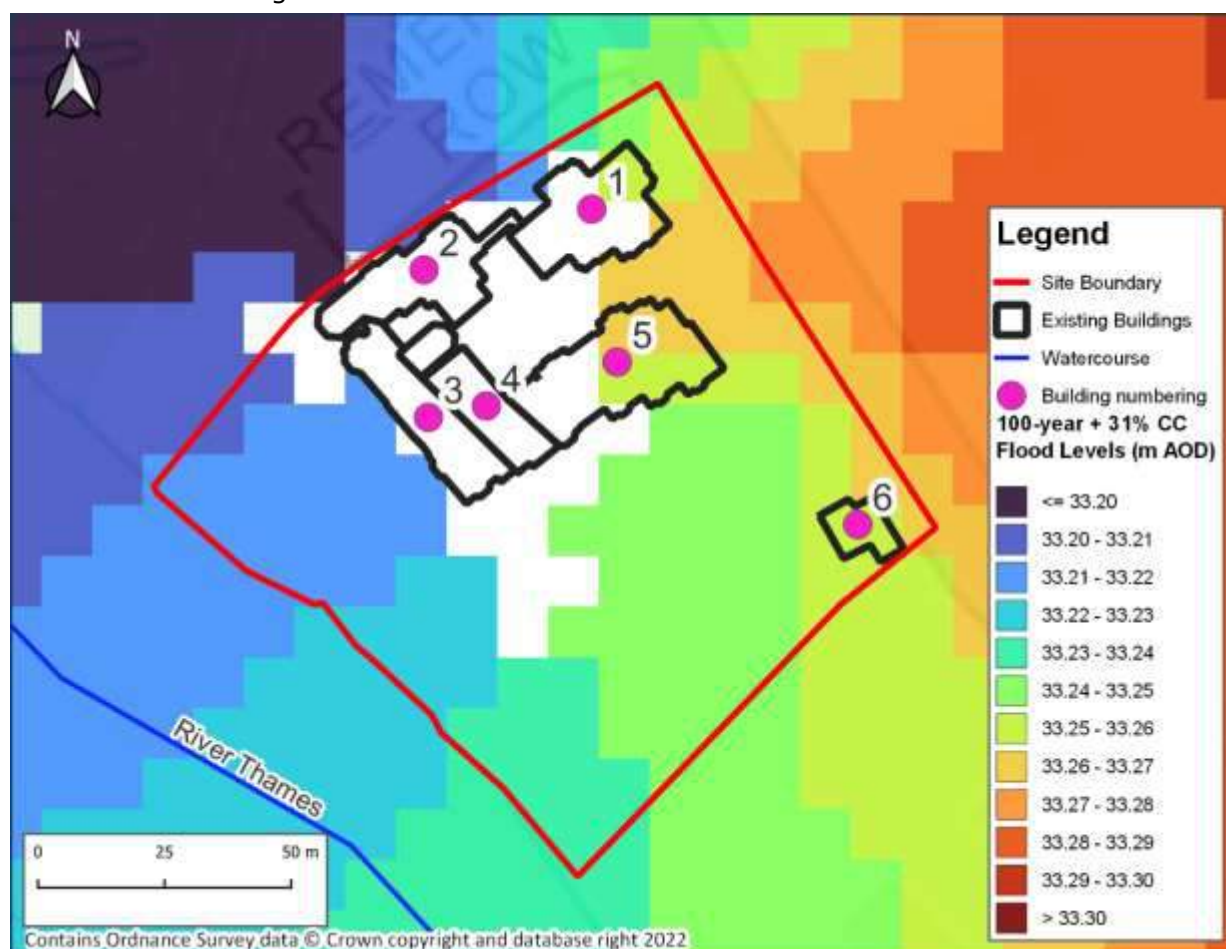


Figure 3-4: Baseline 100-year water levels with 31% climate change scenario

Figure 3-4 shows peak water levels during the 100-year with 31% climate change event. Peak water levels related to each existing building are displayed in Table 3-1.

Building	Existing floor levels (m AOD)*	Peak water levels within existing building (m AOD)
1	33.26	33.27
2	33.83	33.20
3	33.84	33.22
4	33.48	No flooding
5	33.26	33.26
6	32.60	33.26

**: Estimated from Point 2 Surveyors Limited topographic survey dated June 2021*

Table 3-1 shows that, during the 100-year with 31% climate change event, peak water levels are expected to exceed the existing floor levels for building 1 by 0.01m and by 0.66m for building 6.

3.4 Blockage risk analysis

Given the site's location in relation to Henley Bridge, a blockage risk analysis was undertaken. Figure 3-5 shows the location of the node 32.078BU in the model, where a 25% blockage was considered.

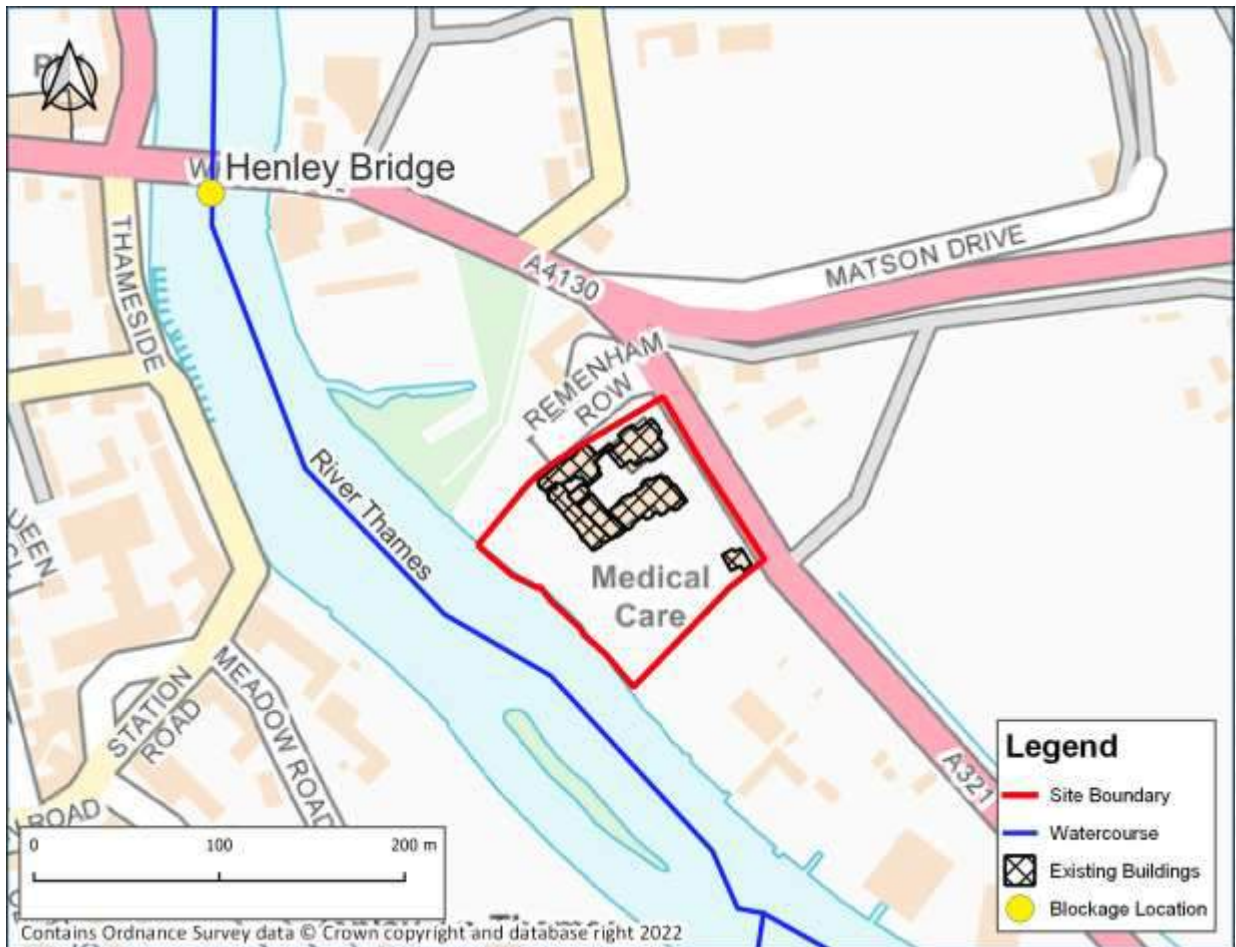


Figure 3-5: Baseline Blockage Risk Analysis location

Figure 3-6: Baseline Blockage Analysis (100-year + 31% climate change) shows the peak flood elevation during 100-year plus 31% climate change flood event when a 25% blockage is applied to Henley Bridge (node 32.078BU).



Figure 3-6: Baseline Blockage Analysis (100-year + 31% climate change)

When compared with Figure 3-4, Figure 3-6 shows that a 25% blockage at Henley Bridge during a 100-year plus 31% climate change flood event will generate an increase of up to 0.77m (approximately) in flood level at the site.

3.5 Hazard-to-people classification

The fluvial hazard-to-people rating during a 100-year with (31%) climate change flood scenario has been mapped using the formula as suggested in Defra's FD2321/TR2 "Flood Risk to People". The different hazard categories are shown in Table 3-2 and the hazard classification to the site during the 100-year with (31%) climate change scenario is shown in Figure 3-7.

Table 3-2: Defra's FD2321/TR2 "Flood Risks to People" classifications

Flood hazard rating depth (velocity+0.5) + DF	Level of Flood Hazard Description	Class label
<0.75	Low	Caution "Flood zone with shallow flowing water or deep standing water"
0.75 to 1.25	Moderate	Dangerous for some (i.e. Children) "Danger: flood zone with deep or fast flowing water"
1.25 to 2.00	Significant	Dangerous for most "Danger: flood zone with deep fast flowing water"
>2.00	Extreme	Dangerous for all "Extreme danger: flood zone with deep fast flowing water"

Using the hazard equation $HR = d \cdot (v + 0.5) + DF$
Where d = depth of flooding (m) v = velocity of floodwaters (m/sec) DF = debris factor

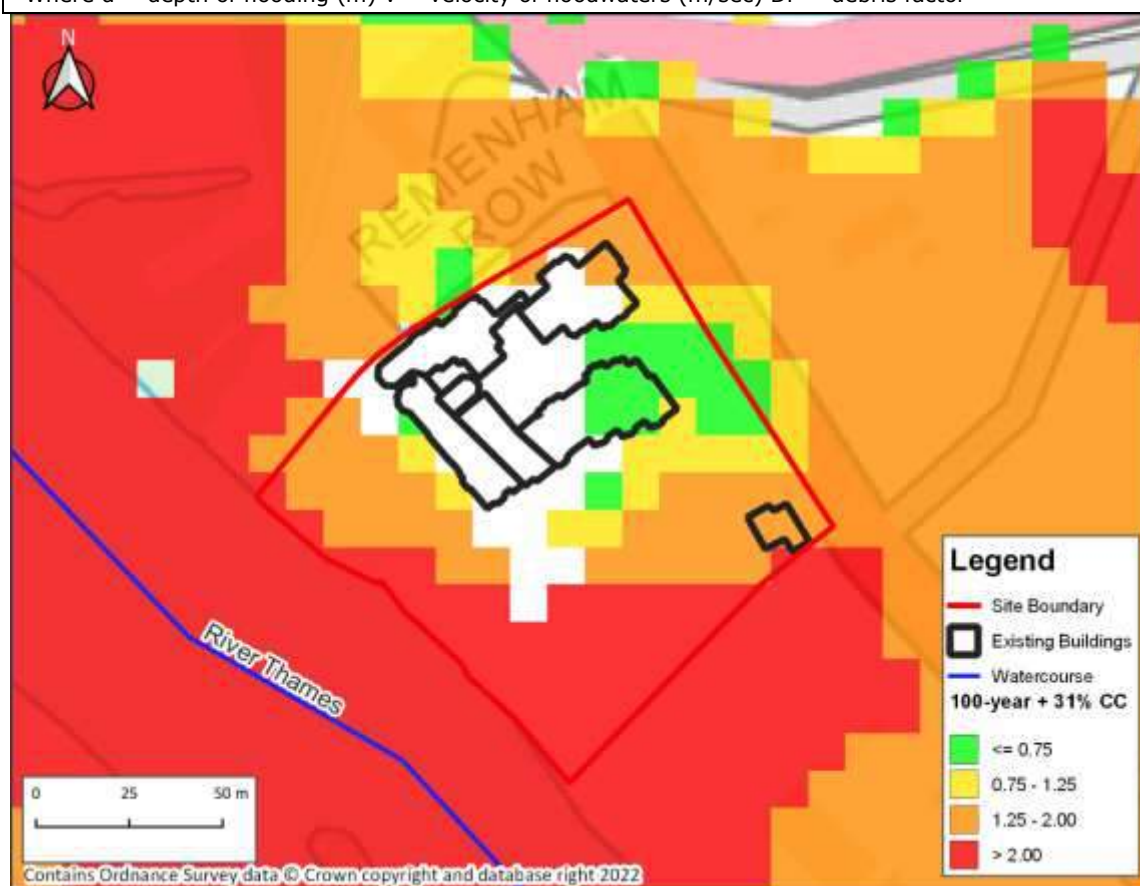


Figure 3-7: Baseline Hazard to People

Figure 3-7: Baseline Hazard to People shows that the Hazard to People rating for the majority of the site and along the A321 (which runs alongside the north-eastern site boundary) fall within the 'low' to 'significant' hazard categories.

4 Conclusions and Recommendations

- JBA Consulting were commissioned by RV Services Limited to undertake a fluvial water hydraulic modelling study at Thamesfield, Wargrave Road, Henley-On-Thames.
- The model has been run for the baseline scenario for 20-year, 100-year, 100-year with 31% climate change and 1,000-year events in order to determine the existing fluvial flood risk to the site.
- Results from the hydraulic model were tested for their sensitivity to changes in Manning's roughness, downstream boundary conditions, and flows. A blockage risk scenario was undertaken for Henley Bridge during the 100-year with climate change flood event. Results from the sensitivity analysis indicate that the model results within the site are relatively insensitive to changes in roughness, downstream boundary or changed flow conditions.
- Results from the updated model runs show that:
 - Water enters the site from overtopping of the River Thames from all of the modelled 20-year, 100-year, 100-year +31% CC and 100-year fluvial flood events, as illustrated in Figure 0-1.
 - The peak flood depth predicted within the site during the 100-year with 31% climate change event is 1.89m.
 - During the 100-year with 31% climate change event, peak water levels are predicted exceed the existing flood levels in 2 off the existing buildings within the site boundary.
 - During the 100-year with 31% climate change scenario the majority of the site falls 'low' to 'significant' hazard categories on the Defra Hazard to People map.
 - The blockage risk analysis undertaken at Henley Bridge (node 32.078BU) during the 100-year with climate change flood event indicates that when a 25% blockage is applied, a significant increase in maximum flood depths of up to 0.77m is predicted within the site.

Appendices

A Appendix A – Site topographic survey

B Appendix B – Survey of Henley Bridge

C Appendix C – Sensitivity analysis

The hydraulic model was tested for sensitivity to key model parameters which might impact flood risk at the proposed development site. This included the following scenarios:

- Increasing flows by 20%
- Increasing the Manning's n values by 20%. This both in the Flood Modeller 1D channel and in the 2D TUFLOW domain.
- Increasing the downstream boundary water levels by 250mm

The following sections discuss the impacts of these sensitivity scenarios.

C.1 Sensitivity to flow

Figure E-4-1 shows the changes in peak water level compared to the baseline 100-year event when an increase of 20% is applied to all inflows.

Figure E-4-1: Sensitivity analysis for +20% inflows



Figure E-4-1 indicates there that there are minimal changes in the peak water level results when increasing the flow with 20%. As a result, the model is considered to be insensitive to increases in flow.

C.2 Sensitivity to roughness

Figure E-4-2 shows the changes in peak water level compared to the baseline 100-year event when a change of +20% is applied Manning's 'n' in both the 1D and 2D domains.

Figure E-4-2: Sensitivity to changes of +20% in roughness



Figure E-4-2 indicates that, the model is relatively insensitive to the roughness values applied to the 1D and 2D domains within the site boundary, with minor changes in the peak flood extents predicted to occur within the south-eastern edge of the site boundary when roughness is increased by +20%.

C.3 Sensitivity to downstream boundary conditions

Figure E-4-3 shows the changes in peak water levels compared to the baseline 100-year event when an increase of 250mm in water level is applied to the downstream model boundary condition.

Figure E-4-3: Sensitivity analysis for +250mm in water level at downstream boundary

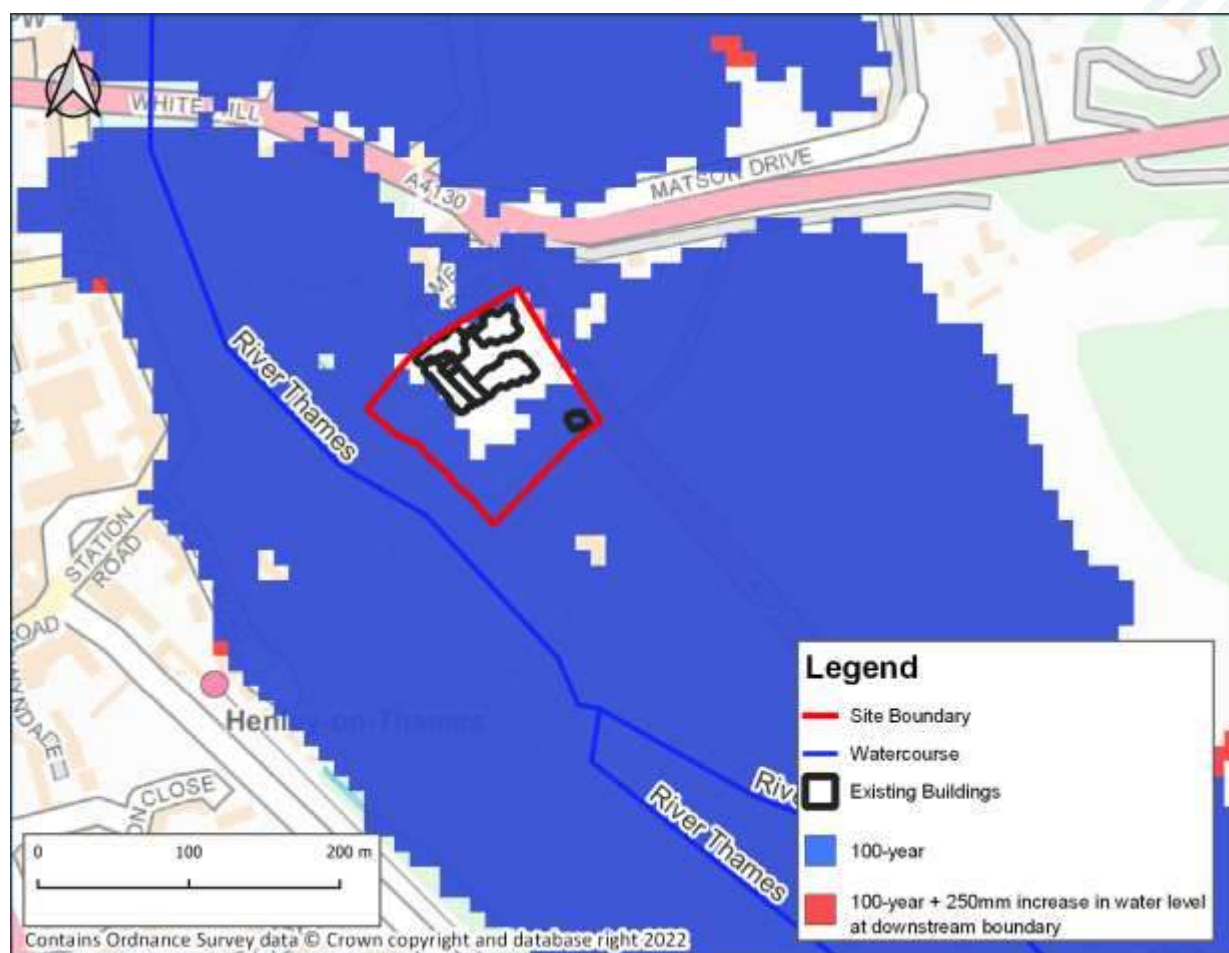


Figure E-4-3 indicates that minimal change can be seen due to the increase in water level at the downstream boundary. As a result, the model is insensitive to changes in downstream boundary condition within the site.

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B Flood Warning and Evacuation Plan (WSP)



RETIREMENT VILLAGES

THAMESFIELD

FLOOD WARNING AND EVACUATION PLAN





RETIREMENT VILLAGES

THAMESFIELD

FLOOD WARNING AND EVACUATION PLAN

TYPE OF DOCUMENT (VERSION) PUBLIC

PROJECT NO. 70089182

OUR REF. NO. TRV-WSP-RP-001

DATE: JULY 2022

RETIREMENT VILLAGES

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QUALITY CONTROL

Issue/revision	First issue	Revision 1	Revision 2	Revision 3
Remarks	Draft Issue	Final Issue		
Date	24/06/2022	13/07/2022		
Prepared by	Kyra Wilson	Kyra Wilson		
Signature	<i>Kwilson</i>	<i>Kwilson</i>		
Checked by	Qianqian Wu	Qianqian Wu		
Signature	<i>Qianqian Wu</i>	<i>Qianqian Wu</i>		
Authorised by	Niall Greenan	Niall Greenan		
Signature	Greenan, Niall (UKNTG001) Digitally signed by Greenan, Niall (UKNTG001) DN: cn=Greenan, Niall (UKNTG001), ou=Active, email=Niall.Greenan@wsp.com Date: 2022.07.05 08:37:41 +01'00'			
Project number	70089182			
Report number	TRV-WSP-RP-001			
File reference	\\Uk.wspgroup.com\central data\Projects\70089xxx\70089182 - Thamesfield Retirement Village\03 WIP\EI EIA and Flood Risk\05 Reports\FWEP			

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APPENDICES

APPENDIX A

COMMUNITY & PERSONAL FLOOD PLAN TEMPLATES

APPENDIX B

FLOOD EVACUATION ROUTE



EXECUTIVE SUMMARY

This Flood Warning and Evacuation Plan (FWEP) was commissioned by Retirement Villages for the existing independent living residents at Thamesfield Villages, Henley-On-Thames, RG9 2LX. This FWEP outlines the flood risk associated with the Site alongside the measures and procedures to be followed in the event of a Flood Warning and necessary evacuation.

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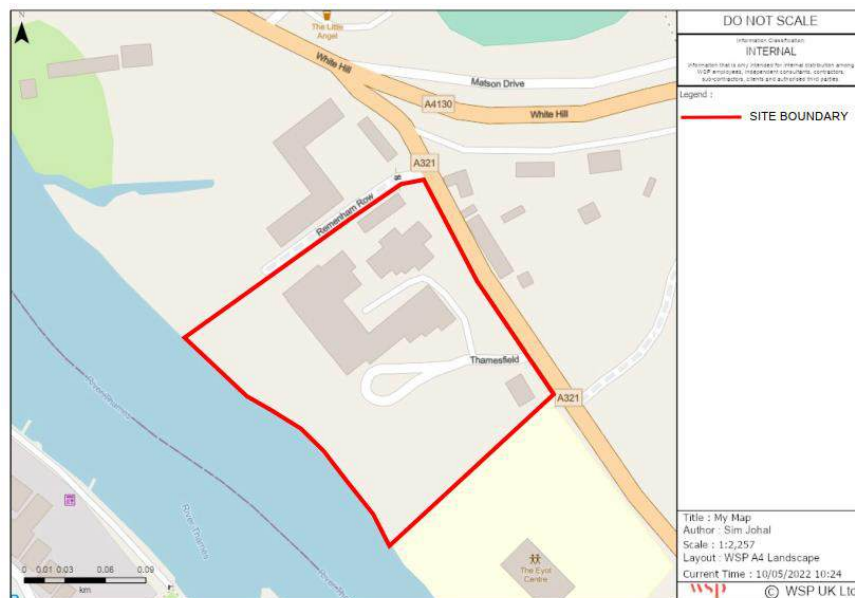
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1. INTRODUCTION, SCOPE & OBJECTIVES

1.1. OVERVIEW

- 1.1.1. This Flood Warning and Evacuation Plan (FWEP) has been prepared by WSP to advise residents of the Thamesfield Village on awareness and preparation for a flood event so that they can evacuate from the site safely.
- 1.1.2. Thamesfield Village is located on Wargrave Road, Henley-on-Thames, RG9 2LX within Wokingham Borough Council, Berkshire. The site is bound by Wargrave Road (A321) to the North-East and by the River Thames to the South-West as shown in the Site Location plan below. The approximate Easting and Northing for the centre of the Site is 476583, 182479 respectively.

Figure 1 - Indicative Site Location Plan



- 1.1.3. Thamesfield Villages is a part of the Retirement Villages Group providing a selection of independent living solutions suitable for elderly residents, alongside Care & Support Facilities available for the residents 24/7. Thamesfield Village is comprised of 36 units, accommodating up to a total capacity of 45 people at any given time.
- 1.1.4. The Site is situated within Wokingham Borough Council (WBC) & within the South Oxfordshire District Council (SODC).

1.2. SCOPE

- 1.2.1. This FWEP has been prepared because the Site is located within Flood Zone 3b, an area of high probability of flooding from Fluvial & Tidal sources.
- 1.2.2. This FWEP has been produced with reference to the Environment Agency's website, which contains up to date guidance on flooding issues. Relevant flood related planning documents have been used from WBC & SODC including their Strategic Flood Risk Assessments (SFRA) and Local Flood Risk Management Strategies (LFRMS).

- 1.2.3. The Environment Agency's 'Community Flood Plan' & 'Personal Flood Plan' templates are included as **Appendix A**. This should be copied and completed for the residents prior to occupation and kept on file.
- 1.2.4. These documents should be reviewed and updated regularly (annually) to ensure that all information contained within is relevant and up to date. Consideration may need to be given to the following:
 - Do the residents understand their responsibilities in the event of a flood?
 - Does the plan demonstrate any changes in the physical layout of the site?
 - Are the photographs and/or other records of possessions up to date?
 - Are the names, titles and telephone numbers in the plan current?
 - Are the residents being briefed on any changes to the plan?
- 1.2.5. A thorough evaluation has been conducted to ensure that the advice provided within this FWEP is wholly accurate and sufficient in detail at the date of issue. It is the responsibility of the owner and future residents to ensure that any additional risks specific to the property are fully considered. WSP accepts no responsibility for any errors, omissions or misleading statements in this guidance or for any loss, damage or inconvenience caused as a result of relying on this guidance document.

1.3. AIMS AND OBJECTIVES

- 1.3.1. The main aim of this FWEP is to ensure the safest possible evacuation for the residents of Thamesfield Villages in Henley-On-Thames before a major flood event and only in exceptional circumstances during a major flood event.
- 1.3.2. The main objectives of the Flood Warning and Evacuation Plan are to:
 - raise awareness of the risk of flooding at the village.
 - ensure safe evacuation of the residents at Thamesfield Villages before a major flood event and only in exceptional circumstances during a major event.
 - define the areas of responsibility for those partaking in the plan.
 - provide details on flood warning & how to act on them.
 - create procedures for implementing the plan.
 - define an escape route from the village and a dry meeting point.
 - advise on minimising financial loss during a flood event.
 - advise on security procedures during a flood event.

2. SUMMARY OF FLOOD RISK

2.1.1. Reference to GOV.UK's 'Flood Map for Planning' and 'long term flood risk information' maps (which makes use of Environmental Agency's data) is made where appropriate, along with reference to the WBC documents and SODC documents.

2.2. TIDAL FLOODING

2.2.1. Tidal flooding is caused by elevated sea levels or overtopping by wave action.

2.2.2. There is no risk of tidal flooding at the Site.

2.3. FLUVIAL FLOODING

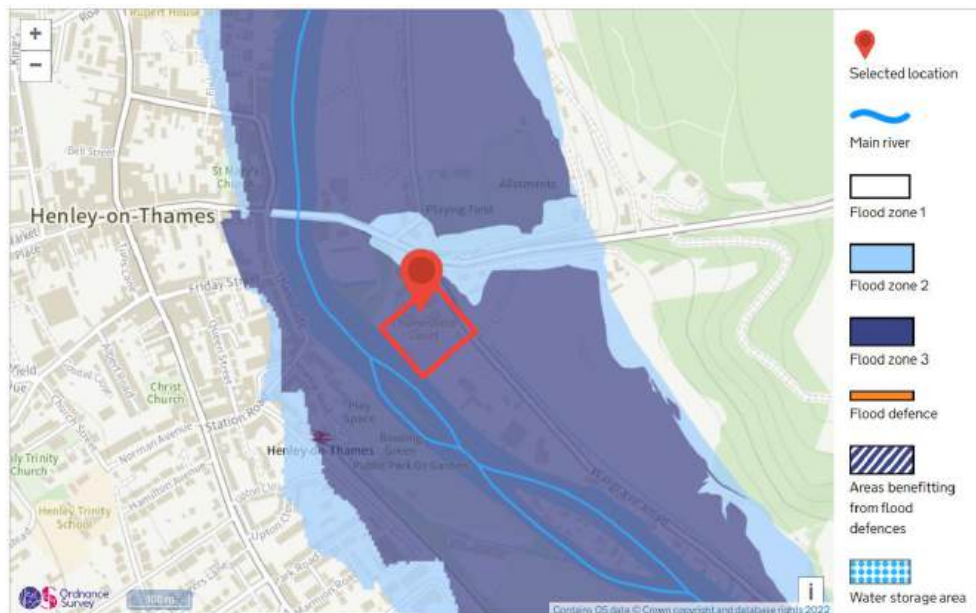
2.3.1. Fluvial flooding is caused by rivers, watercourses or ditches overflowing.

2.3.2. Based on the online GOV.UK Flood Map for Planning, the Site has been identified to lie within Flood Zone 3b - Functional Floodplain i.e. *this zone comprises land where water has to flow or be stored in times of flood*. Please refer to Figure 2.

2.3.3. The WBC SFRA defines Flood Zone 3b - Function Floodplain as:

- Land subject to flooding in the 5% AEP fluvial flood event (1:20 chance), excluding building footprints; and,
- Land which provides a function of flood conveyance (i.e. free flow) or flood storage, either through natural processes, or by design (e.g. washlands and flood storage areas).

Figure 2 - GOV.UK Flood Map for Planning



2.3.4. Based on Hydraulic Modelling undertaken by JBA Consulting, the maximum depth of flooding to occur within the site boundary is 1.89m.

2.3.5. Therefore, the risk of fluvial flooding at the site has been assessed as **high**.

2.4. SURFACE WATER FLOODING

- 2.4.1. Surface water flooding occurs when intense rainfall or overland flow is unable to drain away by traditional means such as into drainage systems or infiltrating into the ground. This excess water could run off quickly off land and result in localised flooding.
- 2.4.2. Based on the online GOV.UK 'Long Term Flood Risk Information', the Site is identified to have 'Very Low' risk of flooding from Surface Water. Please refer to Figure 3.

Figure 3 - GOV.UK Surface Water Flooding Extent



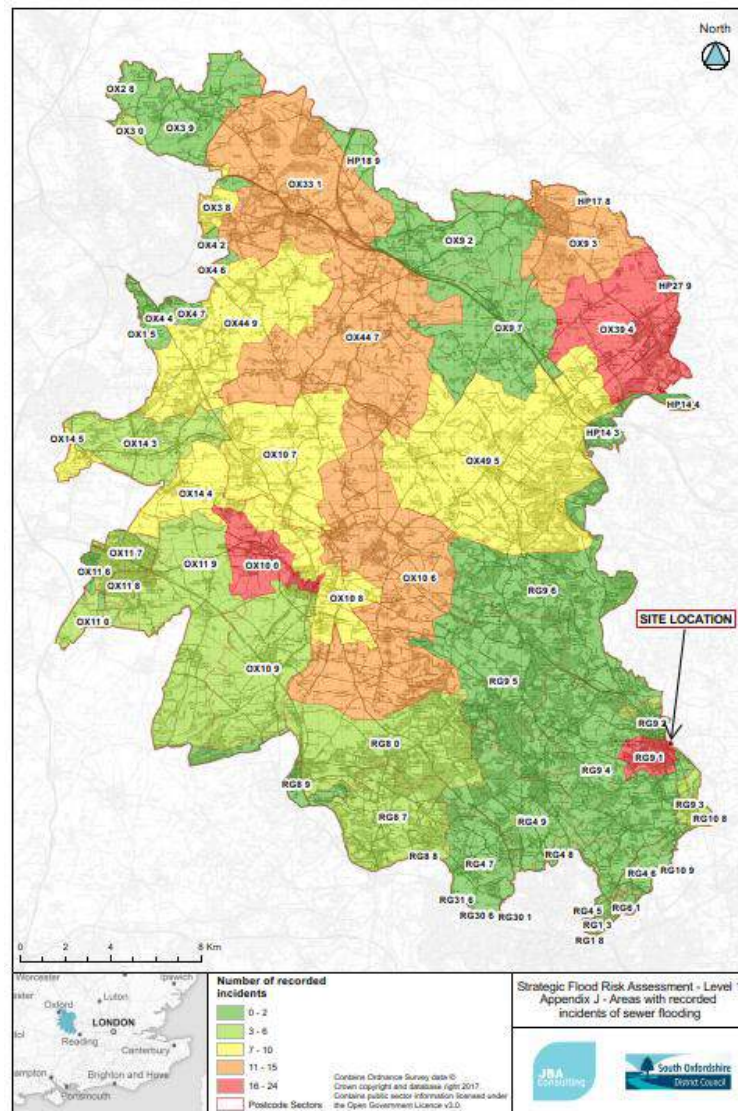
- 2.4.3. Based on the available information the risk of flooding from sewers is considered **negligible**.

2.5. SEWER FLOODING

- 2.5.1. Sewer flooding arises when the drainage system is unable to cope with the volumes of rainfall during an event, causing pipes to back up and surcharge, which may lead to flood flows out of chambers. Flooding can also occur due to the ingress of groundwater into the sewer network, leading to overloading of the sewer system and subsequent flooding.

The SODC SFRA mapping of sewer flooding incidences in the district shows there has been 16-24 incidents of sewer flooding in the vicinity of the Site, however there is no information to state where these sewer floods have occurred specifically. Please refer to Figure 4 below.

Figure 4 - South Oxfordshire District Council Incidence of Sewer Flooding Map



2.5.2. WBC SFRA notes Thames Water maintains records of flooding from their sewers, however due to the Thames Water confidentiality requirements information could only be supplied as the number of flooding incidents by the first part of the post code.

2.5.3. Based on the available information the risk of flooding from sewers is considered **medium**.

2.6. GROUNDWATER FLOODING

2.6.1. Groundwater flooding occurs as a result of water rising up from underlying rocks, typically after long periods of sustained rainfall. It is most likely to occur in low-lying areas underlain by aquifers.

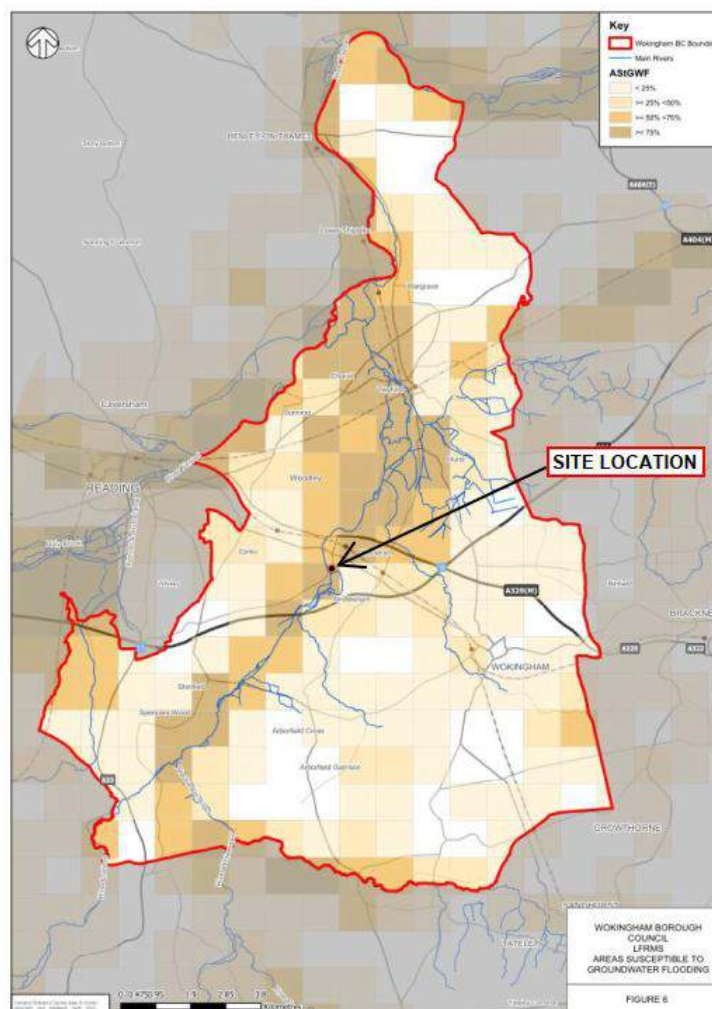
2.6.2. The WBC highlights the high risk of groundwater flooding within their district stating the following:

‘There is a known risk of groundwater flooding within the River Thames floodplain due to the presence of ‘Thames Gravels’. This is a term commonly used to describe the highly permeable soils beneath the historical floodplain of the River Thames. During periods of high-water levels in the river, the local

water table within this gravel layer rises, often resulting in localised groundwater flooding to properties situated away from the direct influence of the river.'

- 2.6.3. The Susceptibility to Groundwater Flooding Map from WBC's LFRMS, confirms this assessment, as an area with greater than 75% susceptibility to groundwater flooding. Please refer to below.

Figure 5 - WBC Groundwater Flooding Areas Susceptible to Groundwater Flooding

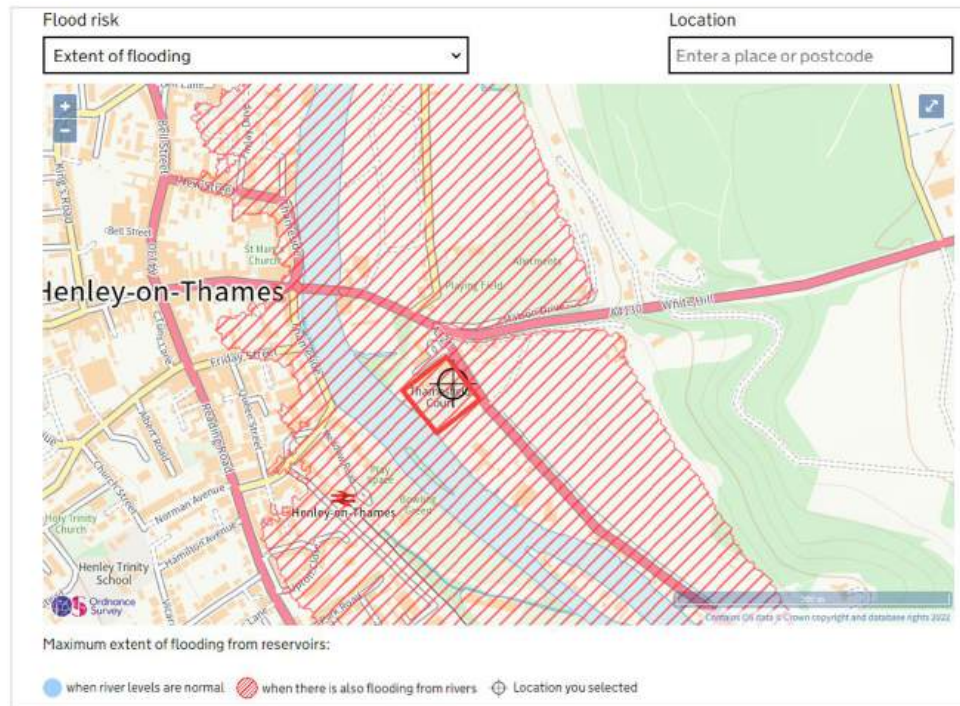


- 2.6.4. Therefore, the risk of groundwater flooding at the site has been assessed to be **high**.

2.7. ARTIFICIAL SOURCES OF FLOODING

- 2.7.1. Areas which lie within the maximum extent of flooding by an uncontrolled release of water from a reservoir are considered to be areas where lives could be threatened.
- 2.7.2. Based on the online GOV.UK's 'Long Term Flood Risk Information', the site has been identified as within the extent of flooding from reservoirs, however only when there is flooding from rivers.
- 2.7.3. Based on the available information, WSP have deemed this flood risk as **low**.

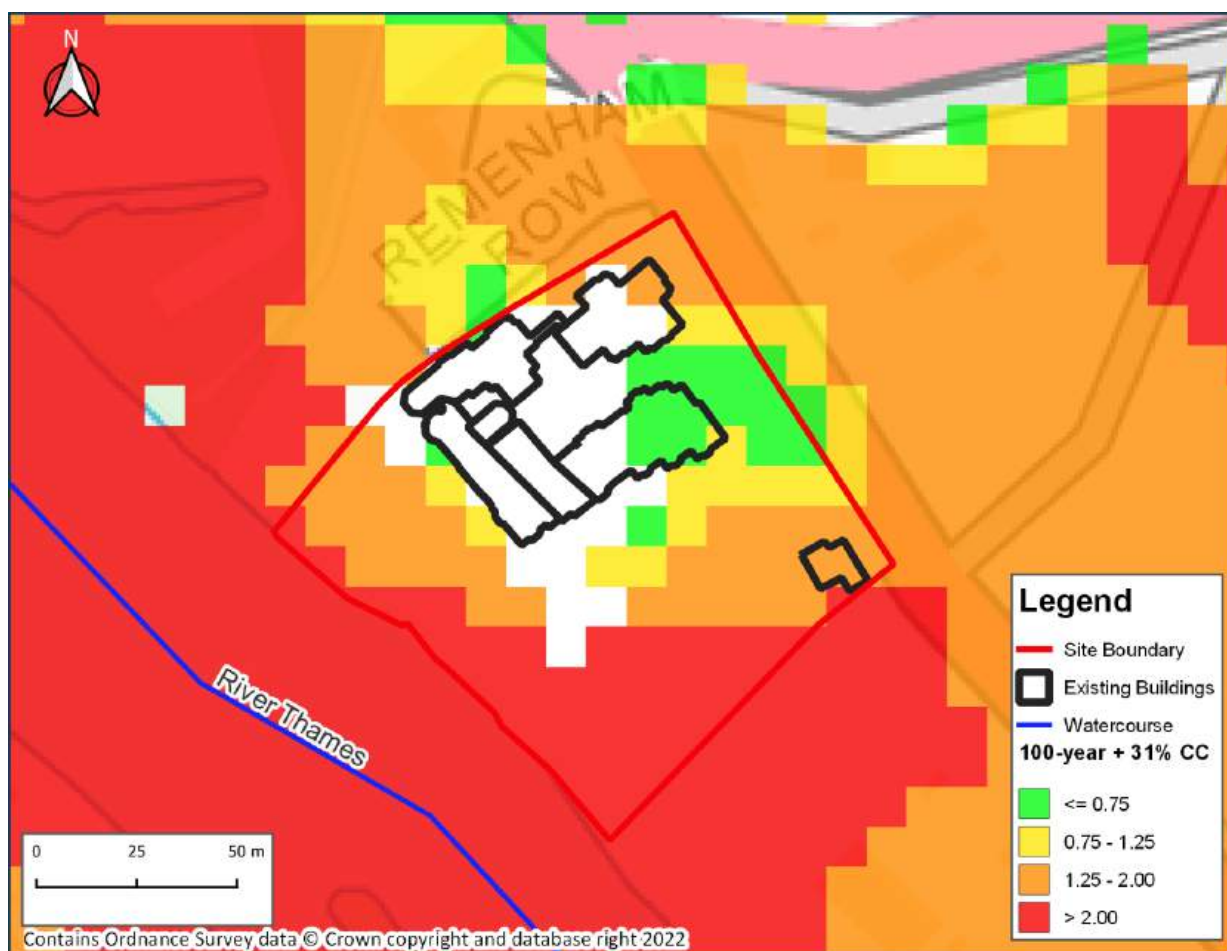
Figure 6 - GOV.UK Reservoir Flooding Extent



3. FLOOD WARNING & ASSOCIATED ACTIONS

- 3.1.1. The Environment Agency are the competent warning authority and operate a flood warning service covering all areas at risk of flooding from tidal and fluvial sources.
- 3.1.2. For more information on the Environmental Agency, their work and their responsibilities please visit www.environment-agency.gov.uk.

Figure 7 – Baseline Hazard To People



Source: JBA Consulting, Hydraulic Modelling Study at Thamesfield, Wargrave Road, Henley-On-Thames

- 3.1.3. Figure 7 above highlights the potential Hazard to People in the event of flooding. This shows that the Site is surrounded by flood risk and during a flood event residents should be evacuated from the premises, escorted to the designated assembly point and onwards to safe locations away from the Flood Hazard.

3.2. FLOOD WARNING SERVICES

ENVIRONMENTAL AGENCY DIRECT SERVICE

- 3.2.1. The Village Manager, along with all residents of the Retirement Village should directly register with the Environment Agency's Floodline Warnings Direct Service. This is a free service that provides flood warnings to those registered, by telephone, SMS text message or email. To register for this either:

- Register online at www.gov.uk/sign-up-for-flood-warnings
- Call Floodline on 0345 988 1188
- SMS Text Floodline on 0345 602 6340

3.2.2. It is recommended that when occupants of the retirement village observe high rainfall and/or stormy river conditions, they should consult the Village Manager and/or the Environment Agency. The Environment Agency can be contacted via the website online (www.environment-agency.gov.uk/flood) and/or phone Floodline on 0345 988 1188 entering the following quick-dial codes, which gives faster access to information for the area:

- **415006** – Marsh to Boveney Lock

NATIONAL UPDATES

3.2.3. The Met Office issues weather forecasts for the UK, including severe weather warnings and information can be found online as follows:

- <https://www.metoffice.gov.uk/weather/warnings-and-advice/uk-warnings>

LOCAL UPDATES

3.2.4. Updates and news on flooding for the local area can be obtained from local television news reports and from local radio stations, including the following sources:

Radio Stations

- BBC Radio Berkshire – 94.6 FM
- River Radio – online at <https://river.radio/>

Television stations

- BBC South
- ITV Meridian

3.2.5. During times of heavy rainfall and/or stormy river conditions, residents of the retirement village should check the TV/radio stations for information regarding flood risk. This may allow for extra preparation time, enabling the properties, contents and people to be better protected against the effects of flooding.

3.2.6. It is the Village Manager's responsibility to advise the occupants of the retirement village home regarding evacuation.

3.3. ENVIRONMENTAL AGENCY FLOOD WARNING AREAS

Flood Warning Codes	Meaning	When is it used	General Advice
ONLINE FLOOD RISK FORECAST	Be aware – keep an eye on the weather situation		- Check weather conditions - Check for updated flood forecasts on the Environmental Agency's Website
 FLOOD ALERT	Flooding is Possible – be prepared	2 hours – 2 days in advance of flooding	- Be prepared to act on your flood plan - Prepare a flood kit of essential items - Monitor local weather levels and the flood forecast on the Environmental Agency's website
 FLOOD WARNING	Flooding is Expected – immediate action required	30 minutes – 1 day in advance of flooding	- Move family, pets and valuables to a safe place - Turn off gas, electricity and water supplies is safe to do so - Move vehicles parked at ground level to a higher level or area outside of the flood zone - Put flood protection equipment in place
 SEVERE FLOOD WARNING	Severe Flooding – danger to life	When flooding poses a significant threat to life	- Stay in a safe place with means of escape - Be ready should you need to evacuate - Co-operate with the emergency services - Call 999 if you are in immediate danger
WARNING NO LONGER IN FORCE 	No further flooding is currently expected in your area.	When river or sea conditions begin to return to normal	- Be careful. Flood water may still be around for several days - If you've been flooded, ring your insurance company as soon as possible

4. PREPARATION & EVACUATION PROCEDURE

- 4.1.1. A Village Manager is responsible for management and operation of the Retirement Village. The Village Manager will be on call 24 hours a day, 365 days per year. In the event of pre-planned leave or any other absence a prior appointed deputy will be available.
- 4.1.2. All residents are to be notified of the flood risk associated with the Retirement Village with Flood Safety Procedures and will be provided with the contact details of the Village Manager. Information will also be made available via notices on communal notice boards and within welcome packs. This information will include a summary of the Flood Evacuation Plan listing the actions to be taken in the event or likelihood of flooding.

4.2. PREPARATION FOR FLOOD EVENT (PRIOR TO OCCUPATION OF NEW RESIDENTS)

- 4.2.1. The Village Manager should undertake the following prior to first occupation:
- Assemble a Personal Flood Plan – a template can be found in **Appendix A**. Copies of the Personal Flood Plan should be kept on site and a copy kept separately by the Village Manager.
 - Assemble the Community Flood Plan – a template can be found in **Appendix A**. Copies of the Community Flood Plan should be kept on site and a copy kept separately by the Village Manager.
 - Forward a copy of this Flood Evacuation Plan, the Personal Flood Plan and the Community Flood Plan to the Emergency Management Service at Wokingham Borough Council.
 - Subscribe to the Environment Agency Floodline service.
 - Fill in the relevant contact details within Section 5 of this FWEP.
 - Activate procedures for residents to receive flood warnings, and train residents in the procedures to be followed in response to receipt of the flood warning.
 - Ensure that future occupants of Thamesfield Villages are made aware of the flood risk associated with the retirement village prior to rental and purchase contracts.
 - Ensure that all occupants of Thamesfield Village are trained in flood evacuation procedures upon arrival with a defined meeting point clearly located.
 - Assemble a flood tool kit for use by residents in an emergency – including a whistle, water resistant high visibility jackets, food and water, hard hats and head lamps (with spares for visitors), key documents, flash lamp, first aid kit and blankets.
 - Compile a list of useful contacts for residents, emergency services, Floodline quick dial numbers, contact details of staff and occupants.
 - Ensure that all residents have been shown how to turn off the electricity, gas and water in an emergency, and how to close shutters.
 - Acquire any flood protection items listed in Personal Flood Plan.
 - Confirm that the insurance policy is adequate.

4.3. PERSONAL SAFETY IN A FLOOD EVENT

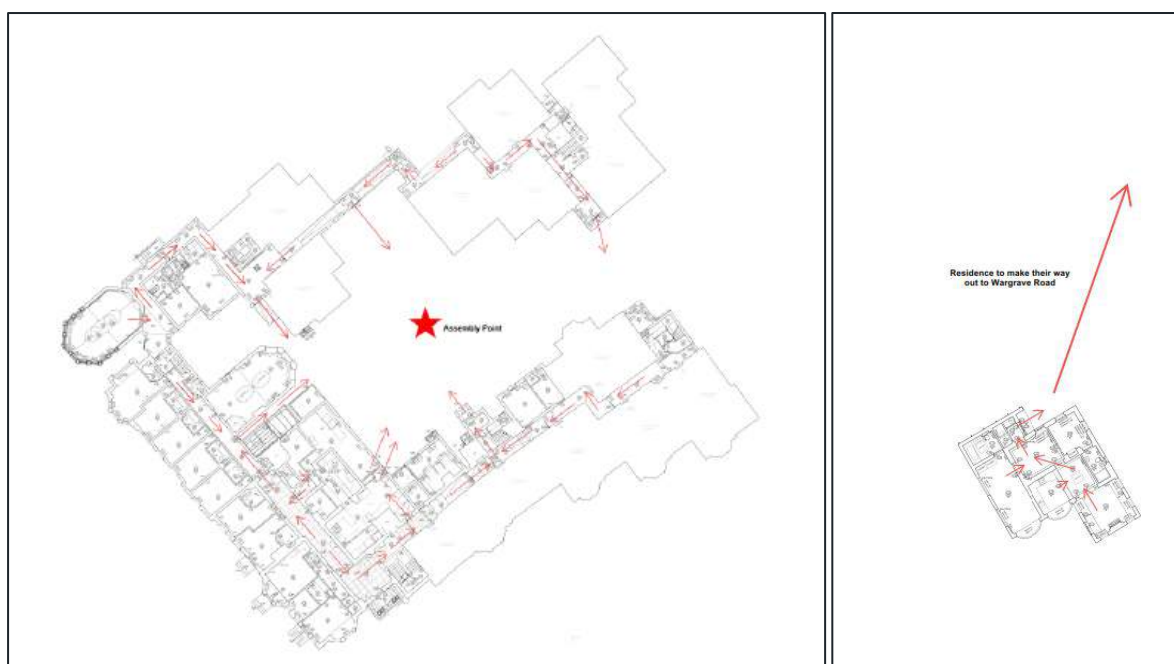
- 4.3.1. The following actions are of great importance and should be considered carefully.
- Stay safe in a flood event.
 - Do not put yourself at risk in the event of a flood, personal safety is paramount. Be aware that floods bring their own unique hazards, the majority of which will be hidden from view.

- Never try swim through fast flowing water as you will be swept away or struck with an object from the flood water.
- Avoid wading through flood water as this is likely to be contaminated with raw sewage as drains and sewers overflow.

4.4. RESPONDING TO FLOOD WARNINGS

- 4.4.1. This FWEP will be overridden by any advice given by competent authorised staff including the Emergency Services or Local Authority responders on the ground in the event of a serious flood event.
- 4.4.2. The Village Manager should immediately contact the occupants of the Retirement Village once receiving a flood warning to ensure all residents are aware of the flood warning currently in place and alert them to prepare for a potential evacuation.
- 4.4.3. Any advice provided by the local Emergency Services, Environment Agency, Local Authority and the Village Manager regarding whether, and where to evacuate should be adhered to. In the absence of advice to the contrary, it is recommended that the internal courtyard is used as a pre-defined meeting point.
- 4.4.4. According to Hydraulic Modelling undertaken by JBA Consulting, the courtyard is not within the extreme (1 in 100 year +31% Climate Change) flood outline. The internal evacuation route to the courtyard is indicated in Figure 8 below and in **Appendix B**.

Figure 8 - Evacuation Route from Retirement Village



- 4.4.5. Subscription to the Flood Warning Service is important to provide another source of flood warning. The Village Manager and occupants should call Floodline on 0345 988 1188, select option 1 and enter quick-dial number 415006 to subscribe. Once subscribed no further action is required.
- 4.4.6. Under '**Flood Alert**' conditions:

- the Village Manager should contact all residents, establish their current location and prepare them for the potential need to evacuate and gather belongings.
- Temporary flood proofing measures such as shutters and flood boards should be fitted if it is safe to do so and there is sufficient time prior to evacuation.
- The Village Manager should be on site following a Flood Alert & monitor the Flood Warning situation. They should advise residents on evacuation procedures should this become necessary.

4.4.7. On receipt of the '**Flood Warning**' status:

- the Village Manager should evacuate the residents immediately.

4.4.8. In the unlikely event that a '**Flood Alert**' and '**Flood Warning**' have been missed, or the Environment Agency Floodline issues an immediate '**Severe Flood Alert**':

- the retirement village should be immediately evacuated provided it is still safe to do so, and without hesitating to close shutters or collecting belongings.
- If it is not safe to evacuate and floodwater is encroaching on the property, residents should seek safety at the upper level of the residence, call emergency services and await assistance.

4.4.9. If it is safe to do so, vehicles should be driven to higher ground. If there is any doubt about the safety of moving vehicles, they should be abandoned. Do not try to walk, drive or swim through deep floodwater. Avoid contact with floodwater – it may be contaminated with sewage.

4.4.10. The Village Manager should ensure that all residents and occupants have evacuated the retirement village successfully and close (and lock) the main entrances until it safe to return.

4.4.11. It is advised that an emergency 2-way communication between the residents and Village Manager is implemented.

4.5. EVACUATION PROCEDURE

4.5.1. In the event an evacuation is required the following evacuation procedure should be implemented throughout the Retirement Village:

1. The Village Manager should contact all residents of the retirement village alerting them that an evacuation of the premises is taking place.
2. Residents should make their way to the nearest exit as shown in the Evacuation Plan and make their way to the Safe Refuge Spot in the internal courtyard.
3. The Village Manager should check all accommodation units to ensure that everyone has left the premises safely and grab the emergency flood kit on their way out.
4. Once all residents are accounted for, the Village Manager is responsible for directing each individual resident onto a safe location, off site and outside the flood zone. Final destinations of the residents needs to be away from the flood zone, in a safe dry location with access to basic human needs.
5. Once residents are in their safe locations off site, they need to contact the Village Manager, informing them of their safe arrival at their destination.

4.6. AFTER FLOOD EVENT

- 4.6.1. Only return to the property once it is safe to do so and following confirmation from the Village Manager and/or emergency services.
- 4.6.2. The Village Manager should commission immediate emergency pumping/repair work if necessary to prevent further damage.
- 4.6.3. Open doors and windows to ventilate properties.
- 4.6.4. The Village Manager will advise on where you can get help to clean up including contacting the local authority or health service for assistance.
- 4.6.5. Contact your utility providers (electricity and water) to have them check services before re-use.
- 4.6.6. Dispose of all food which may have been in contact with floodwater as contamination could have occurred. For further assistance contact your local authority Environmental Health department for advice.
- 4.6.7. Keep a comprehensive record of flood damage (photographs, videos, etc) and retain correspondence with insurance broker after the flood.
- 4.6.8. Contact your insurance broker (24hour) Emergency Helpline. They will be able to provide information on dealing with your compensation claim and provide assistance.
- 4.6.9. Floodline (0345 988 1188), provides an advice guide to repairing flood damaged property.

5. ROLE OF GOVERNING BODIES & CONTACT INFORMATION

- 5.1.1. The response to a major flood event will involve several organisations working together at a local level, including the emergency services, local authority (the council), the Environment Agency and utility companies.
- 5.1.2. The general roles of the main bodies in relation to a major flood event in Wokingham are summarised below. It should be noted that this is a general list, and specific duties may vary between different bodies.

5.2. VILLAGE MANAGER

- 5.2.1. The Village Manager will be responsible for ensuring evacuation of the retirement village is carried out according to this plan and relevant advice from emergency services. The Village Manager should also sign up to the Environmental Agency's Floodline flood warning service.

Village Manager
Name:
Address:
Telephone (Office Hours):
Telephone (Out of Office Hours):

5.3. POLICE DEPARTMENT

- 5.3.1. The police are responsible for the for the overall coordination of the multi-agency response at a major flood event. They will coordinate any multi-agency decision to evacuate & save lives of residents in partnership with key partner agencies.
- 5.3.2. The nearest police station to Thamesfield Village is the Maidenhead Police Station.

999 – Emergencies

5.4. FIRE & RESCUE DEPARTMENT

- 5.4.1. The Fire and Rescue department will be there to assist with the evacuation and search and rescue operations. They will be able to provide and/or obtain specialist advice and assist where hazardous materials are involved.
- 5.4.2. The Fire and Rescue department also assist other relevant agencies, particularly the local authority, to minimise the effects of major flooding to the community.

999 – Emergencies	
Royal Berkshire Fire & Rescue Services (Non-Emergencies):	
	0118 938 4452
	07500 108627
	Centralhubfiresafety@rbfrs.co.uk
	oxboroughn@RBFRS.co.uk
Fire Safety Inspection Officer:	Nick Oxborough

5.5. ENVIRONMENTAL AGENCY

- 5.5.1. Floodline Warnings Direct is a free service which sends you a direct message when flooding is expected and may affect your property. Flood warnings will give you time to prepare for flooding which could save you time, money and heartache. You can receive warnings by telephone, SMS text message & email.

Floodline on 0345 988 1188 SMS Text Floodline on 0345 602 6340
--

5.6. LOCAL AUTHORITIES

- 5.6.1. The local authorities work closely with the police, fire services, rescue services and co-ordinate the response during severe flooding.
- 5.6.2. The Council's Emergency Management Service is concerned with the well-being of the community and environment during and after emergency situations.

Telephone (Emergencies) on 0800 212 111 (Ask for the Emergency management Duty Officer) Telephone (Office Hours) on 0118 974 6000
--

5.7. AMBULANCE SERVICE

- 5.7.1. In the event of a serious medical emergency to one or more residents, it is advised that an ambulance be brought to the site.

999 – Emergencies

5.8. LOCAL PUBLIC TRANSPORT, BUS & TRAIN COMPANIES, TAXI SERVICES

5.8.1. Henley-on-Thames railway station operates regular services going south to Twyford. From there trains can be caught south towards Reading or north to Maidenhead and onto London. Train times can be found on the National Rail and Trainline websites listed below.

- <https://www.nationalrail.co.uk/>
- <https://www.thetrainline.com/>

5.8.2. There are 3 main local bus services running through Henley-On-Thames, information on which can be found below.

Arriva Services:

1. **800** running from Reading to High Wycombe via Henley-On-Thames
2. **850** running from High Wycombe to Reading via Henley-On-Thames

Thames Travel Services:

1. **X38** running between Wallingford & Henley-on-Thames

5.8.3. For residents without a means of self-transportation away from the site, it is recommended that taxi services are called to the assembly point and residents taken to destinations as specified by the Village Manager.

Henley Taxis Ltd – 01491 574 222 Henley Taxi Services – 01491 526566 Maidenhead Taxi Services – 01628 200189 Reading Station Taxis – 07475 661060

5.9. ADDITIONAL CONTACTS

5.9.1. The below contact information is to be provided by the Village Manager.

ELECTRICITY, GAS, WATER & TELEPHONE SERVICE PROVIDERS

Electricity Company Company Name: Contact Number:

Gas Company Company Name: Contact Number:

Telephone Provider

Company Name:

Contact Number:

INSURANCE COMPANY OR PROVIDER**Insurance Company**

Company Name:

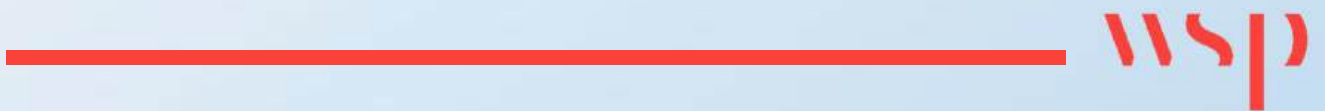
Contact Number:

6. MONITORING AND REVIEW OF THE PLAN

- 6.1.1. This FWEP should be reviewed every 3-5 years to ensure that the Flood Plan is keep up to date and in line with new policies and modelling results.
- 6.1.2. The FWEP should also be reviewed & updated if:
 - There are changes to the contact information & details listed in Section 5.
 - Works (internal & external) have taken place within the development causing the structural layout or landscaping to have changed.
 - Modelled Flood extents have significantly changed since the last issue of the FWEP.

Appendix A

COMMUNITY & PERSONAL FLOOD PLAN TEMPLATES



community flood plan

Parishes and communities working together

Community or group		Address	
Floodline Quickdial Number		Which Environment Agency flood warnings are you registered to receive?	
Local flood warning trigger <i>i.e. when water reaches bottom of the bridge</i>			
Date			

Contents

1. Actions to be taken before a flood

- A - Locations at risk of flooding: flood warnings
- B - Locations at risk of flooding: locations at risk of flooding / sources of flooding
- C - Locations at risk of flooding: map showing direction of flooding

2. Actions to be taken during a flood

- A - Local flood actions
- B - Local volunteers / flood wardens
- C - Important telephone numbers
- D - Available resources
- E - Arrangements between authorities
- F - Vulnerable residents, properties and locations

3. After a flood

- A - Reputable contractors

1A – Locations at risk of flooding: Flood warnings

From the information you have available, make a list of areas liable to flood and the level of warning which would affect them.

Area number	Location of risk	Trigger level	Actions
Area 1			
Area 2			
Area 3			
Area 4			
Area 5			
Area 6			
Area 7			
Area 8			

1B – Actions to be taken before a flood: Locations at risk of flooding / source of flooding

Insert details of areas at risk from flooding and the direction of flooding. Include maps and if possible, details of existing defences.

Area number	Location at risk	Source of flooding	Direction of flooding
Area 1			
Area 2			
Area 3			
Area 4			
Area 5			
Area 6			
Area 7			
Area 8			

1C – Actions to be taken before a flood: Map showing direction of flooding

Include a map in the flood plan showing the flood risk area and direction of flooding.



2A – Actions to be taken during a flood: local flood actions

Identify local flood actions.

Area number	Location at risk	Action / trigger	Local action	Equipment required	Time required
Area 1					
Area 2					
Area 3					
Area 4					
Area 5					
Area 6					
Area 7					
Area 8					

2B – Actions to be taken during a flood: local volunteers / flood wardens

List local volunteers/flood wardens that could be contacted in an incident. They may be required to lift heavy sandbags so should be reasonably active or fit. Consider using other volunteers such as communicators, administrators or minders of vulnerable people during an incident. These volunteers could be registered on the Environment Agency's Floodline Warnings Direct service so they receive the flood warnings. **Volunteers must not put their own life at risk.**

Name	Address	Telephone Day	Telephone Evening	Mobile

2C – Actions to be taken during a flood: Important telephone numbers

Make a list of important telephone numbers so all the information you require during an incident is readily available.

Organisation	Telephone (office hours)	Telephone (out of hours)	Fax
Floodline			
Environment Agency			
District Council			
County Council			
County Contracting			
Fire & Rescue Service			
Police			
Ambulance Service			
Housing Unit			
Environment Unit			
Water Company			
Electricity Company			
Gas Company			
Telecommunications Company			
Adjacent Town/Parish Councils			

2D – Actions to be taken during a flood: Available resources

Identify available resources.

Organisation	Resource	Number	Location	Notes

2E – Actions to be taken during a flood: Arrangements between authorities

Details of specific arrangements between the various authorities to be included here.

Organisation(s)	Agreed arrangement

2F – Actions to be taken during a flood: Vulnerable residents, properties and locations

List vulnerable people, properties and locations where early assistance may be required.

Name	Address	Daytime telephone	Evening telephone	Assistance required

3A – After a flood: Reputable contractors

List companies/reputable contractors whose help you may need after a flood. Get contracts in place, or know who to call for assistance. If help is not needed, you can leave this section blank. If you plan to do the work yourself, leave this section blank.

Company name	Business (e.g. builder)	Telephone	Fax

Personal flood plan

Name



Are you signed up to receive flood warnings?

If not call Floodline on 0345 988 1188 to see if your area receives free flood warnings.

☐

Let us know when you've completed your flood plan by calling Floodline on **0345 988 1188**. This will help us learn more about how people are preparing for flooding.

General contact list	Company name	Contact name	Telephone
Floodline	Environment Agency		0345 988 1188
Electricity provider			
Gas provider			
Water company			
Telephone provider			
Insurance company and policy number			
Local council			
Local radio station			
Travel/weather info			

Key locations

Service cut-off	Description of location
Electricity	
Gas	
Water	

Who can help/who can you help?

Relationship	Name	Contact details	How can they/you help?
Relative			
Friend or neighbour			

Be prepared for flooding. Act now

Personal flood plan

What can I do NOW?



Put important documents out of flood risk and protect in polythene

☐

Look at the best way of stopping floodwater entering your property

☐

Find out where you can get sandbags

☐

Identify what you would need to take with you if you had to leave your home

☐

Check your insurance covers you for flooding

☐

Make a flood plan and prepare a flood kit

☐

Identify who can help you/ who you can help

☐

Understand the flood warning codes

☐

What can you do if a flood is expected in your area?

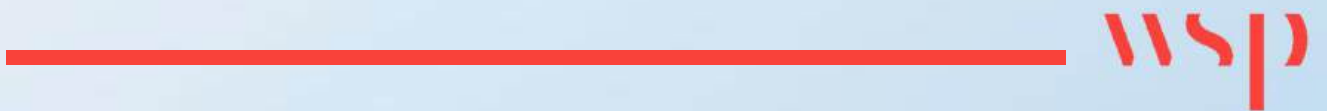
Actions	Location
Home	
• Move furniture and electrical items to safety	
• Put flood boards, polythene and sandbags in place	
• Make a list now of what you can move away from the risk	
• Turn off electricity, water and gas supplies	
• Roll up carpets and rugs	
• Unless you have time to remove them hang curtains over rods	
• Move sentimental items to safety	
• Put important documents in polythene bags and move to safety	
Garden and outside	
• Move your car out of the flood risk area	
• Move any large or loose items or weigh them down	
Business	
• Move important documents, computers and stock	
• Alert staff and request their help	
• Farmers move animals and livestock to safety	
Evacuation - Prepare a flood kit in advance	
• Inform your family or friends that you may need to leave your home	
• Get your flood kit together and include a torch, warm and waterproof clothing, water, food, medication, toys for children and pets, rubber gloves and wellingtons	

There are a range of flood protection products on the market to help you protect your property from flood damage. A directory of these is available from the **National Flood Forum** at www.bluepages.org.uk

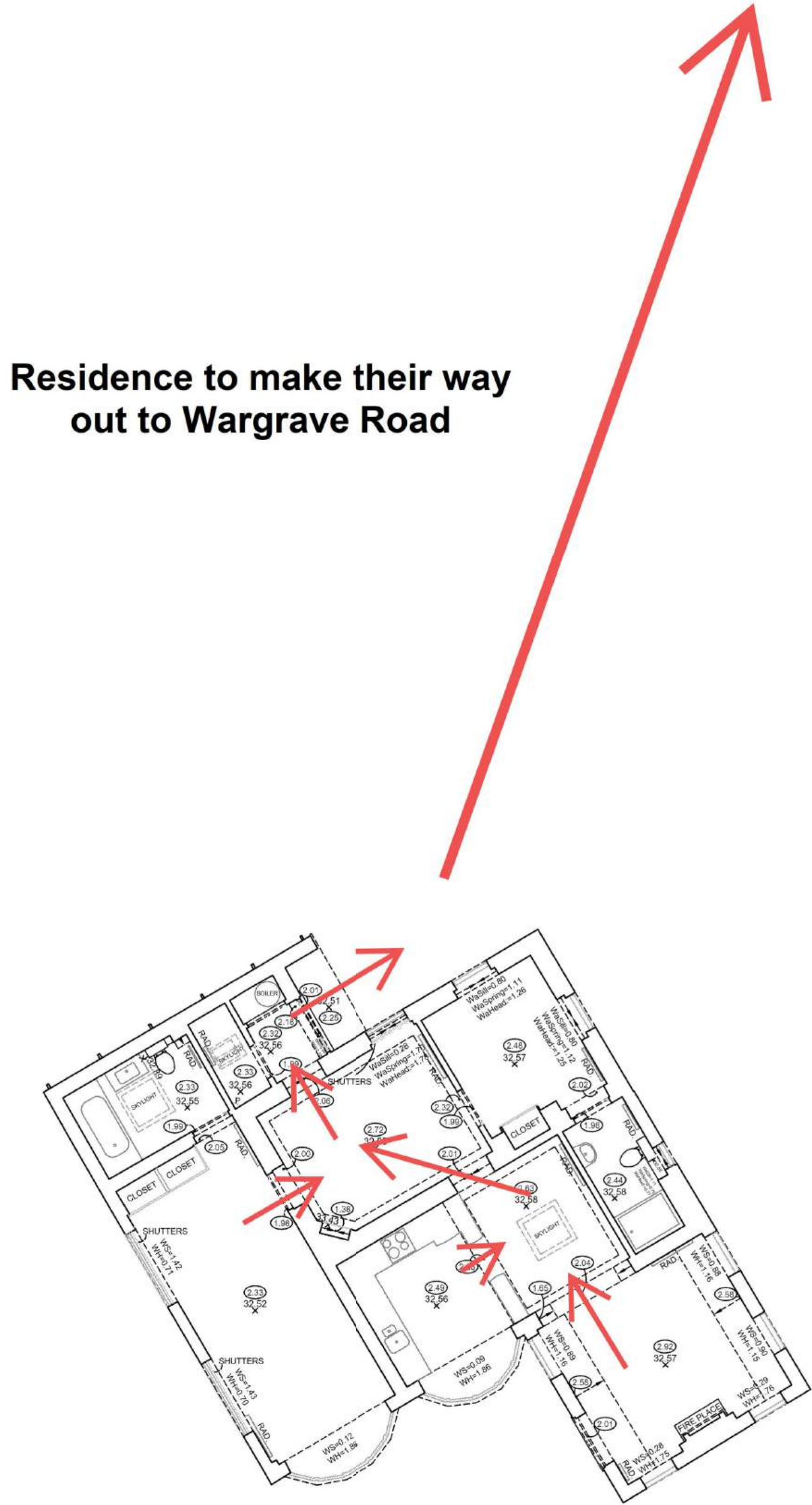
Be prepared for flooding. Act now

Appendix B

FLOOD EVACUATION ROUTE







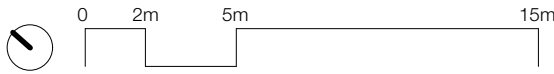
Residence to make their way
out to Wargrave Road



WSP House
70 Chancery Lane
London
WC2A 1AF

wsp.com

C Development proposal

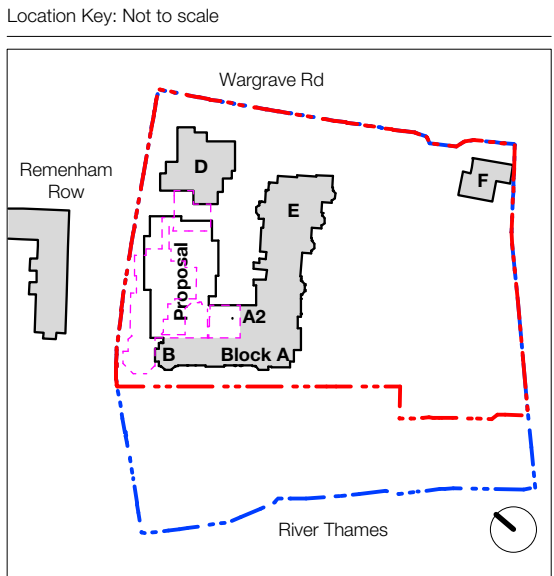


Notes

Do not scale for this drawing. Use written levels and dimensions only.

This drawing is to be read in conjunction with all other relevant documentation produced by Design Engine Architects, Consultants and Sub-Contractors drawings, schedules and Specifications.

Design Engine drawing based on Point 2 Surveyors Ltd drawings, dated July 2021. The site boundaries are those described by the client.



Key:

Site Application Boundary ————

Ownership Boundary ————

Demolished ————

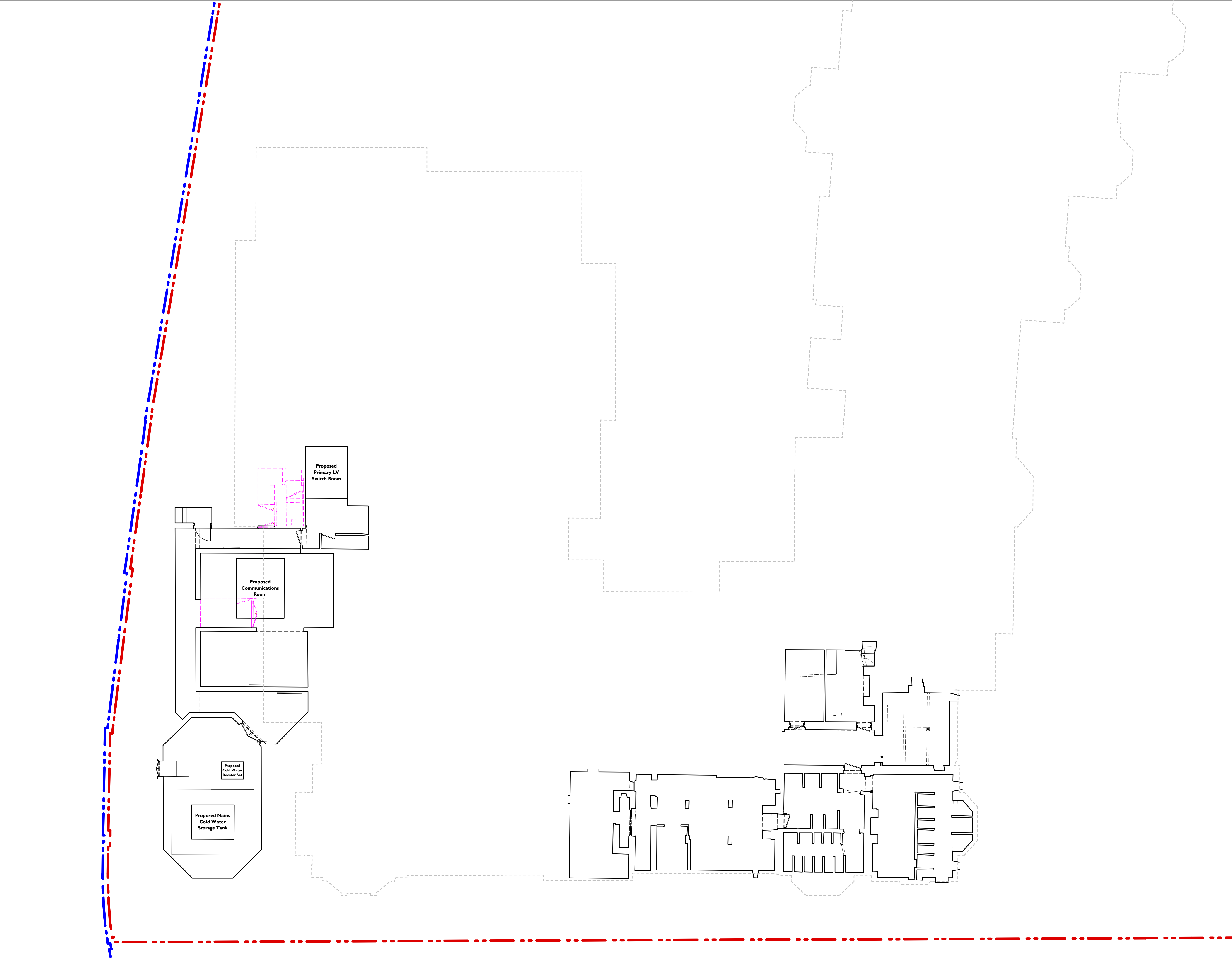
Total Proposed GEA (All Buildings): 2220sqm

00	15/08/23	DESIGN FREEZE ISSUE	KS	RPC
rev	date	notes	drawn	chkd

DESIGNENGINE
ARCHITECTS

Project Name	Thamesfield	Date of issue	August 2023	Scale	1:250 @A1
Client	Retirement Villages Group	Drawing No.	Proposed Site Plan		

Stage	2212-P-100	00
Stage 3		



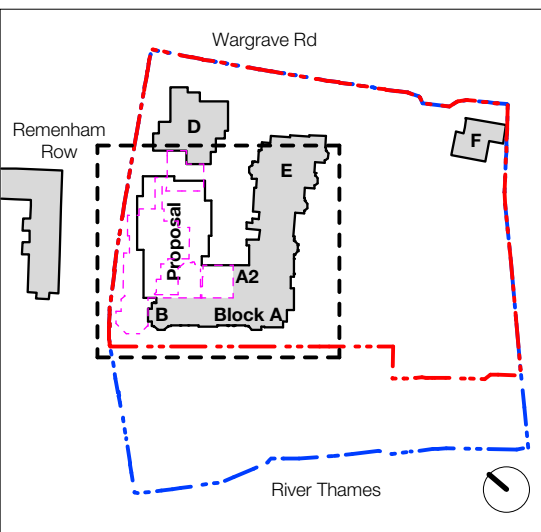
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Design Engine drawing based on Point 2 Surveyors Ltd drawings, dated July 2021. The site boundaries are those described by the client.

Location Key: Not to scale



Key:

- Site Application Boundary
- Ownership Boundary
- Demolished

00	15/08/23	DESIGN FREEZE ISSUE	KS	RPC
rev	date	notes	drawn	chki

DESIGNENGINE
ARCHITECTS

Project Name	Date of issue	Scale
Thamesfield	August 2023	1:100 @A1

Client	Drawing No.
Retirement Villages Group	Proposed Plans - Basement Floor

Stage	Drawing Number	Version
Stage 3	2212-P-200	00

D Hydraulic modelling report

Hydraulic Modelling Study at Thamesfield, Wargrave Road, Henley-On-Thames

Final report

April 2023

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Revision History

Revision Ref / Date	Amendments	Issued to
S03-P01 / May 2022	Draft Report	Caroline Keiller (Retirement Villages Development Ltd)
A01-C01 / July 2022	Final Report	Caroline Keiller (Retirement Villages Development Ltd)
A01-C02 / October 2022	Final Report (following EA review)	Caroline Keiller (Retirement Villages Development Ltd)
A01-C03 / March 2023	Final Report (updated with 30-year event)	Abigail Woods (RPS)
A01-C04 / April 2023	Final Report (Typos)	Abigail Woods (RPS)

Contract

This report describes work commissioned by RPS, on behalf of RVG (Retirement Villages Group) by an email instruction dated 8/12/2021. RPS representative for the contract was Abigail Woods. Emelie Persson and Olivier Saillofest of JBA Consulting carried out this work.

Prepared by Emelie Persson BSc PgCert

Assistant Analyst

Reviewed by Olivier Saillofest BEng MSc CEng MCIWEM
C.WEM

Technical Director

Purpose

This document has been prepared as a Final Report for RPS. JBA Consulting accepts no responsibility or liability for any use that is made of this document other than by the client for the purposes for which it was originally commissioned and prepared. JBA Consulting has no liability regarding the use of this report except to RPS.

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Executive summary

JBA Consulting were commissioned by RPS, to undertake a fluvial water hydraulic modelling study at Thamesfield, Wargrave Road, Henley-On-Thames.

The proposed development located off Wargrave Road, Henley-On-Thames. The surrounding area is a mix of residential and greenfield land. The site is located adjacent to the River Thames (which flows in a northerly direction southwest of the site).

To assess the risk of fluvial flooding at the site, a license has been obtained from the Environment Agency (EA) to re-use the existing 1D-2D Thames Mapledurham to Hurley hydraulic model (2019) of the River Thames. The existing model has been re-run with an updated version of Flood Modeller – TUFLOW, site-specific topographic survey data and cross-sectional data of Henley Bridge.

The model has been run for the baseline scenario for 30-year, 100-year, 100-year with 31% climate change and 1,000-year events in order to determine the existing fluvial flood risk to the site.

In line with the new guidance on Climate Change issued by the Environment Agency in July 2021¹, the effect of climate change was assessed by increasing 100-year peak flows by 31% for the fluvial model (higher central climate change allowance for essential infrastructure developments within the Thames and Chilterns South management catchment).

Results from the hydraulic model were tested for their sensitivity to changes in Manning's roughness, downstream boundary conditions, and flows. A blockage risk scenario was undertaken for Henley Bridge during the 100-year with climate change flood event. Results from the sensitivity analysis indicate that the model results within the site are relatively insensitive to changes in roughness, downstream boundary or changed flow conditions.

Results from the updated model runs show that:

- Water overtops the River Thames' banks and flood the site for all of the modelled flood scenarios (i.e. 30-year, 100-year, 100-year +31% CC and 1,000-year fluvial), as illustrated in Figure 0-1.
- Flood depths of up to 1.89m are predicted to occur within the site during the 100-year with 31% climate change 'design' flood event.
- During the 100-year with 31% climate change fluvial flood event, the peak water levels will exceed the existing floor levels of 2 existing buildings within the site boundary.
- During the 100-year with 31% climate change scenario, the majority of the site falls within the 'low' to 'significant' hazard categories (based on Defra's Hazard-to-People).
- The blockage risk analysis undertaken at Henley Bridge (node 32.078BU) during the 100-year with climate change flood event indicates that when a 25% blockage is applied, a significant increase in maximum flood depths of up to 0.77m is predicted within the site.

1 <https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances>

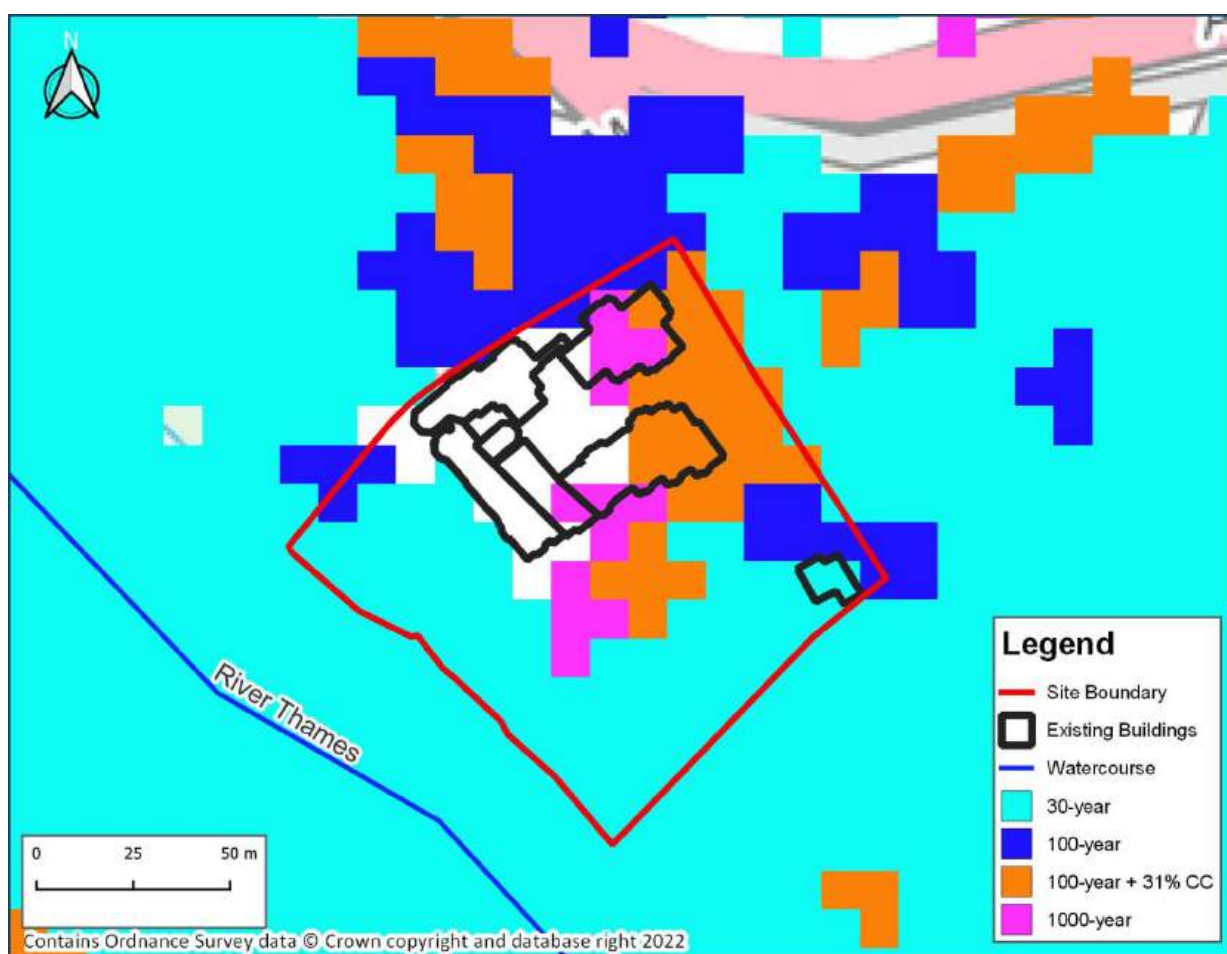


Figure 0-1: Baseline fluvial flood extents

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Abbreviations

1D	One Dimensional
2D	Two Dimensional
CC	Climate Change
DTM	Digital Terrain Model
EA	Environment Agency
ESTRY	Primary 1D engine used by TUFLOW
FEH	Flood Estimation Handbook
FFL	Finished Floor Levels
GCS	Grantham Coates Surveyors
Ha	Hectares
HQ	Head-Flow
JBA	Jeremy Benn Associates
LiDAR	Light Detection and Ranging
m AOD	Metres Above Ordnance Datum
QT	Flow-Time
ReFH	Revitalised Flood Hydrograph
RoFSW	Risk of Flooding from Surface Water
TUFLOW	2D Hydraulic Modelling Software

1 Introduction

1.1 Terms of reference

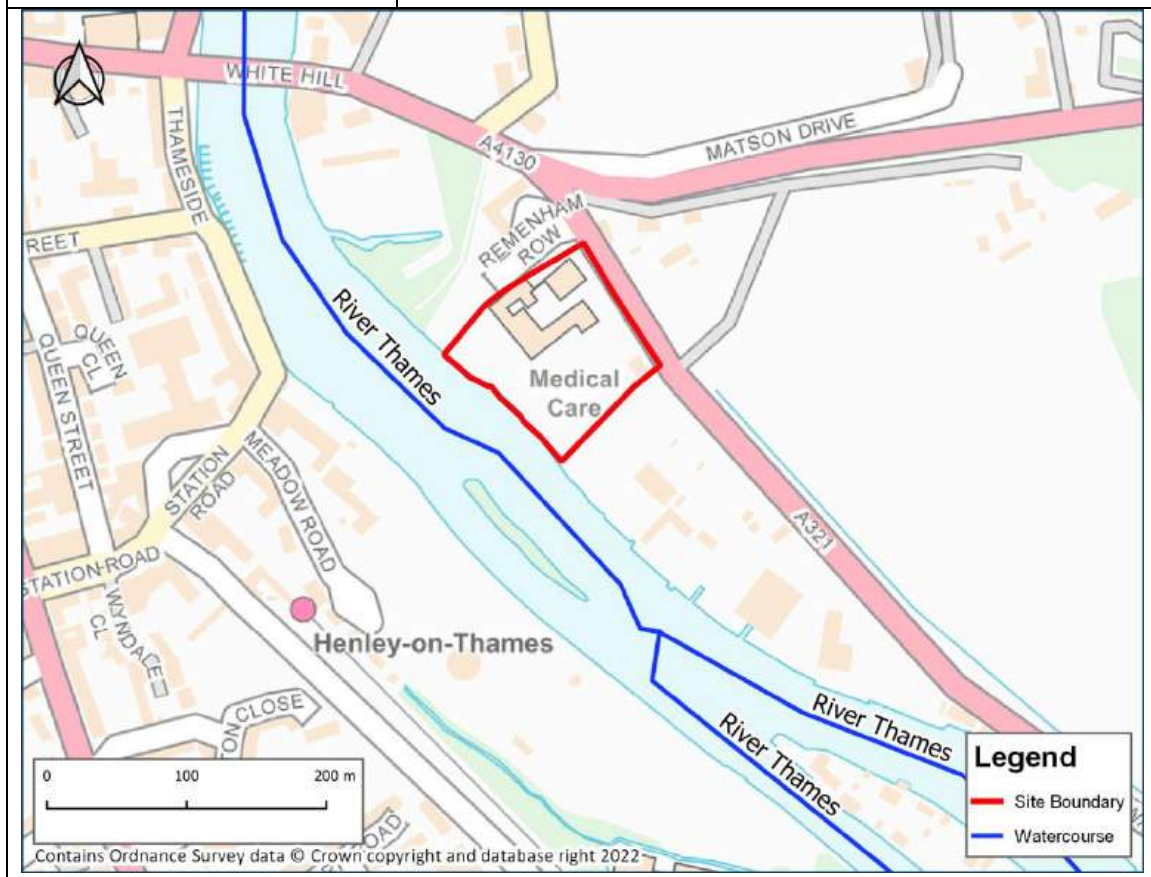
JBA Consulting (JBA) were commissioned by RPS Ltd to undertake a fluvial hydraulic modelling study at Thamesfield, Wargrave Road, Henley-On-Thames.

To support this assessment, the 2019 Thames Mapledurham to Hurley 1D-2D hydraulic model was re-used and re-run with the latest versions of Flood Modeller – TUFLOW and with inclusion of new site-specific topographic survey data to allow accurate representation of the fluvial flood levels, extents and hazards within the site boundary.

1.2 Site details

Table 1-1: Site details

Site name	Thamesfield, Wargrave Road, Henley-On-Thames, RG9 2LX
Site area	1.24ha
Existing land-use	Residential (retirement living accommodations)
OS NGR	SU765824
County	Oxfordshire
Country	England



1.3 Site description

The proposed development site is located off Wargrave Road, Henley-On-Thames. The surrounding area is a mix of residential and greenfield land. The site is currently occupied by an existing retirement village with 35 apartments and a 12-bed care home. The proposal is looking at potential redevelopment opportunities for the site to deliver additional homes and improved facilities.

The River Thames is located immediately adjacent to the site and flows in a northerly direction.

1.4 Existing flood data

It is understood that the Environment Agency's fluvial flood zones currently represents the best source of flood risk information in relation to the site.

To refine flood risk in relation to the site, JBA Consulting was commissioned to carry out an updated version of the detailed fluvial hydraulic modelling study in relation to the proposed development site.

1.5 General approach

The existing 1D-2D Thames Mapledurham to Hurley hydraulic model was obtained from the EA and re-used as part of this project.

The existing model has been updated with new survey data of Henley Bridge and the flood relief culverts located approximately 100 m east of the bridge / 120m northwest of the site. The model is using LiDAR data from the Defra website (flown in 2018 with a 1m grid resolution) and site topographic survey data collected in June 2021 by Point 2 Surveyors Limited, provided in Appendix A.

Given the age of the latest EA model update, flow estimates are deemed representative of current conditions and thus do not need updating. The model has been run for the baseline defended scenario for the 30-year, 100-year, 100-year with 31% climate change and 1000-year flood events in order to determine the existing flood risk to the site.

1.6 Limitations

The 1D-2D Thames Mapledurham to Hurley model uses a 2D grid cell size of 20m within the site area. Given the model run times (i.e. between 1 day and 20hrs) and the prominent location of the site in the Thames floodplain, no attempts were made to refine the model grid cell size. Where results show partial flooding of a building in the model, a comparison of the modelled peak water level with the building floor level was carried and, when relevant, the building was filtered away from the mapped flood extent.

2 Model build phase

2.1 Model geometry

2.1.1 Data availability

The LiDAR used to represent the ground levels within the floodplain has a grid resolution 1m and was last flown in 2018.

Site topographic survey collected by Point 2 Surveyors Limited in June 2021 was provided by the client and used to represent ground levels within the site (see Appendix A). Survey of Henley bridge and the 6 flood relief culverts located approximately 100 m east of the bridge was collected by Grantham Coates Surveys Ltd in March 2022 (see Appendix B).

2.1.2 Model extent and build

2.1.2.1 Fluvial model

To understand fluvial flood risk to the site, the 1D-2D Mapledurham to Hurley 2019 model was obtained from the Environment Agency and re-used as part of this study. The hydraulic model represents the River Thames, and the floodplain in the vicinity of the proposed site. The extent of the fluvial model developed for this study is shown in Figure 2-1.

The channels were represented as 1-dimensional (1D) features using Flood Modeller (version 4.6.0). The 1D model begins approximately 24.6km upstream of the proposed development site and the model extends approximately 7.3km downstream of the site.

The 2D domain was represented using TUFLOW (2020-01-AB-iSP-w64) with floodplain topography represented using LiDAR data. The 2D domain for the fluvial model has an area of 8.27km² and a 5m grid resolution.

The orientation of the grid is southeast to northwest, representing the main direction of floodplain flows. The 1D and 2D domains can be seen in Figure 2-1.

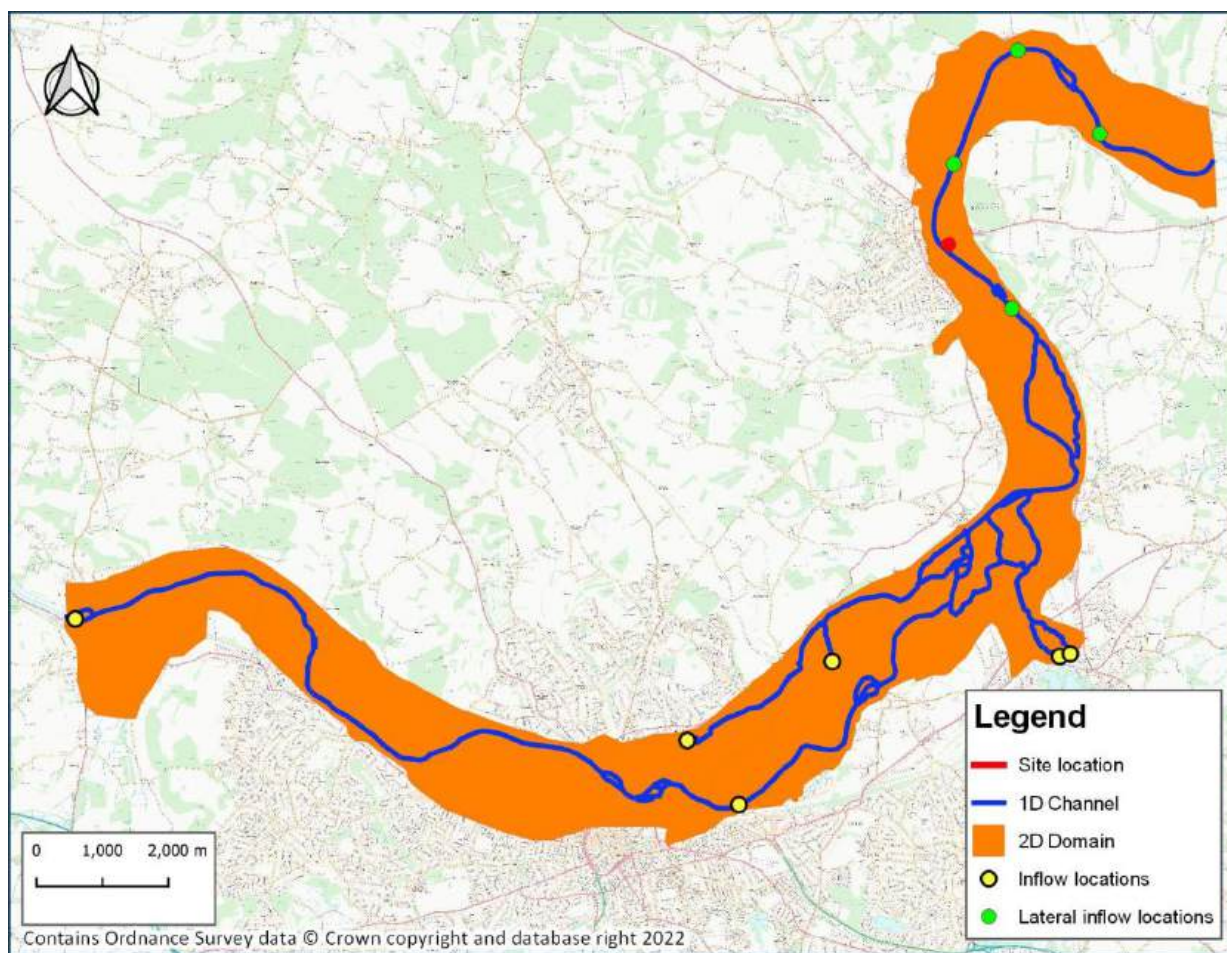


Figure 2-1: Model extent

2.1.3 Model roughness parameters

Manning's n values from the 2019 Thames Mapledurham to Hurley model was re-used to represent roughness values for the channel and floodplain. Table 2-1 gives the range of Manning's n values used in the 1D and 2D domains.

Table 2-1: Manning's n range within the hydraulic model	
1D Channel	0.025 – 0.05 (in channel) 0.075 (banks)
Buildings	0.300
General surface	0.050 – 0.060
Glasshouse	0.200
Inland water	0.045
Landform	0.060
Boulders	0.065
Trees	0.012 – 0.060
Rail	0.045
Roads	0.035

2.2 Model boundary conditions

2.2.1 Model inflows

Flow estimates from 2019 Thames Mapledurham to Hurley hydraulic model was re-used (see Appendix D) and updated in line with the new guidance on Climate Change issued by the Environment Agency in July 2021², the effect of climate change was assessed by increasing 100-year peak flows by 31% for the model (higher central climate change allowance for essential infrastructure developments within the Thames and Chilterns South management catchment).

2.2.2 Downstream boundary conditions

The original downstream boundary conditions used in the 2019 Thames Mapledurham to Hurley hydraulic model was kept in this study. *A rating curve extracted from the Lower Thames modelling was used to derive boundary conditions the model. This characterises the flow vs stage relationship upstream of Hurley Lock for both the channel and the floodplain. The downstream boundary condition was informed by plotting stage vs discharge pairings for the rising limb from each of the design events simulated for the Lower Thames flood risk modelling (20%, 10%, 5%, 3.33%, 4%, 2%, 1.33%, 1%, 0.5% and 0.1% AEP events). Given the close proximity of the downstream boundary location to the Lower Thames model inflow (at Hambleden Lock) the flow data informing the stage vs discharge pairings is based on the Lower Thames model inflow to remove complexity of extracting 1D channel and 2D floodplain flows from the Lower Thames model³.*

² <https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances>

³ JBA Consulting for Environment Agency. Thames Mapledurham – Final Model Report (v2 Mar 2019)

2.3 Calibration

The 2019 Thames Mapledurham to Hurley hydraulic model was calibrated to historic flood events. As a result, new calibration has not been carried out on the model results, however sensitivity testing has been carried out to provide confidence in the model parameters, see Appendix C.

2.4 Model Runs

2.4.1 Modelled scenarios

The following flood scenarios were simulated by the model:

Baseline scenarios

- 30-year (3.33% AEP) fluvial flood event;
- 100-year (1% AEP) fluvial flood event;
- 100-year (1% AEP) plus Climate Change (31%) fluvial flood event;
- 1000-year (0.1% AEP) fluvial flood event.

Blockage scenario

- 100-year (1% AEP) plus Climate Change (31%) fluvial flood event – Henley Bridge (32.078BU) downstream of the site blocked by 25%.

Sensitivity analysis

- 100-year (1% AEP) flood event with +20% increase in peak flows;
- 100-year (1% AEP) flood event with +20% increase in roughness value;
- 100-year (1% AEP) flood event with -20% decrease in roughness value;
- 100-year (1% AEP) flood event with +250mm increase in peak water level at the downstream model boundary.

The results of the baseline and blockage scenarios are discussed in the following section with sensitivity analysis included in Appendix C of this report.

3 Hydraulic model results

3.1 Baseline flood extents

Flood extents for the 30-year, 100-year and 1,000-year fluvial flood events are shown in Figure 3-1.

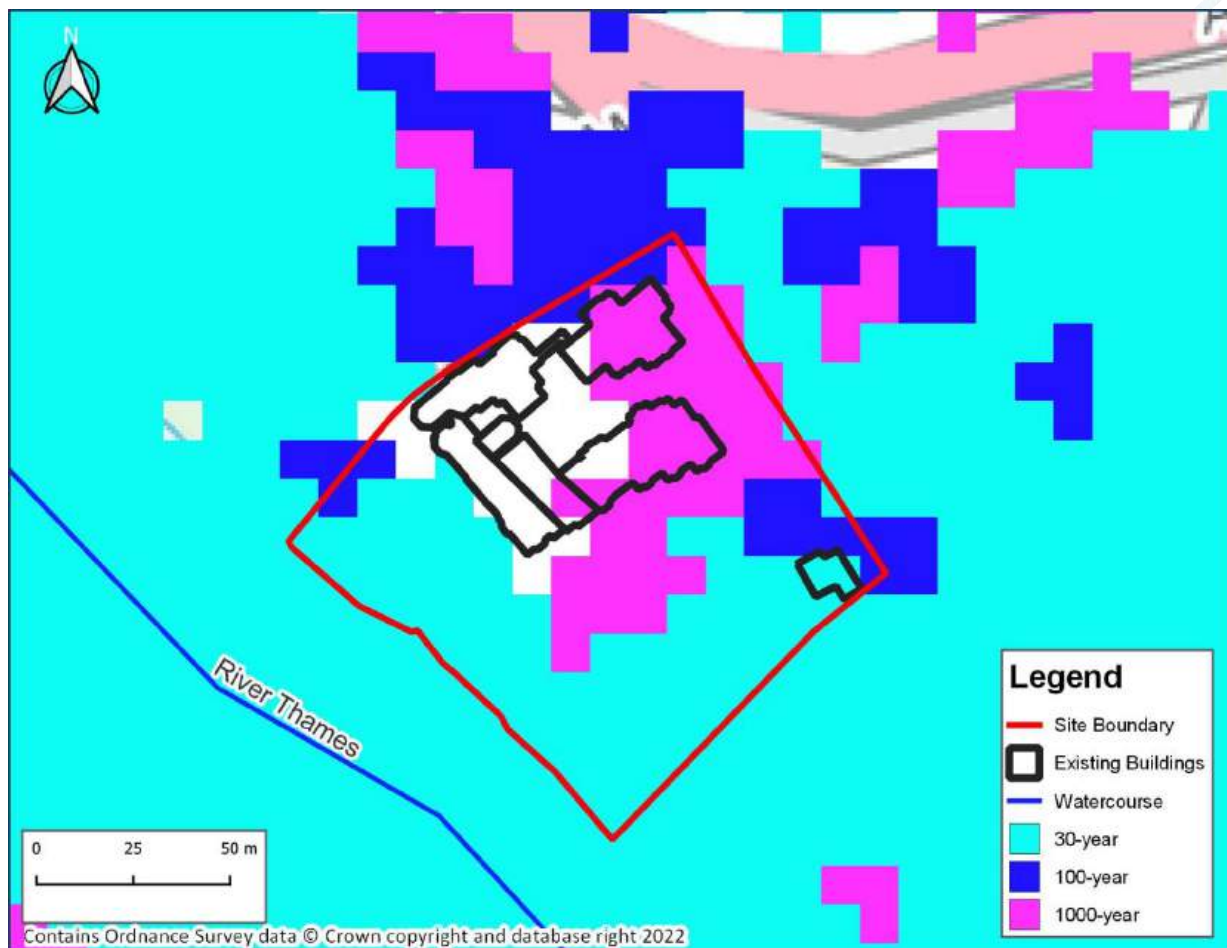


Figure 3-1: Baseline flood extents (30-year, 100-year and 1,000-year)

Figure 3-1 shows that the capacity of the River Thames is exceeded during all of the modelled events and flooding occurs on the site for all of the three modelled events. Flood extent for the 100-year with (+31%) climate change is represented in Figure 3-2.

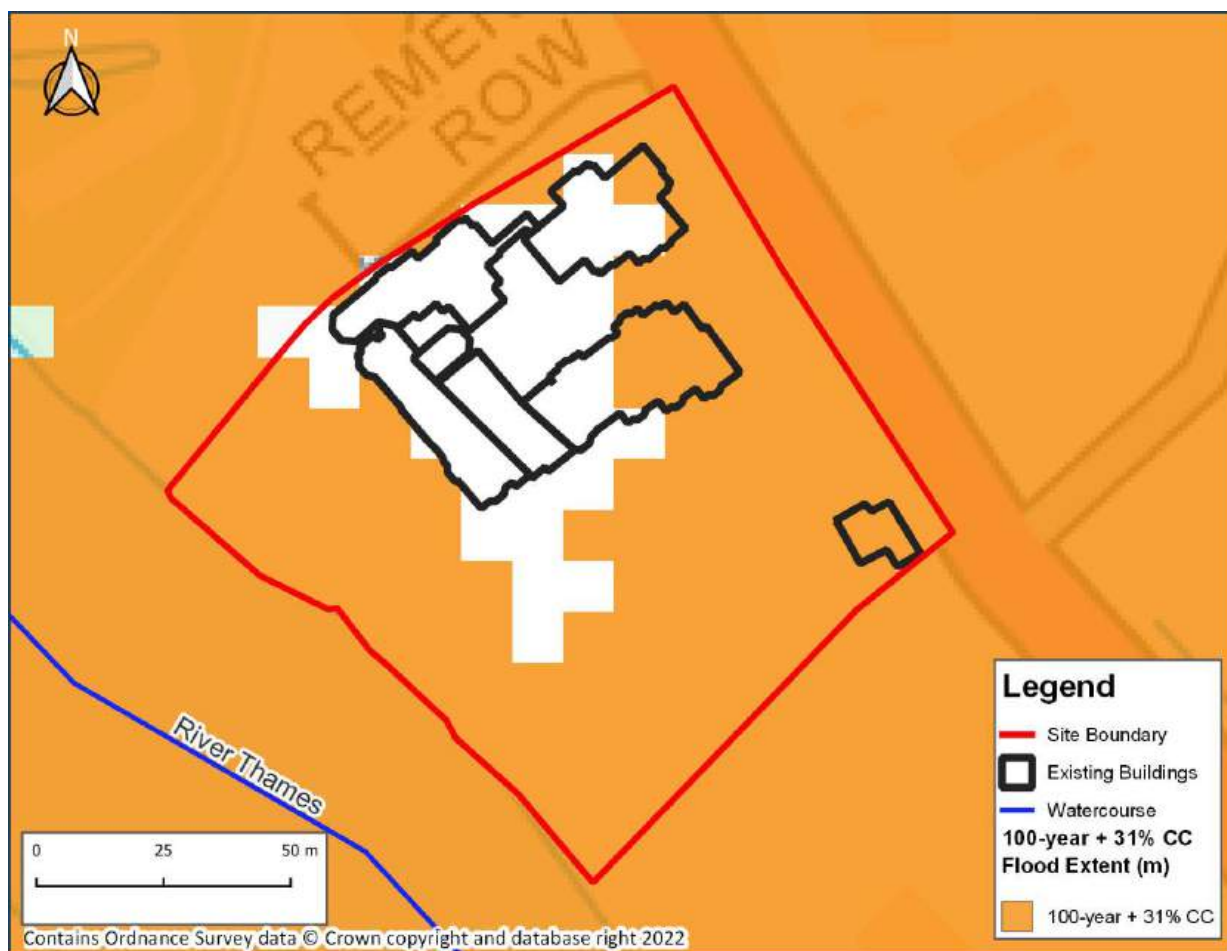


Figure 3-2: Baseline 100-Year flood extents with 31 % climate change scenario

Figure 3-2 shows the extent of flooding during the 100-year with 31% climate change scenario.

3.2 Baseline flood depths

The baseline flood depths during the 100-year with 31% climate change event in the vicinity of the site are shown in Figure 3-3.

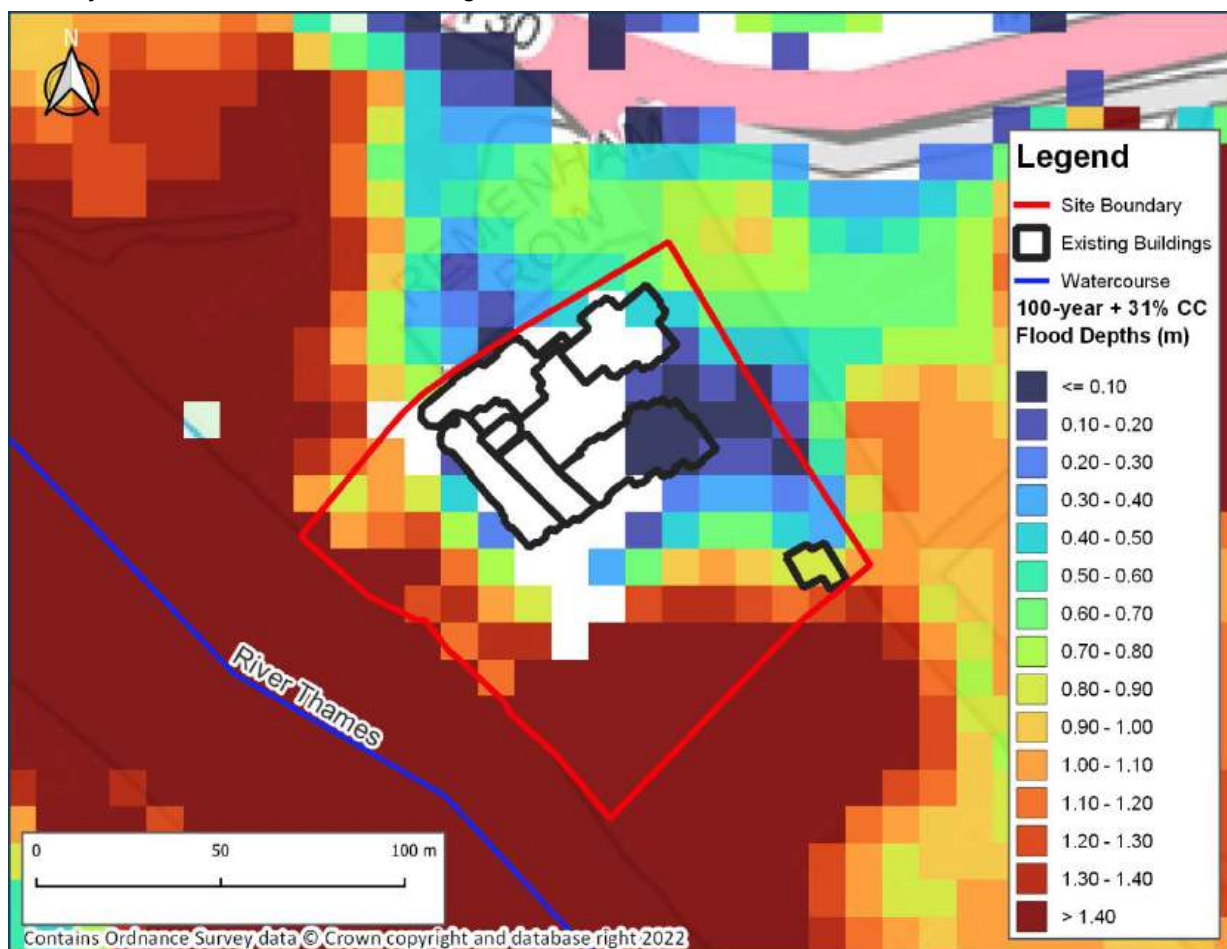


Figure 3-3: Baseline 100-year flood depths with 31% climate change scenario

Figure 3-3 shows the maximum predicted flood depths within the site during the 100-year with 31% climate change event. An approximate maximum depth of 1.89m is predicted within the southern part of the site.

3.3 Baseline flood levels

The baseline flood levels during the 100-year with 31% climate change return period are shown within Figure 3-4 below.

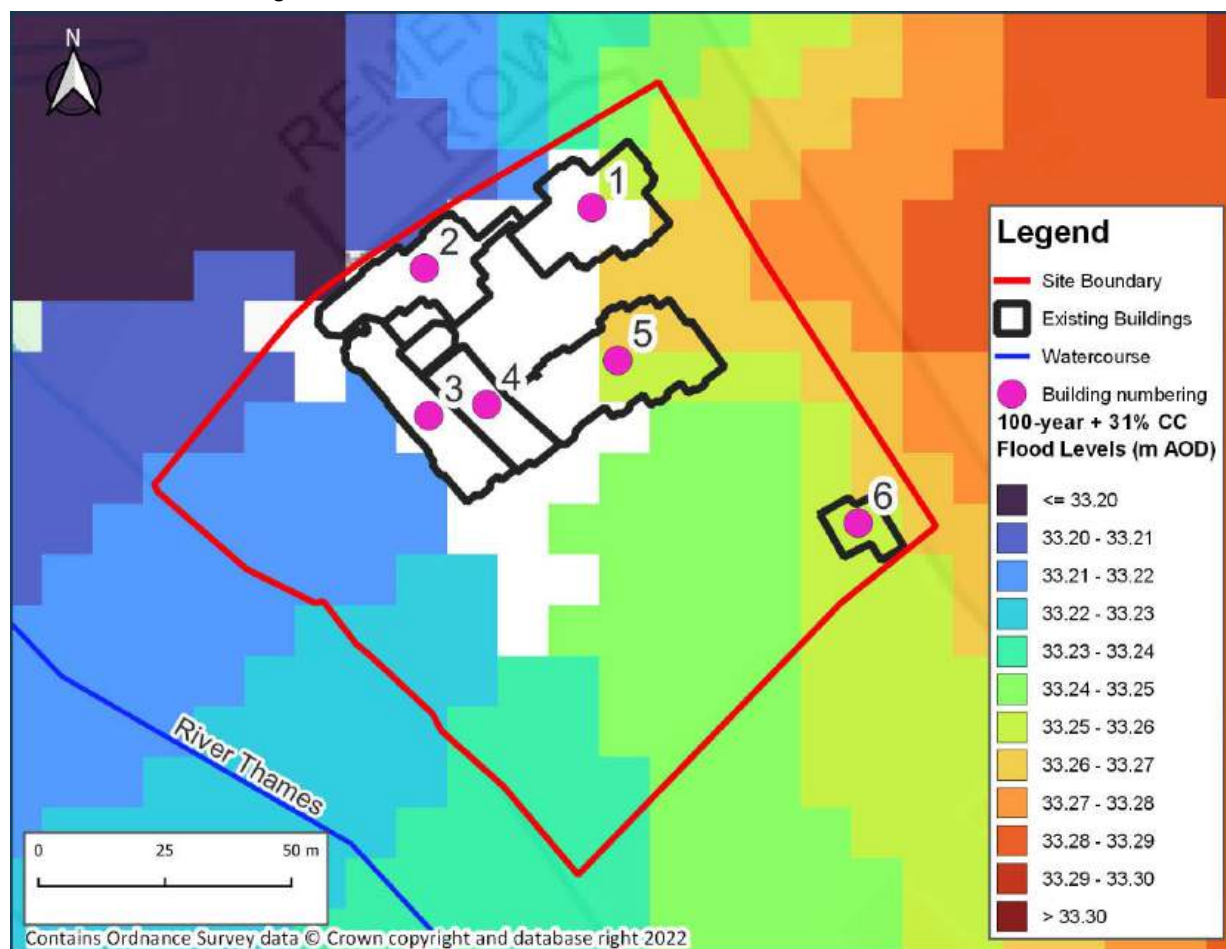


Figure 3-4: Baseline 100-year water levels with 31 % climate change scenario

Figure 3-4 shows peak water levels during the 100-year with 31% climate change event. Peak water levels related to each existing building are displayed in Table 3-1.

Building	Existing floor levels (m AOD) *	Peak water levels within existing building (m AOD)
1	33.26	33.27
2	33.83	33.20
3	33.84	33.22
4	33.48	No flooding
5	33.26	33.26
6	32.60	33.26

*: Estimated from Point 2 Surveyors Limited topographic survey dated June 2021

Table 3-1 shows that, during the 100-year with 31% climate change event, peak water levels are expected to exceed the existing floor levels for building 1 by 0.01m and by 0.66m for building 6.

3.4 Blockage risk analysis

Given the site's location in relation to Henley Bridge, a blockage risk analysis was undertaken. Figure 3-5 shows the location of the node 32.078BU in the model, where a 25% blockage was considered.

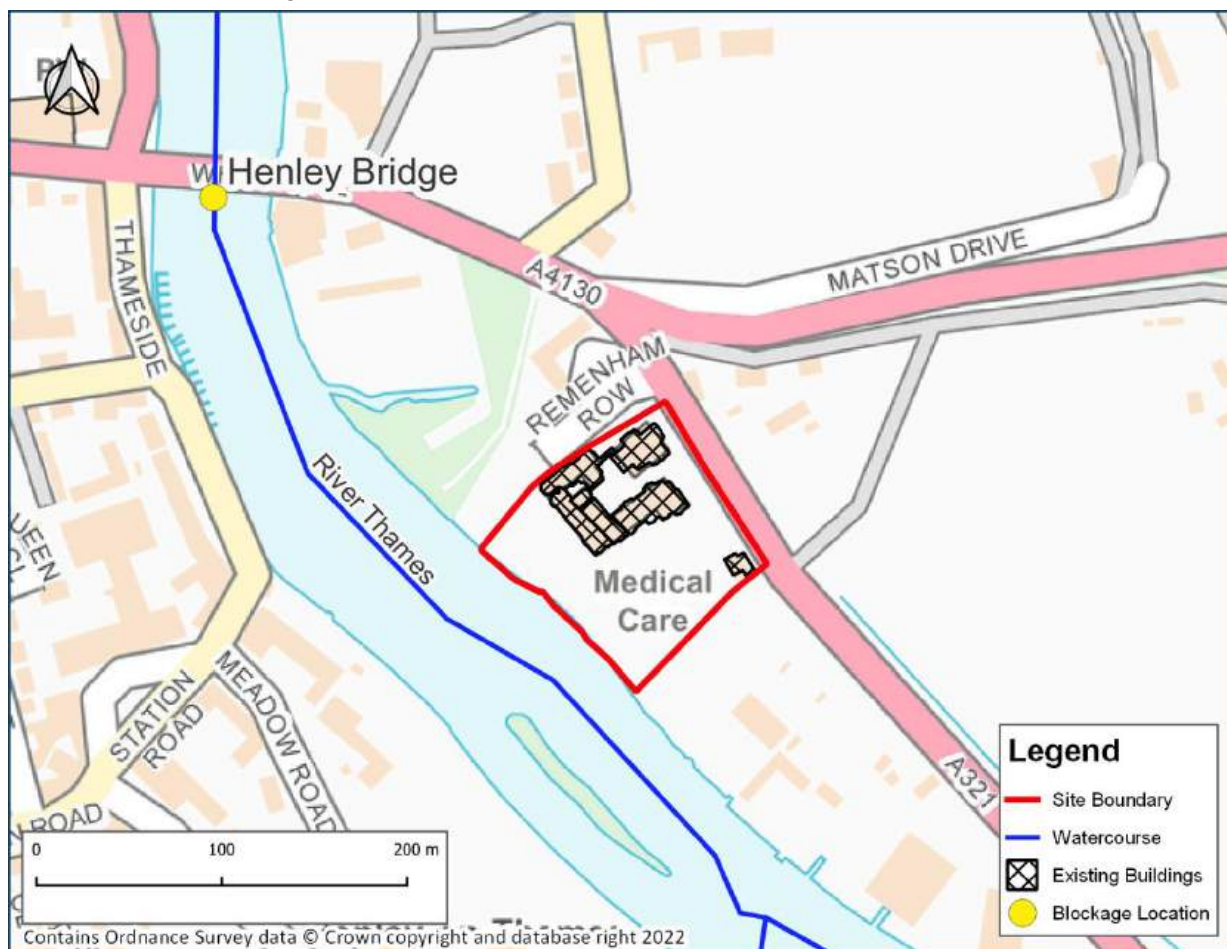


Figure 3-5: Baseline Blockage Risk Analysis location

Figure 3-6: Baseline Blockage Analysis (100-year + 31% climate change) shows the peak flood elevation during 100-year plus 31% climate change flood event when a 25% blockage is applied to Henley Bridge (node 32.078BU).

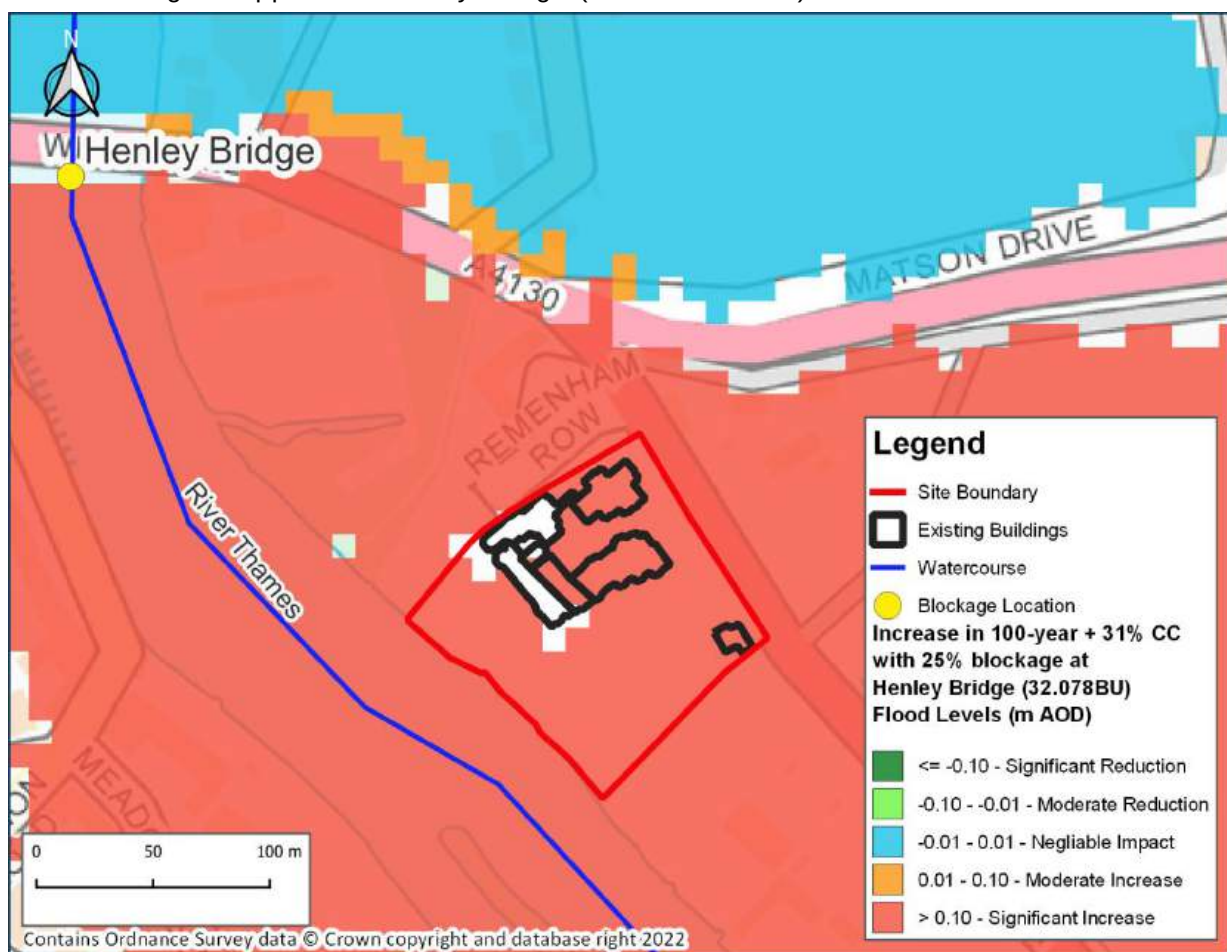


Figure 3-6: Baseline Blockage Analysis (100-year + 31 % climate change)

When compared with Figure 3-4, Figure 3-6 shows that a 25% blockage at Henley Bridge during a 100-year plus 31% climate change flood event will generate an increase of up to 0.77m (approximately) in flood level at the site.

3.5 Hazard-to-people classification

The fluvial hazard-to-people rating during a 100-year with (31%) climate change flood scenario has been mapped using the formula as suggested in Defra's FD2321/TR2 "Flood Risk to People". The different hazard categories are shown in Table 3-2 and the hazard classification to the site during the 100-year with (31%) climate change scenario is shown in Figure 3-7.

Table 3-2: **Defra's FD2321/TR2 "Flood Risks to People" classifications**

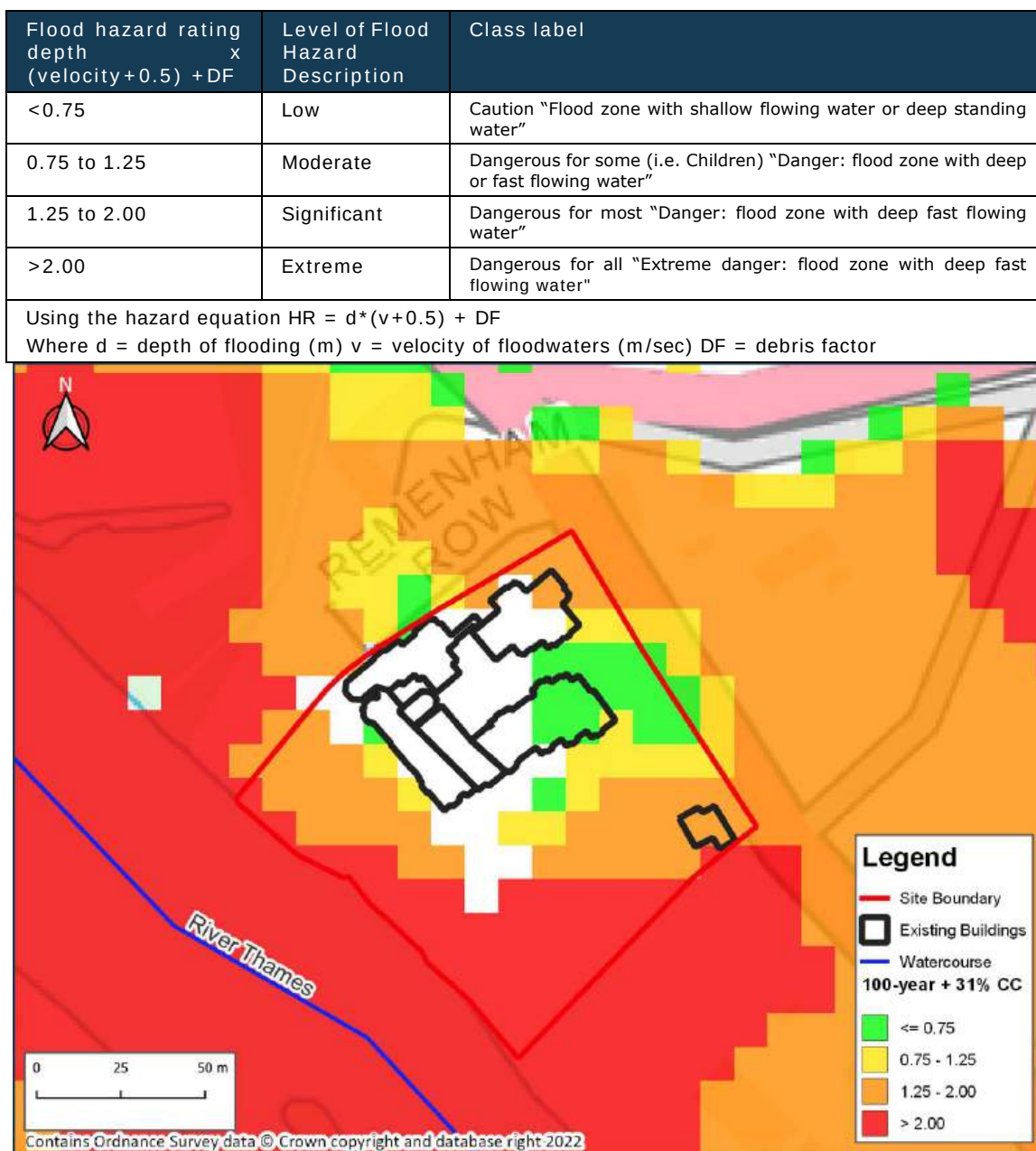


Figure 3-7: Baseline Hazard to People

Figure 3-7: Baseline Hazard to People shows that the Hazard to People rating for the majority of the site and along the A321 (which runs alongside the north-eastern site boundary) fall within the 'low' to 'significant' hazard categories.

3.6 Model result comparison

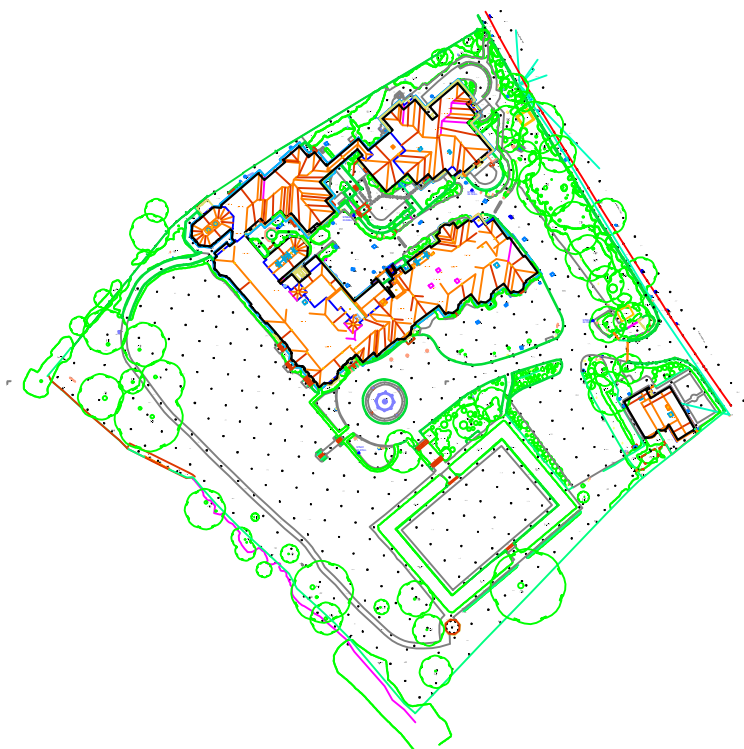
An 80mm decrease in peak water levels at the proposed site was noted when comparing the 100-year peak water levels at the proposed site from the 2019 Thames Mapledurham to Hurley with the updated model results produced by this hydraulic modelling study. This difference in peak water levels at the proposed site is considered negligible.

4 Conclusions and Recommendations

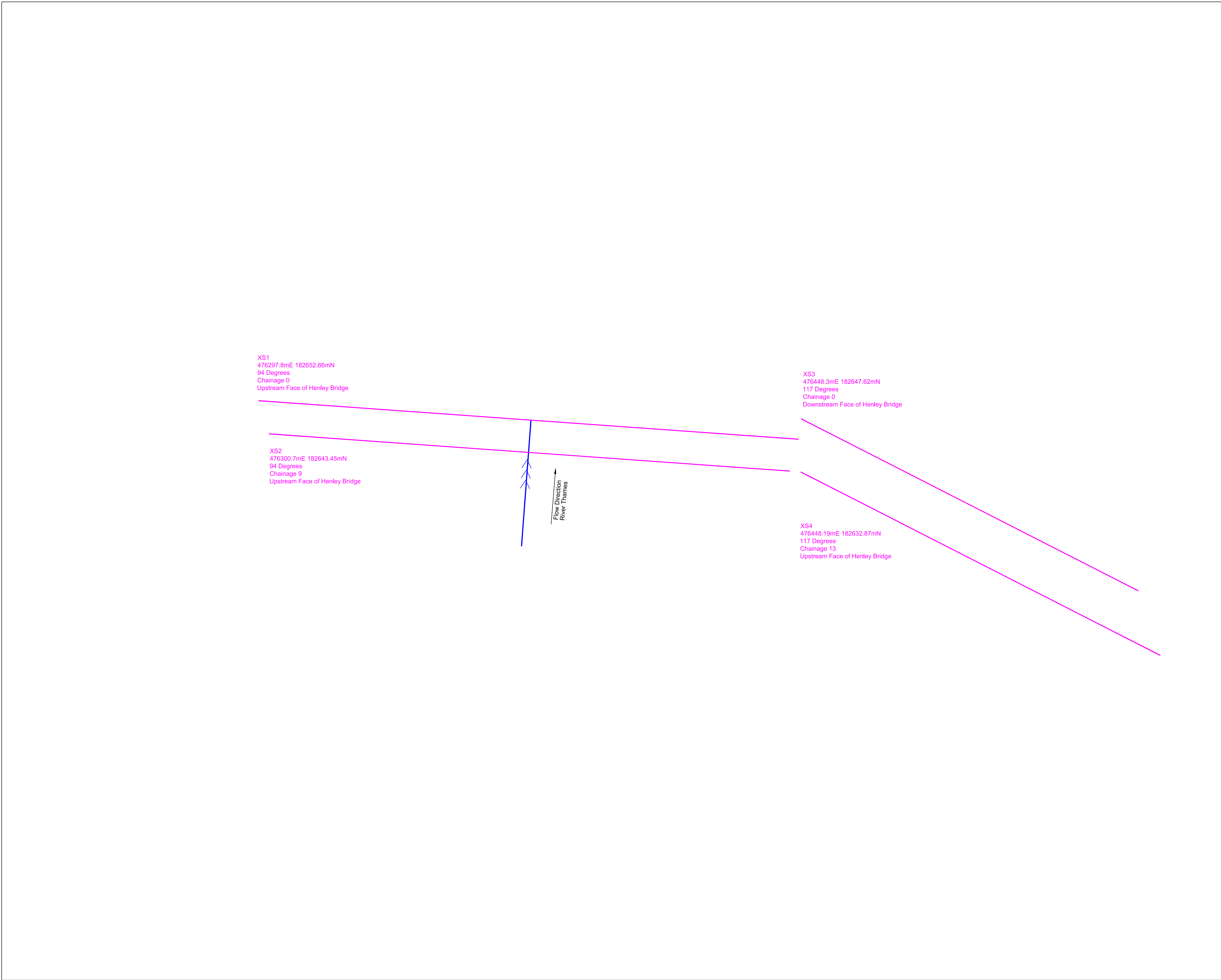
- JBA Consulting were commissioned by RPS to undertake a fluvial water hydraulic modelling study at Thamesfield, Wargrave Road, Henley-On-Thames.
- The model has been run for the baseline scenario for 30-year, 100-year, 100-year with 31% climate change and 1,000-year events in order to determine the existing fluvial flood risk to the site.
- Results from the hydraulic model were tested for their sensitivity to changes in Manning's roughness, downstream boundary conditions, and flows. A blockage risk scenario was undertaken for Henley Bridge during the 100-year with climate change flood event. Results from the sensitivity analysis indicate that the model results within the site are relatively insensitive to changes in roughness, downstream boundary or changed flow conditions.
- Results from the updated model runs show that:
 - o Water enters the site from overtopping of the River Thames' banks from all of the modelled 30-year, 100-year, 100-year +31% CC and 100-year fluvial flood events, as illustrated in Figure 0-1.
 - o The peak flood depth predicted within the site during the 100-year with 31% climate change event is 1.89m.
 - o During the 100-year with 31% climate change event, peak water levels are predicted exceed the existing flood levels in 2 off the existing buildings within the site boundary.
 - o During the 100-year with 31% climate change scenario the majority of the site falls 'low' to 'significant' hazard categories on the Defra Hazard to People map.
 - o The blockage risk analysis undertaken at Henley Bridge (node 32.078BU) during the 100-year with climate change flood event indicates that when a 25% blockage is applied, a significant increase in maximum flood depths of up to 0.77m is predicted within the site.

Appendices

A Appendix A – Site topographic survey



B Appendix B – Survey of Henley Bridge





Notes

This survey should only be relied upon for its original purpose. Grantham Coates Surveys Limited accepts no responsibility for use of this plan outside of the original remit, or by use of any party other than the original client.

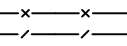
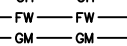
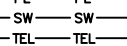
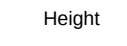
Whilst every effort has been made to identify all above ground details, it should be noted that some items may have been obscured at time of survey.

Below ground drainage information as been visually inspected from the surface and should therefore be treated as approximate only.

Where this survey has been carried out for the purpose of enabling trackside drainage design. The position of any running rail has been surveyed in line with a general topographic survey and should not be used for the purpose of track design.

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

Legend

AIR VALVE	AV	WATER TAP	TAP
BOLLARD	BD	TEMPORARY BENCH MARK	TBM
BORR HOLE	BHL	TELEPHONE CALL BOX	TCB
BUS STOP	BS	TELEPHONE POST	TEL
BT INSPECTION COVER	BT	THRESHOLD LEVEL	THL
BT BOX	BTB	TRAFFIC LIGHT	TL
CABLE TV INSPECTION COVER	CTV	TOP OF WALL	TOW
COVER LEVEL	CL	TELEGRAPH POLE	TP
DOWN PIPE	DP	UNABLE TO LIFT	UTL
DROPPED KERB	DK	VENT PIPE	VP
ELECTRICITY CONTROL BOX	ECB	RAIL WELD	WE
EAVES HEIGHT	EH	WATER METER	WM
ELECTRICITY MANHOLE	EM	WASHOUT	WO
ELECTRICITY POLE	EP		
EARTH ROD	ER		
FINISHED FLOOR LEVEL	FFL		
FIRE HYDRANT	FH	SURVEY STATION	△ GCS1
FOUL WATER	FW		
GULLY	GV		
GATE POST	GP	BUSHES	
GAS VALVE	GV		
INSULATED BLOCK JOINT	IBJ		
INSPECTION COVER	IC	HEDGES	
INVERT LEVEL	IL		
KERB OUTLET	KO		
LAMPPOST	LP	TREES	
LITTER BIN	LB		
MARKER POST	MK		
MP	MP		
POST	PO		
RODDING EYE	RE	GATE	
RIDGE HEIGHT	RH		
ROAD NAMEPLATE	RN		
ROAD SIGN	RS	SECURITY FENCE	
STUMP	SP	FENCE	
SOFFIT LEVEL	SF	OVERHEAD CABLES	
SIGNAL POST	SIG	FOUL WATER	
RAIL SLEEPER LEVEL	SLP	GAS MAIN	
SIGNALS AND TELECOMS BOX	STB	UG POWER LINE	
SIGNALS AND TELECOMS CABLE	STC	STORM WATER	
SIGNALS AND TELECOMS POST	STP	UG TELEPHONE	
SIGN POST	SN	WATER MAIN	
STOP TAP	ST		
STOP VALVE	SV		
STAY	SY		
STORM WATER	SW		

Control Table

Station	Description	Eastings	Northings	Height

Grid and Datum

Grid: OS National Grid **Datum: Ordnance Datum Newlyn**

Survey related to Ordnance Survey National Grid (OSGB36) via GPS and the OS Active Network.

A National Grid (OSGB36) coordinate has been established on site via Transformation OSTN15 and Geoid Model OSGM15, a further OS coordinate was used to orientate the survey to Ordnance Grid.

No scale factor has been applied to the survey

Title:

WATERCOURSE SURVEY AT
Henley Bridge
(Key Plan)

Client:

JBA CONSULTING
The Library
St. Philip's Courtyard
Coleshill
Warwickshire B46 3AD



**Grantham Coates
Surveys Ltd**

Land - Engineering - Building Surveyors

2 Arden Court, Arden Road, Alcester
Warwickshire, B49 6HN

Tel: 01789 764420

E-Mail: info@gcsurveys.co.uk
Web Site: www.gcsurveys.co.uk

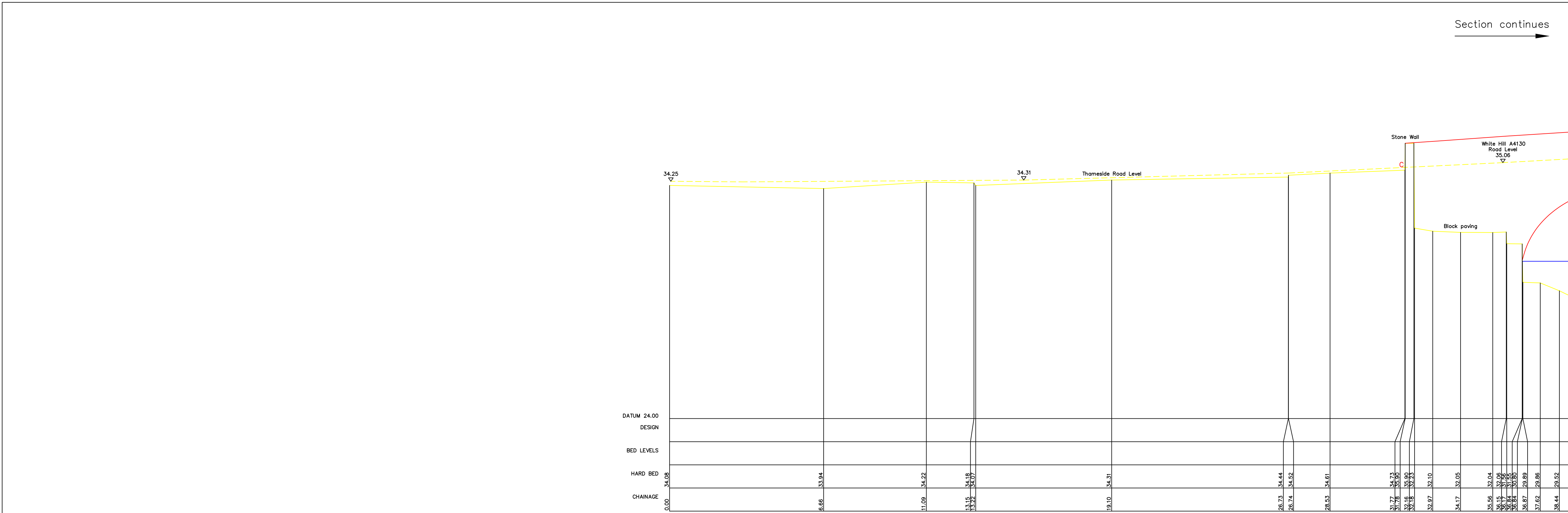


Drawing No:	Rev:
GCS/JBA/Henley Bridge/1	-

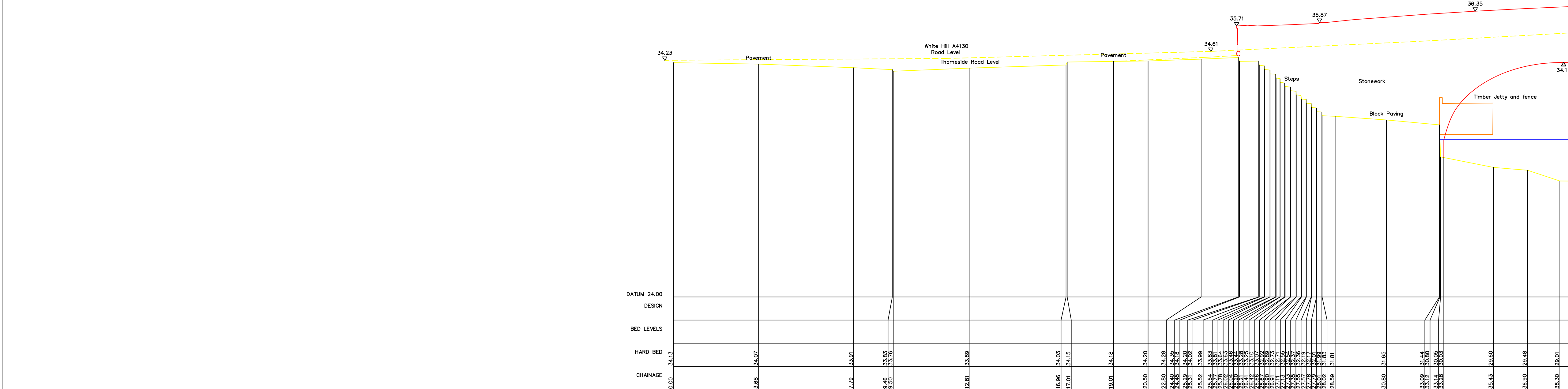
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Drawn:	Checked:	Scale:	Date:
SC	JMG	1:500	17/03/22

File Name:	Sheet size:	Sheet:
GCS-JBA-Henley Bridge-1	A1	1 of 6



XS1
476297.8mE 182652.66mN Brg 94
Chainage 0
Upstream Face of Henley Bridge



XS2
476300.7mE 182643.45mN Brg 94
Chainage 9
Upstream Face of Henley Bridge



Notes

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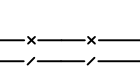
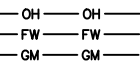
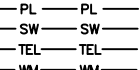
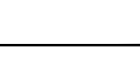
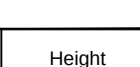
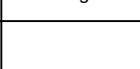
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BT INSPECTION COVER	BT	THRESHOLD LEVEL	THL
BT BOX	BTB	TRAFFIC LIGHT	TL
CABLE TV INSPECTION COVER	CTV	TOP OF WALL	TOW
COVER LEVEL	CL	TELEGRAPH POLE	TP
DOWN PIPE	DP	UNABLE TO LIFT	UTL
DROPPED KERB	DK	VENT PIPE	VP
ELECTRICITY CONTROL BOX	ECB	RAIL WELD	WE
EAVES HEIGHT	EH	WATER METER	WM
ELECTRICITY MANHOLE	EM	WASHOUT	WO
ELECTRICITY POLE	EP		
EARTH ROD	ER		
FINISHED FLOOR LEVEL	FFL		
FIRE HYDRANT	FH	SURVEY STATION	△ GCS1
FOUL WATER	FW		
GULLY	GV		
GATE POST	GP	BUSHES	
GAS VALVE	GV		
INSULATED BLOCK JOINT	IBJ		
INSPECTION COVER	IC	HEDGES	
INVERT LEVEL	IL		
KERB OUTLET	KO		
LAMPPOST	LP	TREES	
LITTER BIN	LB		
MARKER POST	MK		
POST	PO		
RODDING EYE	RE		
ROAD NAMEPLATE	RN		
ROAD SIGN	RS	SECURITY FENCE	
STUMP	SP	FENCE	
SOFFIT LEVEL	SL	OVERHEAD CABLES	
SIGNAL POST	SP	FOUL WATER	
RAIL SLEEPER LEVEL	SLP	GAS MAIN	
SIGNALS AND TELECOMS BOX	STB	UIG POWER LINE	
SIGNALS AND TELECOMS CABLE	STC	STORM WATER	
SIGN POST	SN	UIG TELEPHONE	
STOP TAP	ST		
STOP VALVE	SV		
STAY	SV		
STORM WATER	SW		

Control Table

Station	Description	Eastings	Northings	Height

Grid and Datum

Grid: OS National Grid

Datum: Ordnance Datum Newlyn

Survey related to Ordnance Survey National Grid (OSGB36) via GPS and the OS Active Network.

A National Grid (OSGB36) coordinate has been established on site via Transformation OSTN15 and Geoid Model OSGM15, a further OS coordinate was used to orientate the survey to Ordnance Grid.

No scale factor has been applied to the survey

Title:

WATERCOURSE SURVEY AT
Henley Bridge
(Cross Sections)

Client:

JBA CONSULTING
The Library
St. Philip's Courtyard
Coleshill
Warwickshire B46 3AD

 Grantham Coates
Surveys Ltd

Land - Engineering - Building Surveyors

2 Arden Court, Arden Road, Alcester
Warwickshire, B49 6HN

Tel: 01789 764420

E-Mail: info@gcsurveys.co.uk

Web Site: www.gcsurveys.co.uk

 THE SURVEY
ASSOCIATION
FULL MEMBER

 ICCS

Drawing No:

GCS/JBA/Henley Bridge/1

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Date:

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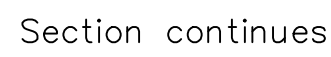
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Notes

Whilst every effort has been made to identify all above ground details, it should be noted that some items may have been obscured at time of survey.

Below ground drainage information has been visually inspected from the surface and should therefore be treated as approximate only.

Where this survey has been carried out for the purpose of enabling trackside drainage design. The position of any running rail has been surveyed in line with a general topographic survey and should not be used for the purpose of track design.

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

Legend

[illegible]

Control Table

Station	Description	Eastings	Northings	Height

Grid and Datum

Grid: OS *National Grid* **Datum:** *Ordnance Datum Newlyn*
Survey related to Ordnance Survey National Grid (OSGB36) via GPS and the OS Active Network.
A National Grid (OSGB36) coordinate has been established on site via Transformation OSTN15 and Geoid Model OSGM15, a further OS coordinate was used to orientate the survey to Ordnance Grid.
No scale factor has been applied to the survey

Title:

WATERCOURSE SURVEY AT Henley Bridge (Cross Sections)

Client:

JBA CONSULTING
The Library
St. Philip's Courtyard
Coleshill
Warwickshire B46 3AD



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el: 01789 764420



THE SURVEY
ASSOCIATION
FULL MEMBER

E-Mail: info@gcsurveys.co.uk
Web Site: www.gcsurveys.co.uk

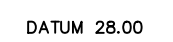


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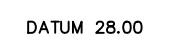
Date:	Notes:	Name:	Rev:

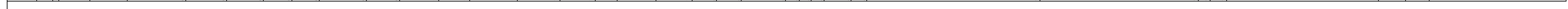
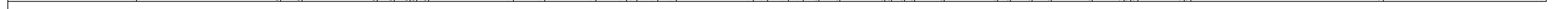
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XS4
476448.19mE 182632.87mN Brg 117
Chainage 13.2
Upstream Face of Henley Bridge





AV	WATER T
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WATERCOURSE SURVEY AT

Henley Bridge



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C Appendix C – Sensitivity analysis

The hydraulic model was tested for sensitivity to key model parameters which might impact flood risk at the proposed development site. This included the following scenarios:

- Increasing flows by 20%
- Increasing the Manning's n values by 20%. This both in the Flood Modeller 1D channel and in the 2D TUFLOW domain.
- Increasing the downstream boundary water levels by 250mm

The following sections discuss the impacts of these sensitivity scenarios.

C.1 Sensitivity to flow

Figure E-4-1 shows the changes in peak water level compared to the baseline 100-year event when an increase of 20% is applied to all inflows.

Figure E-4-1: Sensitivity analysis for +20 % inflows

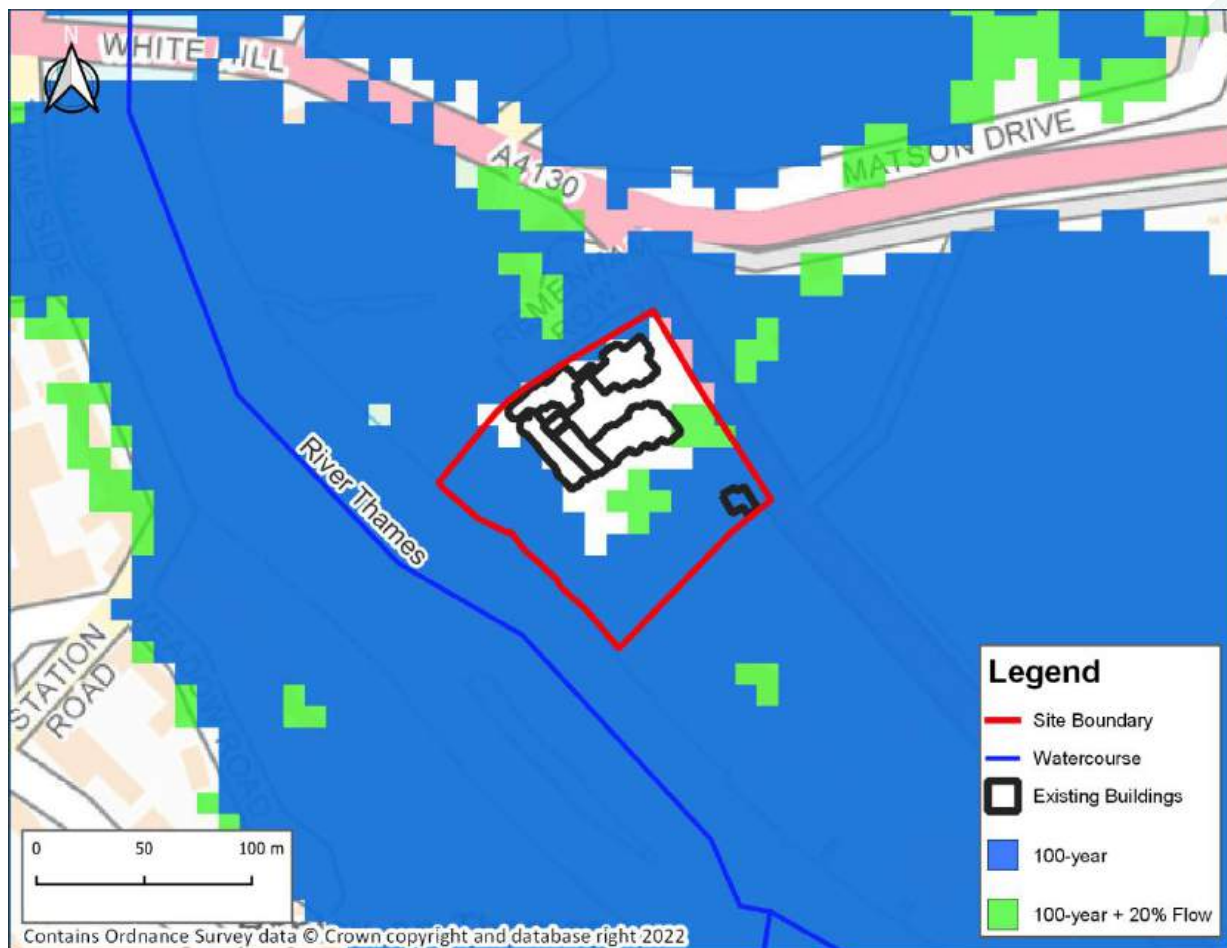


Figure E-4-1 indicates there that there are minimal changes in the peak water level results when increasing the flow with 20%. As a result, the model is considered to be insensitive to increases in flow.

C.2 Sensitivity to flow

Figure E-4-2 shows the changes in peak water level compared to the baseline 100-year event when an increase of 20% is applied to all inflows.

Figure E-4-2: Sensitivity analysis for +20 % inflows

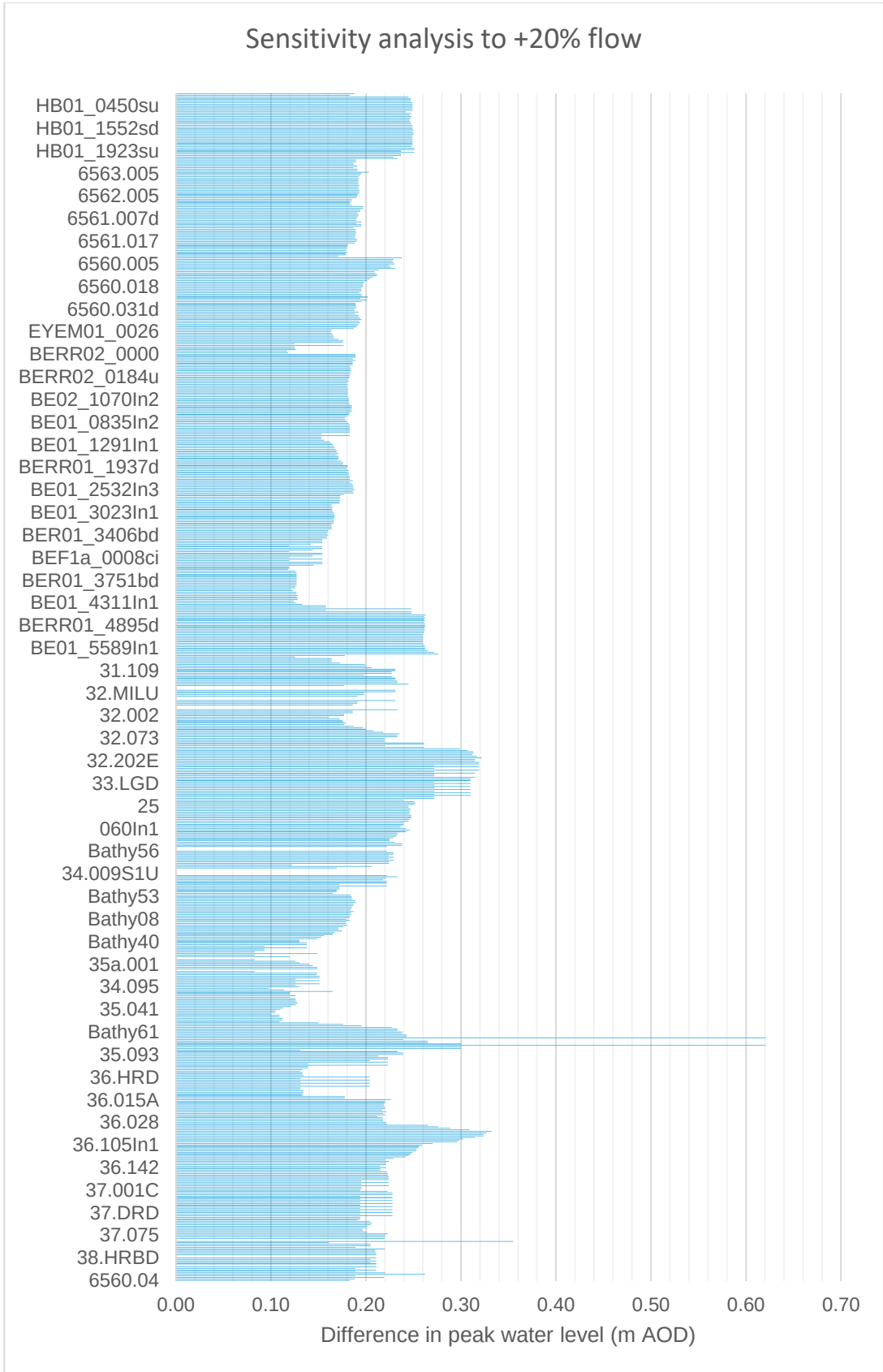


Figure E-4-2 indicates there is a maximum increase in peak water level of 0.62m around 36b.001 and Bathy58 cross sections, both located approximately 16km upstream of the site and is unlikely to affect the water levels at the site location. The results show that the model is considered insensitive to increases in flow.

C.3 Sensitivity to roughness

Figure E-4-3 shows the changes in peak water level compared to the baseline 100-year event when a change of +20% is applied Manning's 'n' in both the 1D and 2D domains.

Figure E-4-3: Sensitivity to changes of +20% in roughness

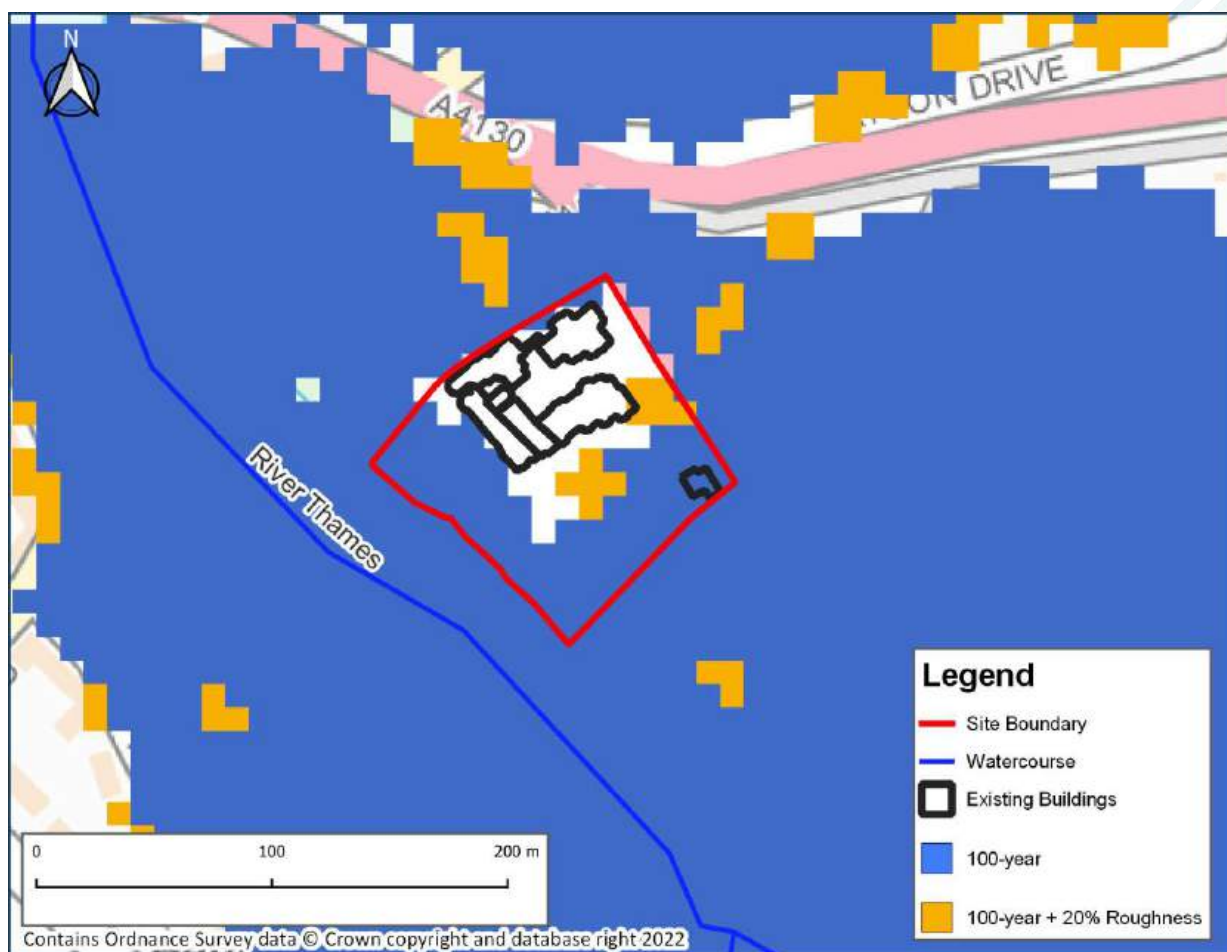


Figure E-4-3 indicates that, the model is relatively insensitive to the roughness values applied to the 1D and 2D domains within the site boundary, with minor changes in the peak flood extents predicted to occur within the south-eastern edge of the site boundary when roughness is increased by +20%.

C.4 Sensitivity to roughness

Figure E-4-4 shows the changes in peak water level compared to the baseline 100-year event when a change of +20% is applied Manning's 'n' in both the 1D and 2D domains.

Figure E-4-4: Sensitivity to changes of +20 % in roughness

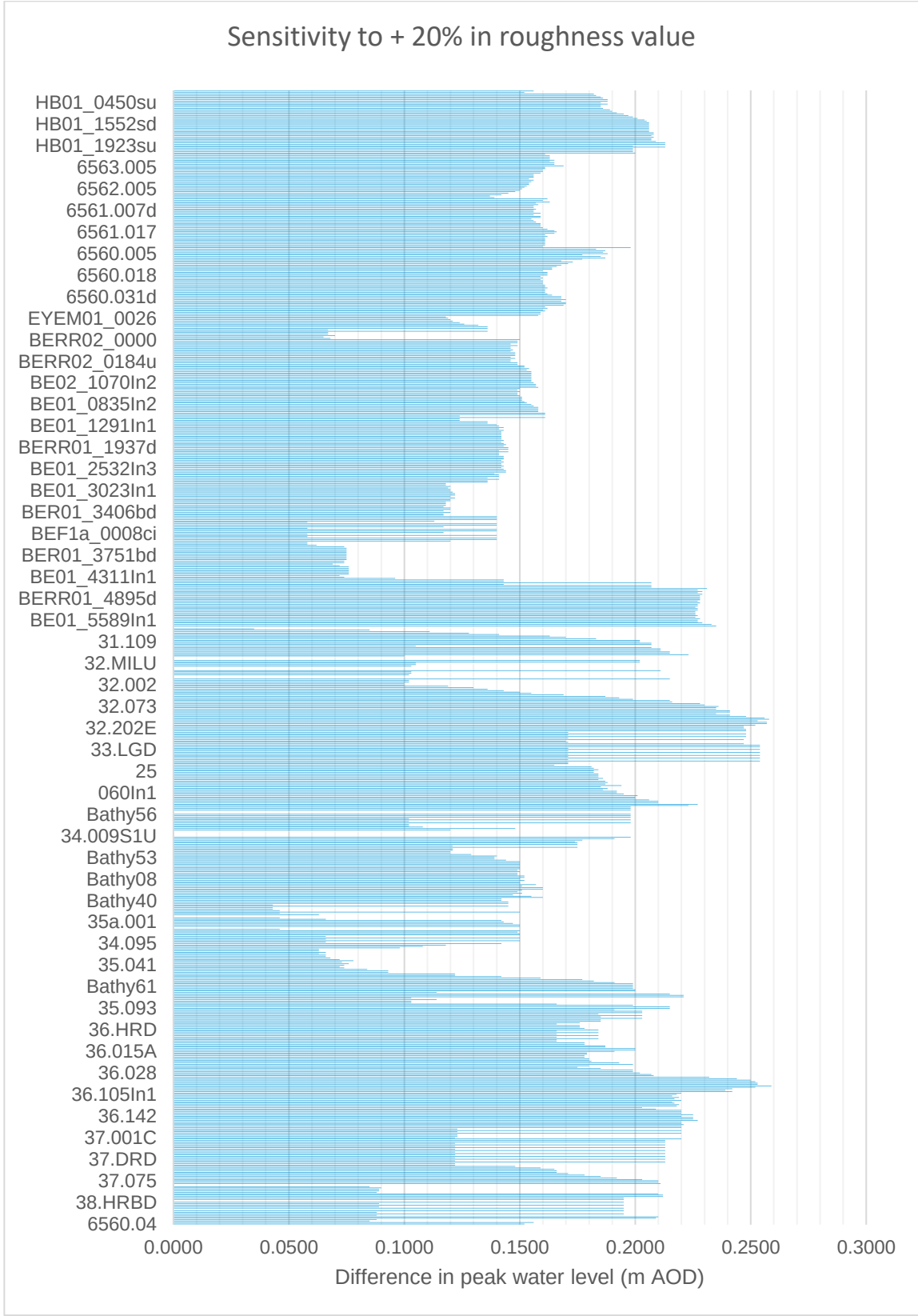


Figure E-4-4 indicates there is a maximum increase in peak water level of 0.26m around 36.071A cross section, which is located approximately 17km upstream of the site and is unlikely to affect the water levels at the site location. The results show that the model is relatively insensitive to increases in roughness values.

C.5 Sensitivity to downstream boundary conditions

Figure E-4-5 shows the changes in peak water levels compared to the baseline 100-year event when an increase of 250mm in water level is applied to the downstream model boundary condition.

Figure E-4-5: Sensitivity analysis for +250mm in water level at downstream boundary

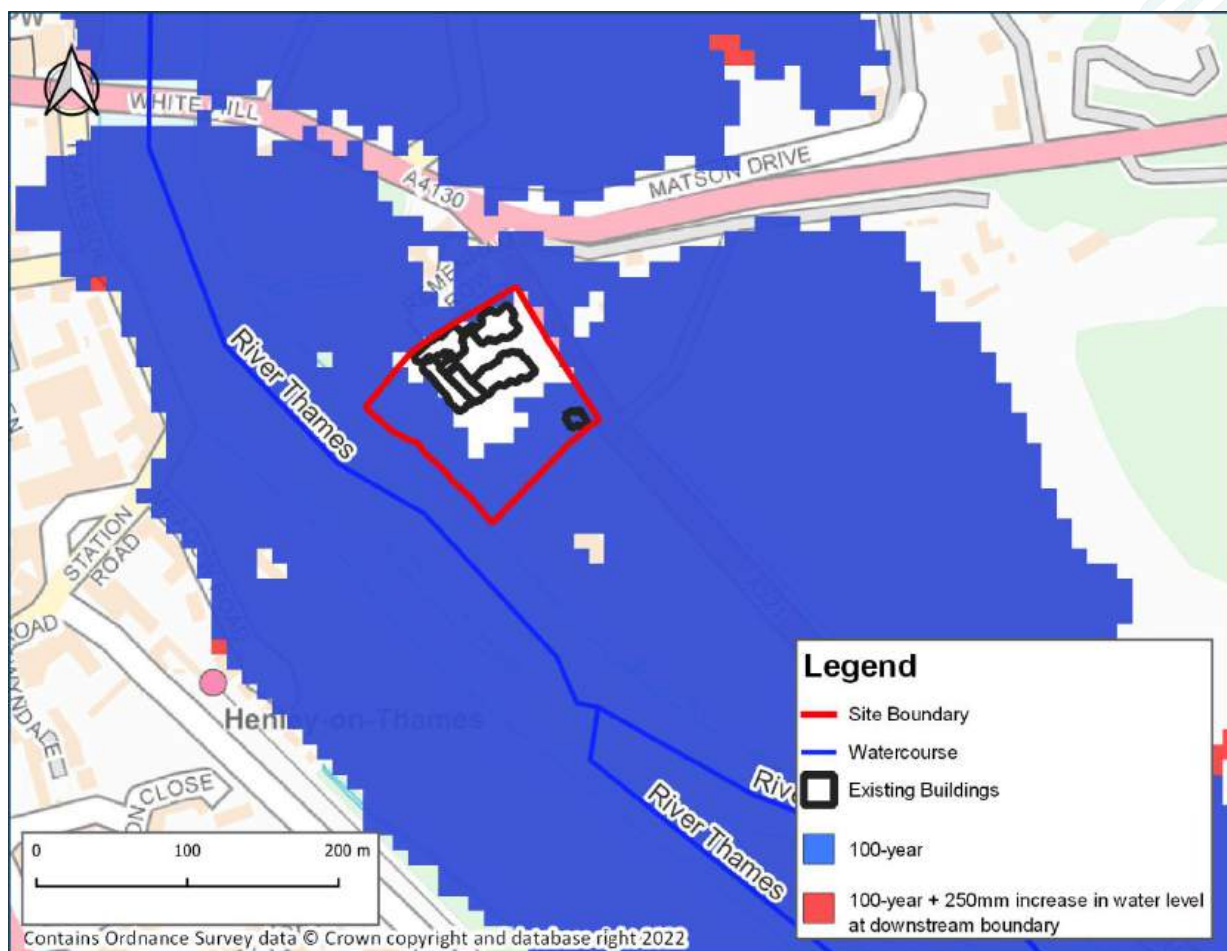


Figure E-4-5 indicates that minimal change can be seen due to the increase in water level at the downstream boundary. As a result, the model is insensitive to changes in downstream boundary condition within the site.

C.6 Sensitivity to downstream boundary conditions

Figure E-4-6 shows the changes in peak water levels compared to the baseline 100-year event when an increase of 250mm in water level is applied to the downstream model boundary condition.

Figure E-4-6: Sensitivity analysis for +250mm in water level at downstream boundary

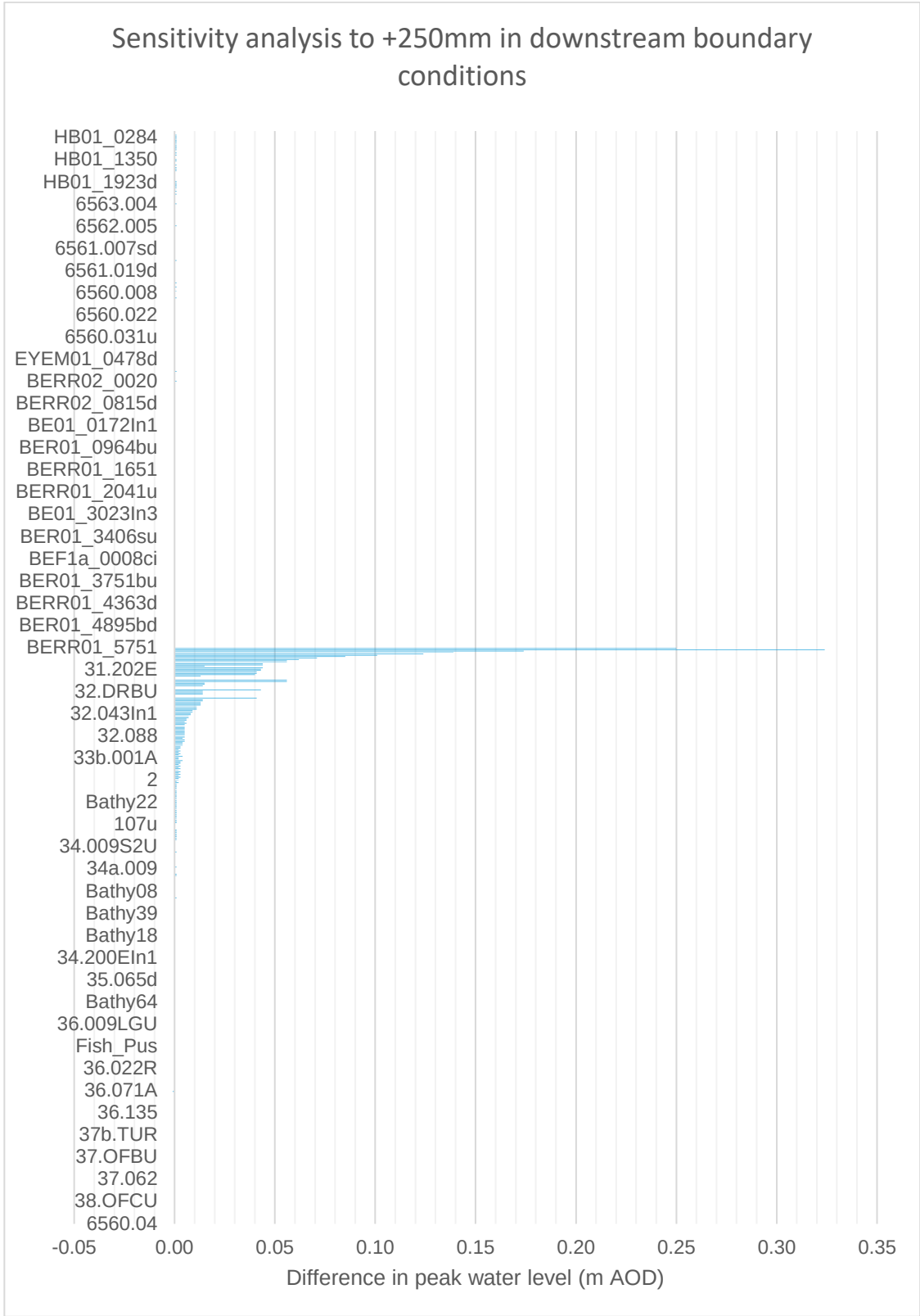


Figure E-4-6 indicates that the maximum increase in peak water level at the downstream boundary is 0.32m at cross section 31.055 located at the downstream extent of the model. The model is considered insensitive to changes in downstream boundary condition within the site.

D Appendix D – Flood Estimation Report

Flood estimation report

Introduction

This report template is based on a supporting document to the Environment Agency's flood estimation guidelines (Version 5, 2015). It provides a record of the hydrological context, the method statement, the calculations and decisions made during flood estimation and the results.

Contents

1	Method statement	1
2	Locations where flood estimates required	24
3	Statistical method	27
4	Discussion and summary of results	33
5	Annex	38

Revision history

Revision ref / date issued	Amendments	Issued to
V1 / 17 May 2017	None. Discusses the proposed methods and results of exploratory analyses.	Caroline Drewett
V2 / 21 July 2017	Changes as per EA comments from method statement and completion of Chapter 2 onwards.	Caroline Drewett
V3 / 29 August 2017	Clarifications added following an external review, mostly regarding assumptions used in the analysis	Caroline Drewett

Approval

	Name and qualifications	Date
Method statement prepared by:	James Molloy BE(Hons) MEngSc / Duncan Faulkner MA MSc FCIWEM CSci	20 April 2017
Method statement reviewed by:	Ben Gibson BSc MSc MCIWEM C.WEM / Rachel Huitson-Little MSc MCIWEM C.WEM CEnv	17 May 2017
Calculations prepared by:	James Molloy BE(Hons) MEngSc	20 July 2017
Calculations reviewed by:	Duncan Faulkner MA MSc FCIWEM CSci	21 July 2017

Abbreviations

AM.....	Annual Maximum
AREA	Catchment area (km ²)
BFI	Base Flow Index
BFIHOST	Base Flow Index derived using the HOST soil classification
CFMP	Catchment Flood Management Plan
CPRE.....	Council for the Protection of Rural England
FARL.....	FEH index of flood attenuation due to reservoirs and lakes
FEH.....	Flood Estimation Handbook
FSR.....	Flood Studies Report
HOST	Hydrology of Soil Types
NRFA	National River Flow Archive
POT.....	Peaks Over a Threshold
QMED	Median Annual Flood (with return period 2 years)
ReFH	Revitalised Flood Hydrograph method
SAAR	Standard Average Annual Rainfall (mm)
SPR.....	Standard percentage runoff
SPRHOST	Standard percentage runoff derived using the HOST soil classification
Tp(0)	Time to peak of the instantaneous unit hydrograph
URBAN	Flood Studies Report index of fractional urban extent
URBEXT1990	FEH index of fractional urban extent
URBEXT2000	Revised index of urban extent, measured differently from URBEXT1990
WINFAP-FEH	Windows Frequency Analysis Package – used for FEH statistical method

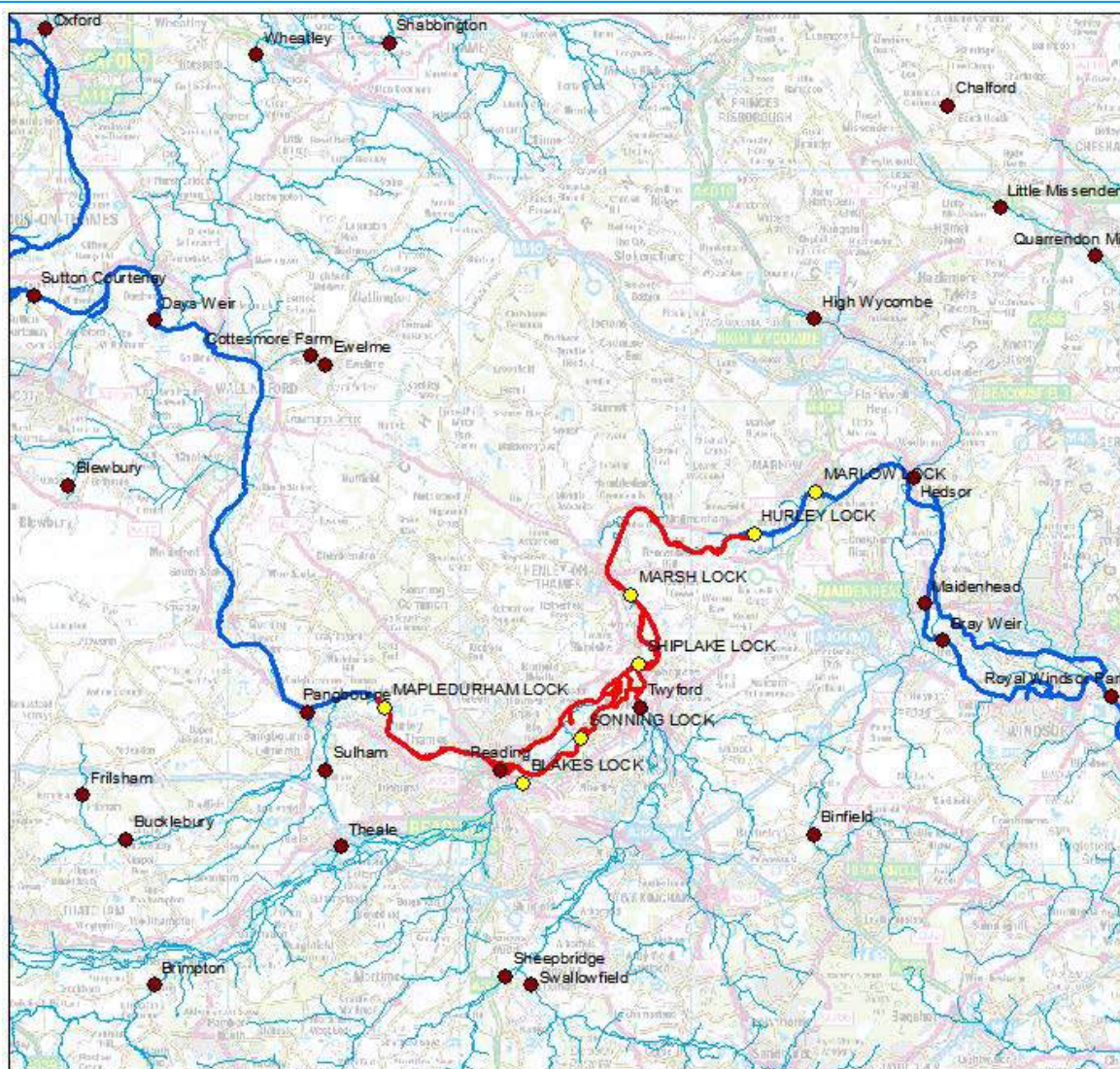
1 Method statement

1.1 Requirements for flood estimates

Overview • Purpose of study • Peak flows or hydrographs? • Range of return periods and locations	The aim of the project is to improve the quality of flood modelling from upstream of the Reading area down to Hurley and to provide improved flood mapping. As well as the Thames, the model is to include the River Loddon below the A4, along with the Borough Lake Stream and the St Patrick's Stream. Future use of the model outputs may also be required for flood alleviation modelling, in areas of flood risk including Caversham, Charvil and Hurley. The scope states that inflows to the models are to be obtained from the Thames at Mapledurham from the Thames (Sandford to Tilehurst) 2016 model and outflows from the model are to match the design inflow to the lower Thames 2016 model at Hurley. We will review whether or not these requirements are hydrologically sensible given that design floods are not usually expected to occur during the same event along the entire length of a river. The model is to be hydrodynamic so hydrographs will be needed. The project scope requires results for annual exceedance probabilities (AEPs) of 50%, 20%, 10%, 5%, 3.33%, 2%, 1.33%, 1%, 0.5%, 0.2% and 0.1%. For the 1% AEP event, three climate change scenarios are required, with flows increased by 25%, 35% and 70%. Note that these requirements were amended from those in the original scope (email from the Environment Agency on 20 February 2017). A brief review of a previous report on the hydrology of the study reach (Jacobs, 2011) is provided in Section 1.3.
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1.2 The catchment

Map of study reach and broader context showing surrounding gauging stations



Legend

- Flow gauge on NRFA
- Other flow/level gauges in study area
- Rivers to be modelled
- River Thames
- Other watercourses

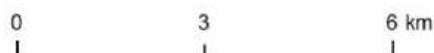
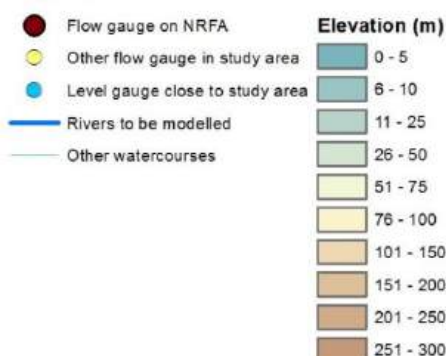
0 5 10 20 km

Contains OS data © Crown copyright and database right 2016

More detailed map of study reach



Legend



Contains OS data © Crown copyright and database right 2016

Description	Please refer to previous reports such as Jacobs (2011) for a description of the Thames catchment. The Redgrave Pinsent Rowing Lake between Caversham and Sonning Eye was created from Caversham Lakes (former gravel pits) and was completed in 2006. It is a significant conveyor of flood flows. The River Kennet joins the Thames in the eastern part of Reading. It drains a large catchment, which at this point forms 20% of the Thames catchment. The Kennet drains rural Chalk downs and so is a largely permeable catchment, with BFIHOST equal to 0.74. The River Loddon inflows enter the Thames both above and below Shiplake Lock. The Loddon adds 11% to the area of the Thames catchment at this point. It drains a moderately permeable catchment (BFIHOST 0.59) with some urbanisation (URBEXT2000 0.12). The Berry Brook rises in the eastern part of Lower Caversham and flows along the edge of the Thames floodplain, eventually joining the Thames via a network of
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channels near Shiplake. Its catchment area at the upstream limit of the model reach is very small, less than 1km ² . By the time it joins the Thames it is draining an area of some 10km ² , largely rural and with moderately high permeability (BFIHOST 0.68).
--

1.3 Review of previous reports

1.3.1 Context

The scope requires a review of the hydrology report on the River Thames (Mapledurham to Sonning), 2011. This is provided below. It also calls for familiarisation with the hydrology reports for the Whitchurch to Henley model (2000) and Henley to Hurley model (2002). The reports provided did not quite match either description; a report was provided on the Whitchurch to Hurley flood mapping study (1998) and this referred back to the 1991 Caversham Lakes flood hydrology report for the estimation of design floods.

There has been a large volume of work carried out relating to flood studies on the Thames. Selected reports have been reviewed to develop an understanding of the runoff characteristics of the River Thames and to inform on issues such as data quality and reliability of gauging sites in the study reach. This list includes but is not limited to:

- Beran and Field (Institute of Hydrology, 1988), Maidenhead, Windsor and Eton Flood Study Stage 2 Hydrology Report.
- PBA (1991), Caversham Lakes Development Flood Hydrology Analysis. Report to NRA.
- Crooks (1994), Changing flood peak levels on the River Thames, Proc. Inst. Civil Engrs.
- Dunsmore (1997), River Thames Flood Hydrology Design Curves. J. CIWEM (11).
- Jacobs (2005), Lower Thames FRM Project Hydrology Report Issue No. 6.0.
- Jacobs (2011), Reading Complex Change Project Final Mapping Stage. Hydraulic modelling report.
- Marsh and Harvey (2012), The Thames flood series: a lack of trend in flood magnitude and a decline in maximum levels, Hydrology Research **43**(3).
- JBA Consulting (2014) Lower River Thames Flood Modelling Study, Hydrology Report.

1.3.2 Review of 2011 hydrology

The Reading Complex Change Project was also known as the Mapledurham to Sonning project and this is the one referred to in the scope. It was carried out by Jacobs and the revised draft hydrology report, Reading Flow Gauge Flood Frequency Analysis, is dated March 2011. An earlier draft from September 2010 was peer reviewed by JBA in February 2011 and so the comments below do not attempt to repeat that detailed critique. Our 2011 review concluded that the results in the draft report were suitable for use in the initial development of the Reading Flood Alleviation Scheme and for the ongoing flood mapping study, but the method described in a supplementary note for estimation of the 1000-year flow was not suitable and needed significant revision.

To estimate design flows, a flood peak series for the Reading area was extended back to 1892 using data on tailwater levels at locks, which was converted to flow using high flow rating curves derived from flow data at Reading, Windsor and Days Weir in conjunction with tailwater levels at Goring, Whitchurch and Mapledurham Locks. These locks were chosen in preference of those downstream of the confluence with the River Kennett. This analysis relies on the assumption of an unchanging stage-discharge curve over the period from 1892 to date. The report mentions that there has been little dredging or gravel extraction over the relevant reach.

The analysis also incorporated historical data in the form of flood levels at Whitchurch from 1768, converted to approximate flows. The flood growth curve was adjusted informally to incorporate these data, an approach which can be improved on using the maximum likelihood method. As a result, design flows were increased for return periods longer than 50 years.

The resulting estimate of the 1% AEP flood at Reading was 375 m³/s. The 2003 flood would have had an AEP between 4.0% and 2.0% according to the results of the flood frequency analysis. The March 1947 flood peak had an AEP between 1.33% and 1.00% (using the best estimates for the event peak from Jacobs 2011).

The method used to estimate design flood hydrographs was similar to that employed on a previous project, the Lower Thames Flood Study (2005). The hydrograph shape at Reading was set to that of the 2003 flood. Inflows to the Thames between Reading and Bray/Windsor i.e. from the Kennet, Loddon, Wye and Cut, were set in order to match the flood frequency curve on the Thames at Bray/Windsor.

The hydraulic modelling report also provides some brief information on the hydrological analysis. Flow data for calibration of the model was obtained from gauges. Routing models were used to check that the inflow hydrographs when routed through the system sum to match the hydrographs gauged downstream at Windsor. Inflows were adjusted as necessary to account for ungauged portions of the catchment. This adjusted inputs give an acceptable match with the gauged flows at Windsor.

1.4 Source of flood peak data

Source	NRFA peak flows dataset, Version 5, April 2017. This contains data up to water year 2014-15 for England, Wales and Northern Ireland and 28 gauges in Scotland and up to water year 2005-6 for the remaining gauges in Scotland.
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1.5 Gauging stations (flow or level)

(at or very near to the sites of flood estimates)

Water-course	Station name	Gauging authority number	NRFA number	Catchment area (km ²)	Type (rated / ultrasonic / level...)	Start of record and end if station closed
Thames	Sutton Courtenay	1800	39046	3,425	Ultrasonic	1974 -
Thames	Days Weir	1900	39002	3,480	Rated	1938-
Thames	Maple-durham Lock	2199	n/a		Level and rating for flood flows	Late 1800s-
Thames	Reading	2200	39130	4,634	Ultrasonic	1992-
Thames	Caversham Lock		n/a		Level	Late 1800s-
Thames	Sonning Lock	2301	n/a		Level	Late 1800s-
Thames	Shiplake Lock	2302	n/a		Level	Late 1800s-
Thames	Marsh Lock	2495	n/a		Level	Late 1800s-
Thames	Hurley Lock	2497	n/a		Level	Late 1800s-
Thames	Maidenhead	2604	n/a	6,910	Ultrasonic	2003-
Thames	Taplow	2603	n/a	6,910	Ultrasonic	2003-
Thames	Windsor	2700	39072	7,124	Ultrasonic	1979-
Thames	Kingston / Teddington	3400	39001	9,948	Mixed	1882-
Kennet	Theale	2290	39016	1,033	Rated	1961-
Loddon	Twyford	2490	39138	751	Mixed	1994-

1.6 Data available at each flow gauging station in Table 1.5

Note: Comments on the Thames gauges are based on those in the Lower Thames draft hydrology report (JBA Consulting, 2014), with additions from the Environment Agency's Review of Flow Derivation Method documents.

Station name	Start and end of NRFA flood peak record	Update for this study?	Suitable for QMED?	Suitable for pooling?	Data quality check needed?	Other comments on station and flow data quality
Sutton Courtenay	None	Yes	n/s	n/s	No	See discussion of the nearby Days Weir gauge below
Days Weir	1938-2014	Yes	Yes	Yes	No	See below.
The Days Weir gauge is found in the NRFA peak flows database whereas the nearby Sutton Courtenay gauge is not. Comments provided by the Environment Agency Hydrometry team state that there is a higher level of confidence in flood flow measurements at the latter gauge however. The NFFS rating at Sutton Courtenay is also considered more reliable in flood conditions compared to the ultrasonic flow records (D Rylands, comments received 02 June 2017). The catchment areas of the two gauges are within 1% of each other. Sutton Courtenay was intended to be a replacement for Days Weir. Days Weir was built in 1885, modified in 1938 (when flow recording started) and rebuilt in 1968-9. It currently has 15 radial gates and a moveable thin plate weir. When the gates are fully opened the bankfull limit is about 140 m³/s (just below QMED); at higher flows there is a large amount of overspill and the weir is bypassed. Flows have been recorded at Sutton Courtenay using ultrasonic equipment since the start of the record in 1974. In 1982 the original single-path gauge was replaced by a multi-path device. A rating curve (calibrated from spot gaugings) is used to convert river levels to flows at Days Weir. In high flows, the rating curve calculates flows solely from the tailwater level. The location of the Days Weir gauge is not favourable, located on a meander and also potentially affected by backwater effects from the confluence with the River Thame 2km downstream. JBA (2014) compared flows at Days Weir from the rating with the limited number of spot gaugings available and found no bias at high flows. There were few spot gaugings available in the high flow range, with insufficient data to draw conclusions for the performance of the gauging site for flows larger than QMED. The reason given in the NRFA for Days Weir being suitable for pooling is that "Calculated flows are within 5% of measured flows, though this can increase to 10% over 100 m³/s." The highest flow recorded since the weir was replaced in 1969 is about 240 m³/s. The highest check gauging is at 140 m³/s. Given the amount of extrapolation of the rating and the potential for bypassing it is suggested that the rating would benefit from extension using a hydraulic model and until this happens the largest flood peak data at Days Weir should be treated with caution. Jacobs (2011) state that two hydraulic modelling studies have both indicated that the 1947 recorded flow figure at Days Weir is overestimated by approximately 60 m³/s.						
Maple-durham	None	n/a	n/a	n/a	Yes	See comments on Reading gauge.
Reading	None	n/a	n/a	n/a	Yes; see below.	See below.

Station name	Start and end of NRFA flood peak record	Update for this study?	Suitable for QMED?	Suitable for pooling?	Data quality check needed?	Other comments on station and flow data quality
The maximum reliable flow for Reading is estimated at 240m³/s according to the Gauging Station Data Quality (GSDQ) reports. This limit has been exceeded by just one or two floods since records began in 1992. The gauge is classed as good for high flow derivation by GSDQ in a two-page summary document for the gauge provided by the EA, but the "Review of flow derivation method" EA report and Jacobs (2011) state the GSDQ score is instead classed as "Fair". According to Jacobs (2011) this is due to a low relative height of the top-most ultrasonic path at the gauge. Comments received from the Environment Agency state that there is moderate underestimation at high flows due to bypassing. The flood forecasting model originally accounted for this bypassing using a high flow rating based on levels recorded at Reading gauge, but these are affected by gate movements just downstream at Caversham weir and sometimes by inflows from the Kennet, and also by the changes to the rowing course area further downstream. For these reasons since 2014 the forecast model has used the NFFS rating at Mapledurham instead during high flow conditions (developed by Capita, "Hydraulic Models for Forecasting, 2014 Improvements"). During this period, up to February 2017, there have been no major floods. This NFFS rating can be applied to the historic tailwater level record at Mapledurham, as an alternative to using the flow record at Reading. This gives an advantage of a much longer period of record at Mapledurham, available from the Lock Keeper POT records, as well as less sensitivity in levels than at Reading from the issues discussed above. Caution would need to be applied due to the step-change in Thames levels which occurred after the 1947 flood after the Thames was dredged. Gaps in the Lock Keeper record at Mapledurham in years where the AMAX flow was relatively low could be infilled from calculating a relationship between flows at Days Weir/Sutton Courtenay and Reading (with caution, as the Thame catchment enters the Thames between these gauges). It is recommended to review the NFFS Mapledurham rating, as flow gauging at this point is key to the flood-frequency calculations for this project (see the discussion of Rating Equations below) Notes from the Environment Agency state that there were problems with the ultrasonic flow gauge over the winter 2013-14 period due to debris affecting the measuring equipment at the gauging site. JBA (2014) compared the flows measured by the ultrasonic gauge with spot gaugings and concluded that the gauge performed moderately well, apart from in February 2014 as noted above. It was not possible to comment on the performance of the gauge during out-of-bank conditions (flows above 240m³/s), due to a lack of spot gaugings in this range. Hence, it was decided that an AMAX record derived from this gauge will give a representative QMED value and could potentially also be used to estimate design flows for short return periods.						
Maidenhead and Taplow	None	n/a	n/a	n/a	No	See below.
The Maidenhead and Taplow gauges are located just downstream of the point where the Jubilee River extracts flow from the Lower Thames, using ultrasonic equipment to measure channel flows. Flow diversion from the River Thames occurs for incoming flows above 180m³/s. For the purposes of the Lower Thames modelling study, the flow records were added at these two sites to provide a composite record, referred to as 'Maidlow'. These gauging sites were opened in 2002 to monitor flows after the construction of the Jubilee River flood alleviation scheme. Flows at both sites are measured using multi-path ultrasonic gauges. The gauges captured the January 2003 event on the Thames, but were not in place for a sufficient length of time to allow for an adequate calibration. Hence records of the January 2003 flood are less reliable at this site. The GSDQ reports for these sites give a "Good" quality flag for high flow measurements at both sites. Notes provided by S. Everitt and L. Lovell state that the upper range of reliability of these gauges is unknown, but likely to be above 230m³/s and 160m³/s for the Maidenhead and Taplow gauges respectively, which were the peak flows observed in February 2014. Hence the combined upper reliable limit for 'Maidlow' is of the order of 400m³/s. . These notes also state that the Taplow gauge did not perform well during the peak of the January 2014 peak, but appeared satisfactory for the February 2014 event. There are also reported problems with shifting bed levels over time at both sites and with turbulence in the measurement channel caused by an island upstream of the Maidenhead gauge.						
Windsor	1979-2014	No	Yes	No	No	Ultrasonic data have been used to measure flows from 1979. Data quality reviewed in detail in the JBA 2013 Lower Thames study. Past studies have attempted to extend the flow record here using nearby lock keeper records. There are concerns that the high-flow data quality at this gauge are lower quality due to the gauge location on a bend, and possible bypassing in extreme floods. The EA report a reliable upper limit of 330m³/s.

Station name	Start and end of NRFA flood peak record	Update for this study?	Suitable for QMED?	Suitable for pooling?	Data quality check needed?	Other comments on station and flow data quality
Kingston	1882-2014	No	Yes	Yes	No	Ultrasonic equipment has been used at Kingston to record flows since 1974. However, sub-daily resolution data are available here from 1984 onwards only. A much longer daily-resolution record is available from the Teddington site (located 2km downstream of Kingston), where flow was recorded twice-daily at low tide via a complex combination of weirs, gates and sluices. This earlier period of record extends back to the late 1800s.
Theale	1961-2014	Yes	Yes	Yes	Yes	There are two rating curves available at this site (WISKI and NFFS), giving significantly different flows in flood conditions. Following discussions with the EA, it was decided to apply the NFFS rating in this study. See further discussion below.
Twyford	None	n/a	n/a	n/a	No	Two side-looking ADCP devices, installed since 2010, located within two rectangular road bridge culverts. These replaced an ultrasonic gauge shortly downstream which was shut down following persistent mechanical and in-channel issues with the lower paths of the ultrasonic caused by a build-up of silts and weeds, resulting in dropouts and suspicious readings in the data. Substantial gaps in the flow data supplied from the ultrasonic gauge for the period 2006-10. A velocity index rating was developed from numerous flow gaugings. In November 2016 corrections were made to the calculation of flow and stage. GSDQ classes this gauge as "Caution" for high flow derivation.

1.7 Rating equations

Station name	Type of rating e.g. theoretical, empirical; degree of extrapolation	Rating review needed?	Comments and link to any rating reviews
Days Weir	Theoretical, checked with gaugings.	No; outside study area	Non-standard weir calculation for peak flows that is specific to this site. Rating formulae based upon gaugings - tailwater calibration applies for flows > 70 m ³ /s; above 100 m ³ /s overspill occurs.
Mapledurham	Empirical	Yes (see details of review below)	Rating derived by regression of tailwater level at Mapledurham on flow from the ultrasonic gauge at Reading. Currently used in the NFFS to estimate peak flows at Reading. Rating was derived by Capita (2014), recommending that Mapledurham tail levels are less sensitive to downstream effects from the Kennet and downstream rowing lakes, compared to the Reading gauge. A review of the Mapledurham NFFS rating is provided below.
Theale	Theoretical, checked.	No	There is an alternative rating used in NFFS which can give very different flows from the rating applied in WISKI. Peak flows from the former are considered more accurate in flood conditions, hence it is proposed to use the NFFS rated flows in preference to the WISKI rating at Theale in this study, as agreed following a conversation with EA hydrometry staff (pers. comm with D Rylands, 18/07/2017). It is noted that neither rating accounts for possible bypassing and storage through nearby gravel pits. Comparisons of flow hydrographs for an available period of overlapping data (2010 – 2016) show that the NFFS rating gives a close match to flows at the relatively new Blakes Lock gauge near the Thames confluence downstream, indicating that this issue is less critical if using the NFFS rating. This also indicates that adjustments for the additional drainage area downstream of the Theale gauge to the Thames confluence are not necessary when representing the entire Kennet contribution to flows in the Thames. The Kennet modelling study, being carried out in parallel to this study, also proposes to use the NFFS rating at Theale.
Marsh Lock	Not currently rated	Yes (see details below)	Moderately long tail water level record available (22 years of 15-min data, plus the long historic POT series of water levels), located downstream of the confluence of the River Loddon. Some issues with frequent spikes and gaps in the telemetry however. See below for a discussion of development of a rating curve at this site.

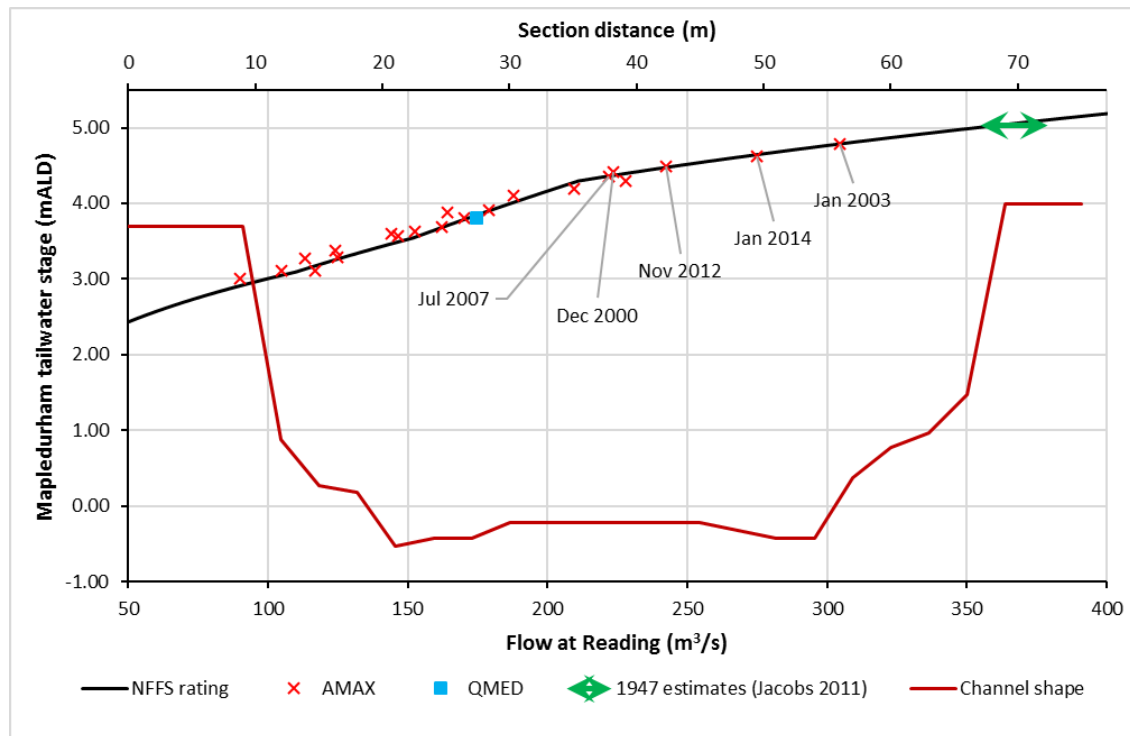
1.7.1 Analysis of Mapledurham existing NFFS rating

The existing NFFS rating curve for flows at Reading related to tailwater levels at Mapledurham is as follows, where $Q = C * (h - A)^B$ (previously reported by Capita, 2014):

Limb	C	A	B	SGmax
1	2.6493	0.0	3.2934	3.10
2	7.3968	0.0	2.3859	3.55
3	17.3902	0.0	1.7112	4.30
4	1.4628	0.0	3.4084	7.00

This rating is not applicable for levels at the downstream Mapledurham gauge below 2.44mALD.

The NFFS rating was checked by plotting pairs of AMAX flows from Reading against the corresponding peak levels at Mapledurham (1995 – 2016 water years). The best available range for the peak flow of the 1947 event, taken from Jacobs (2011) is also plotted.

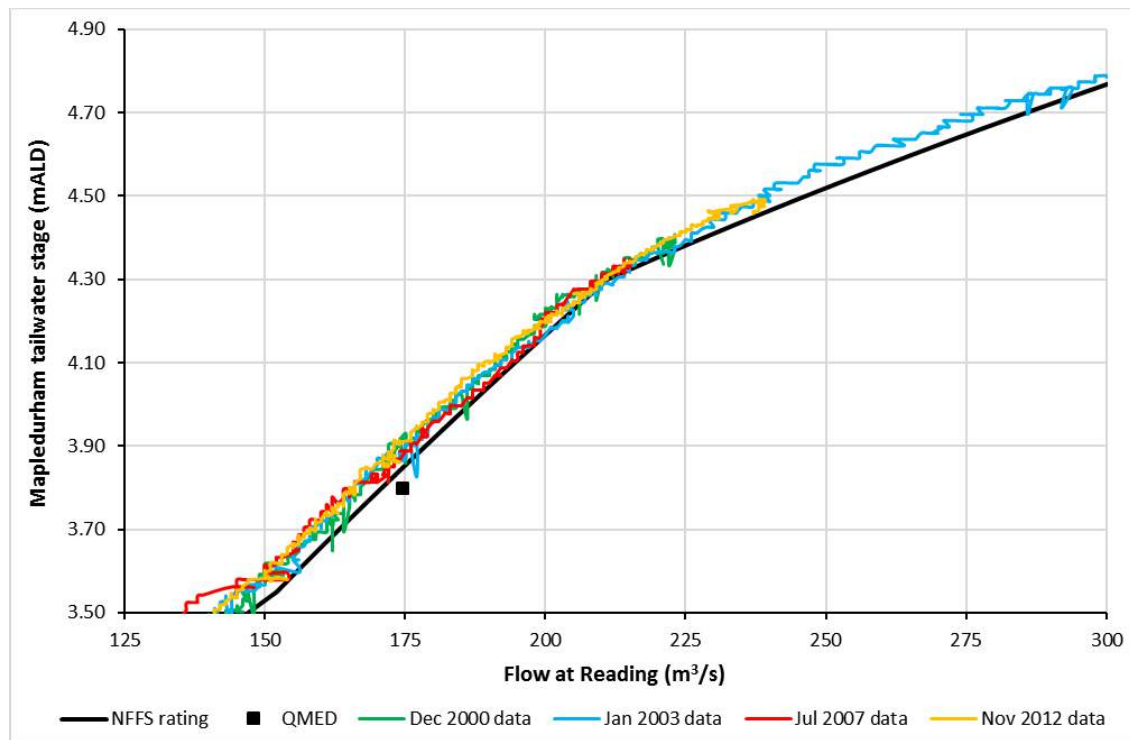


The comparison above shows that:

- The rating curve parameters appear sensible. The limb break positions also appear sensible, for example between limbs 2 and 3 a break occurs slightly above bank-full conditions.
- Flows are contained in-bank up to QMED only.
- The Mapledurham NFFS rating over-estimates flows less than QMED, however the error is not significantly large and would have little effect on overall flood-frequency calculations of higher return period peak flows.
- At and above QMED, the rating appears to perform well, matching well to peaks of large events.
- The rating was mainly derived using measured flows at the Reading ultrasonic gauge combined with levels at Mapledurham. The peak spot gauging at Reading is 240m³/s. The Capita 2014 study also used model output to estimate the rating shape for very large events, for example the March 1947 flood.

A similar comparison was carried out using the rising limb of four large event hydrographs at Reading & Mapledurham as follows (two before and two after the changes at the rowing lake):

- December 2000
- January 2003
- July 2007
- November 2012



This more detailed comparison shows that:

- The NFFS rating at first appears to slightly over-estimate flows by 5 - 10m³/s at Reading for extreme events. However it is known that there is a minor bypassing route of the Reading gauge (Jacobs, 2011) in large floods which accounts for this apparent small discrepancy, which the NFFS rating takes into account.
- A similar issue for smaller flows less than QMED as noted above is also apparent in this comparison.
- There appears to be no change in the stage-discharge relationship using the Mapledurham stage data before and after construction of the rowing lake, which confirms the assumption that the NFFS rating is insensitive to this issue.
- Above QMED, up to a stage of 4.40mAOD, there is an excellent match with the gauged data.

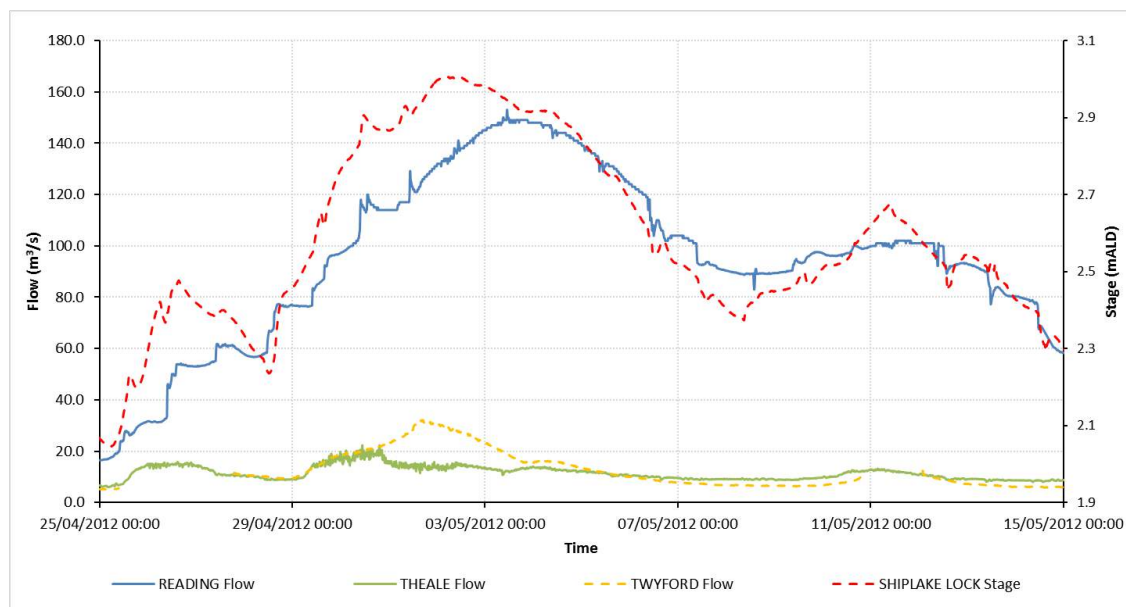
Following a discussion with EA staff (pers. comm with D Rylands, 18/07/2017), it was recommended that the ultrasonic record at Reading is reliable up to bankfull, but the NFFS Mapledurham rating is considered more reliable above this. Using the plots above and comparing the two flow datasets, it was decided here to apply a cutoff flow of 180m³/s (roughly corresponding to QMED at this site). Flows below this threshold are taken from the Reading ultrasonic gauge in this study, above this limit flows are taken from the Mapledurham NFFS rating.

1.7.2 Rating development at Shiplake / Marsh Lock

A separate report for the new Marsh/Shiplake Lock rating described below is beyond the agreed scope of this study. All relevant details for these calculations are provided below,

Flows downstream of the Loddon confluence could be estimated by creating a “virtual” flow gauge, using a sum of flows from Reading, Theale and Twyford. However the quality and presence of numerous gaps in the Twyford record limits the accuracy of this method. The Loddon adds a considerable area of over 500km² to the drainage area of the Thames downstream, so represents a significant inflow to the system. Alternate possibilities include using higher quality gauges further upstream in the Loddon catchment or downstream on the Thames. The significant flow accretion between these more distant gauges would require the use of simplifying assumptions when recreating the virtual flow series however. (for instance, there is over 200km² of drainage area between the Sheepbridge/Swallowfield gauges and the Twyford gauge on the Loddon).

As an alternative to the above, it was decided to estimate a rating curve at a downstream lock gauge on the Thames, where there are good quality continuous level records. Development of a rating curve is beneficial downstream of the Loddon confluence as it would help quantify the behaviour of the Thames and how flows might be affected by the Loddon inflow. This would also be useful at the model downstream boundary, as the overall increase in catchment area from here to Hurley Lock is relatively small. It appears that levels at Shiplake Lock are affected by inflows from the Loddon as shown in the example plot below (the plot shows an early peak in the Shiplake levels that cannot be attributed to flows from Reading or Theale):

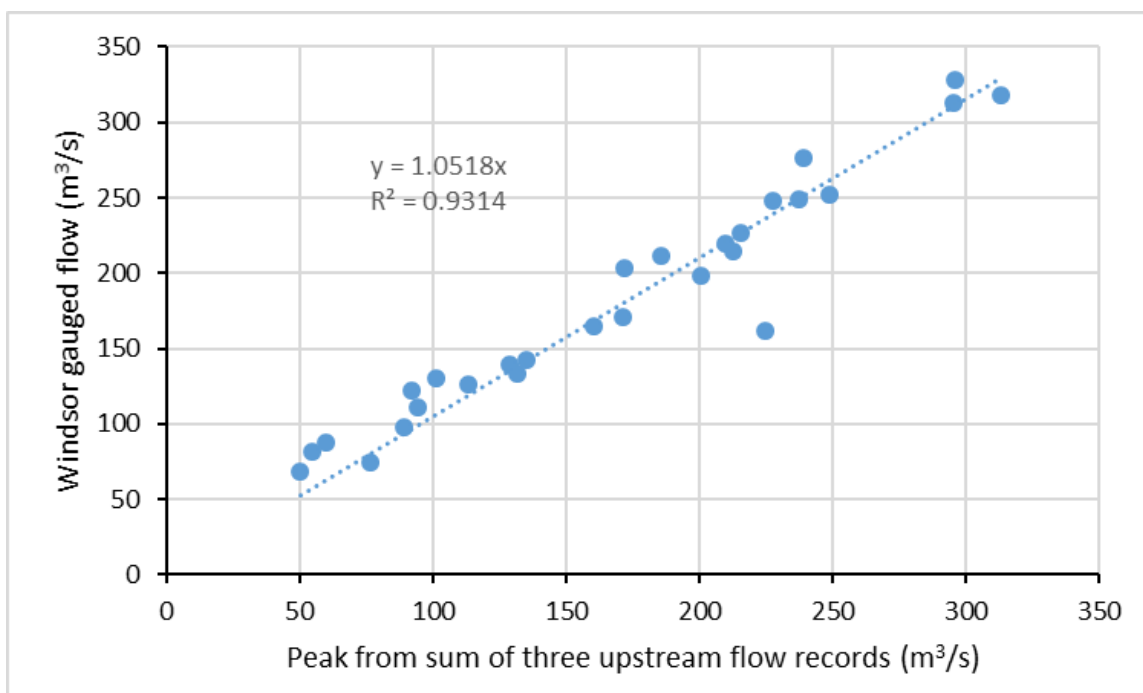


Two candidate lock levels sites were identified for development of a new rating:

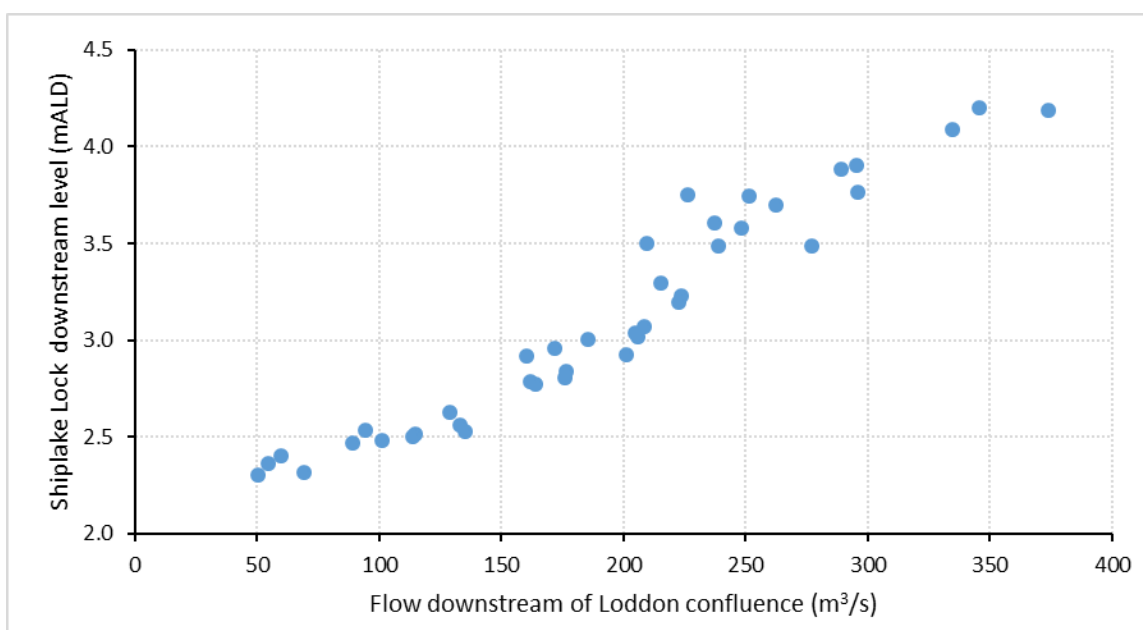
- Shiplake Lock (downstream gauge) (41 events extracted)
- Marsh Lock (downstream gauge) (46 events extracted)

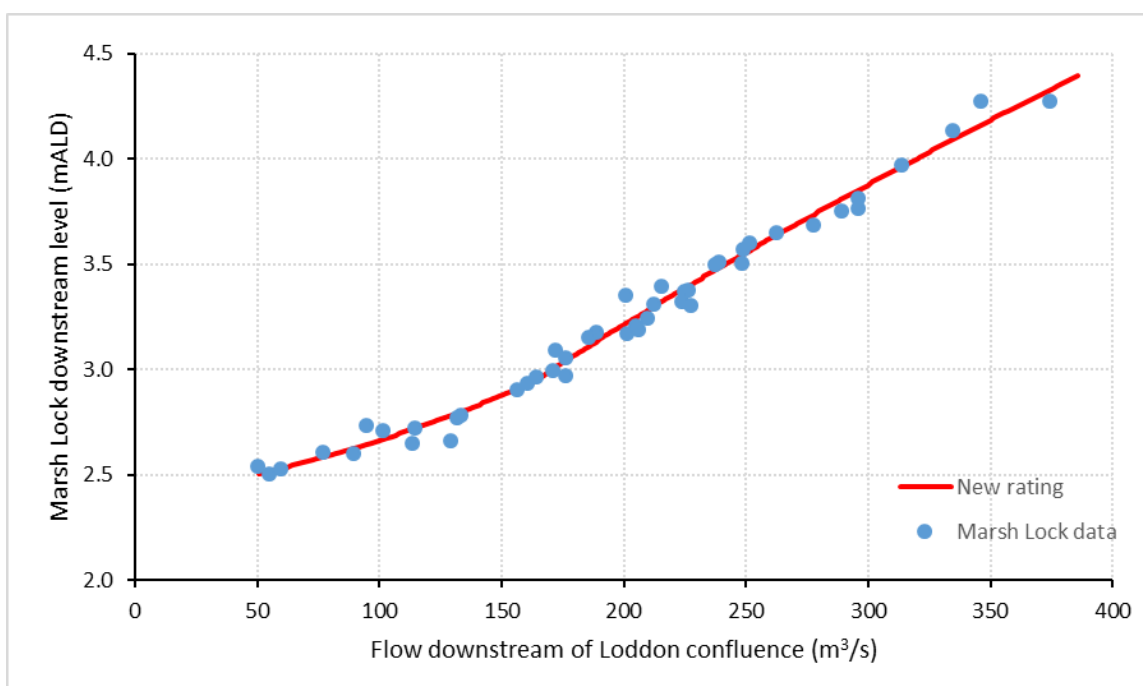
Numerous event peak levels at both locks were extracted from 15-minute telemetry. Corresponding peak flows for these peak levels were obtained from one of the following sources:

- Preferably, using the peak flow from a sum of event flow hydrographs from Reading (either the ultrasonic or NFFS rating, depending on the magnitude as discussed in Section 1.7.1), Theale (NFFS rating), and Twyford gauges. Summing the full hydrographs allows for possible variations in the arrival times of peaks from the three rivers.
- Often the above calculation was hindered by gaps or low quality data in the Twyford gauge. In these cases the event peak flow was instead extracted from the Windsor gauge further downstream, reduced by 5% based on a comparison of event peak flows from Windsor against the sum method above (effectively accounting for the small increase in drainage area between the Loddon confluence and the Windsor gauge). See the comparison of peak flows at Windsor against the sum from the upstream gauges in the plot below.



Once stage-discharge pairs were collected for both Shiplake and Marsh Lock as described above the data were plotted and examined. There was a moderate degree of scatter found in the Shiplake Lock stage-discharge plot. The Marsh Lock plot on the other hand gives a more linear relationship with significantly less scatter. This greater degree of scatter at Shiplake Lock is likely due to the complex interactions between various inter-connected channels around the Loddon confluence. It was therefore decided to carry the Marsh Lock dataset forward for development of a rating equation for estimation of flows downstream of the Loddon confluence.





The following rating equation was fitted to the Marsh Lock data (red line in the above plot), where $Q = C * (h - A)^B$

C	A	B	SGmin	SGmax
249.708	2.422	0.646	2.500	2.931
71.275	1.168	1.442	2.931	4.400

Combining this new rating curve with the full 15-minute available period of level record at Marsh Lock (November 1995 to present) allows abstraction of a 21-year AMAX peak flow dataset. This method gives a more robust estimate of QMED or other low return-period flows compared to a flow record created by summing upstream gauged flows, which are significantly affected by data quality and drop-out issues at the Twyford gauge.

Hydrological checks on a rating can sometimes be carried out to ensure the overall volume predicted by the rating is realistic. Given the size of the upstream catchment and the number of rainfall datasets required to give a reliable estimate of the catchment average rainfall, it was decided that this check was beyond the scope of this analysis. Instead, the comparison of peak flows from this new rating against the Windsor flow record downstream is considered a simpler and more robust method for this purpose. As the analysis above shows a realistic 5% increase in flows between the Loddon confluence and the Windsor gauge, it is concluded that the rating above is robust between the range of flows indicated in the rating curve plot above.

Future studies could refine the above rating curve further using hydraulic modelling, helping increase the reliability of the rating even further, or to extend it for extreme flood conditions for flows above 300m³/s.

1.8 Other data available and how it has been obtained

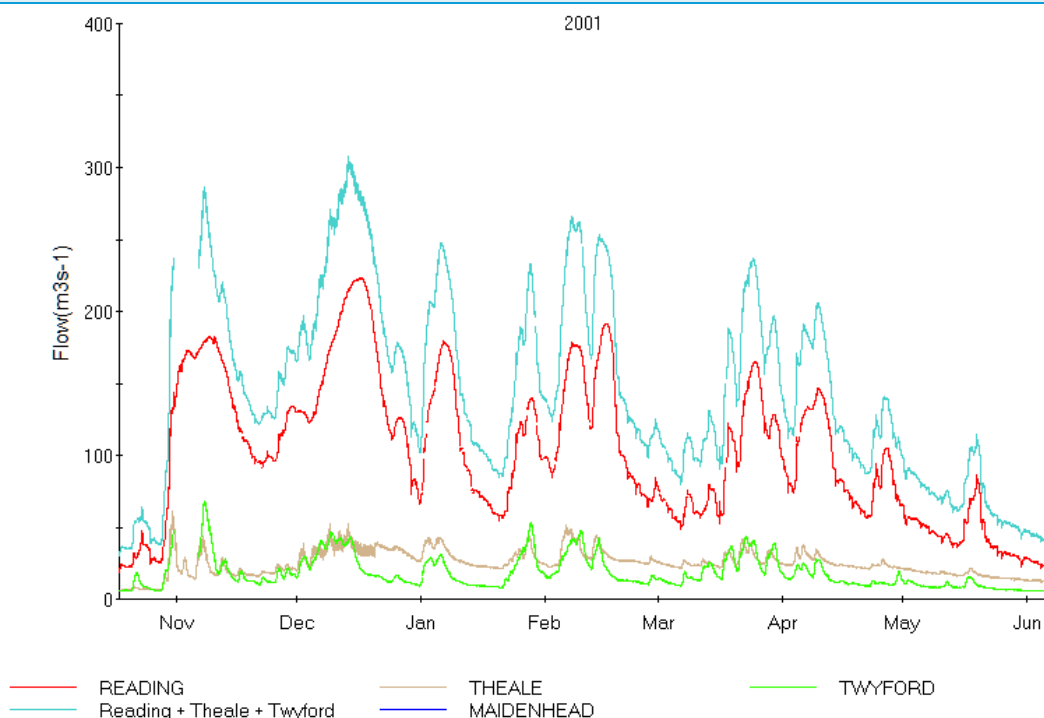
Type of data	Data relevant to this study?	Data available ?	Source of data	Details
Check flow gaugings (if planned to review ratings)	Yes	Yes	EA	Data already incorporated in adjustments of flood peak series for Reading, as part of Lower Thames study.
Historic flood data	Yes	Yes	EA	Historic Lock Keeper POT series of water levels, provided to JBA previously as part of the Lower Thames (2013s7653) project.
			Jacobs (2011)	Figure 4.4 of the Jacobs (2011) hydrology report gives historic event flood peaks relative to the recent record upstream of Reading.
			PBA (2002), Whitchurch to Hurley Weir, Flood History Database	This report cannot be located by the Environment Agency. It is mentioned in Jacobs (2011).
			Other	Scope excludes collection of flood history data from sources apart from EA. There are other potential sources of information such as peak levels at Long Wittenham for floods back to 1768 in Volume 4 of the Flood Studies Report.
Flow or river level data for events	Yes	Yes	EA	Full records of flow provided for Days Weir, Reading and Theale. Full records of level provided for Reading, Theale and headwater & tailwater at locks in the study reach.
Rainfall data for events	No	n/a	n/a	Scope calls for rainfall-runoff model parameterisation using hydrometric data but rainfall-runoff modelling is unlikely to be a preferred method of design flood estimation.
Potential evaporation data	No	n/a	n/a	
Results from previous studies	Yes	Yes	EA	Discussed in section 1.3.
Other data or information	Yes	Yes	EA	The EA hold information of a spot gauging used to estimate flow entering the rowing lakes downstream of Reading, taken in January 2014.

1.9 Hydrological understanding of catchment

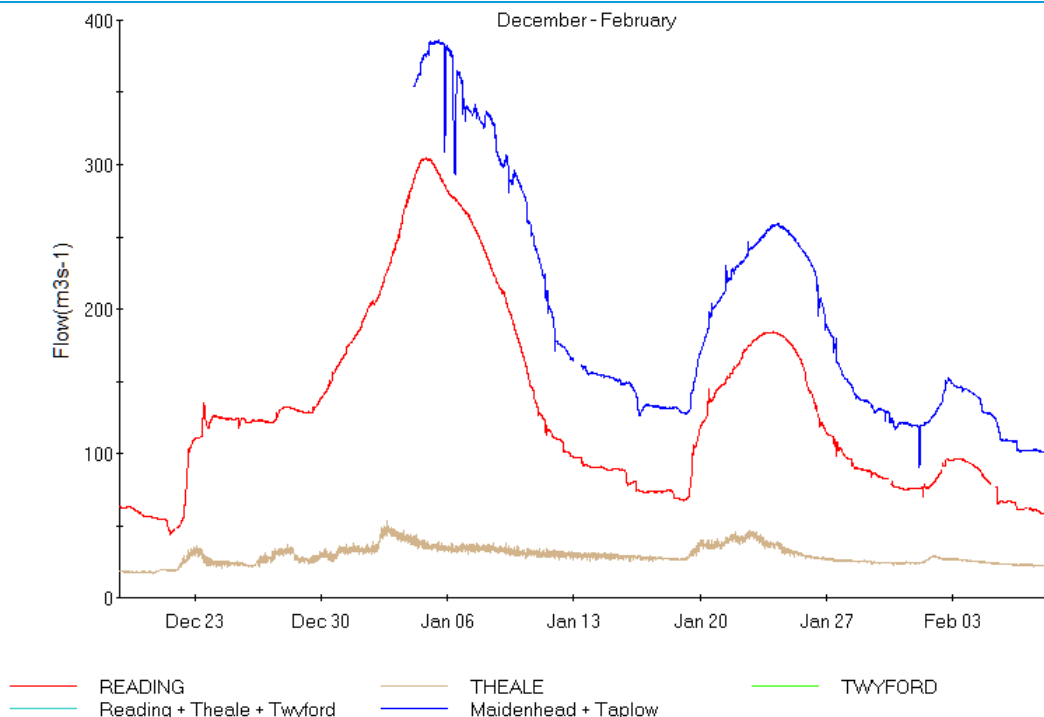
The flood event plots below include flow measured at gauges and also two summed flow series; one that combines Reading, Theale and Twyford, so approximating flow in the model reach downstream of Wargrave. The other adds the Thames at Maidenhead and the Jubilee River at Taplow, thus representing the combined flow on the Thames around Maidenhead, downstream of the present model reach.

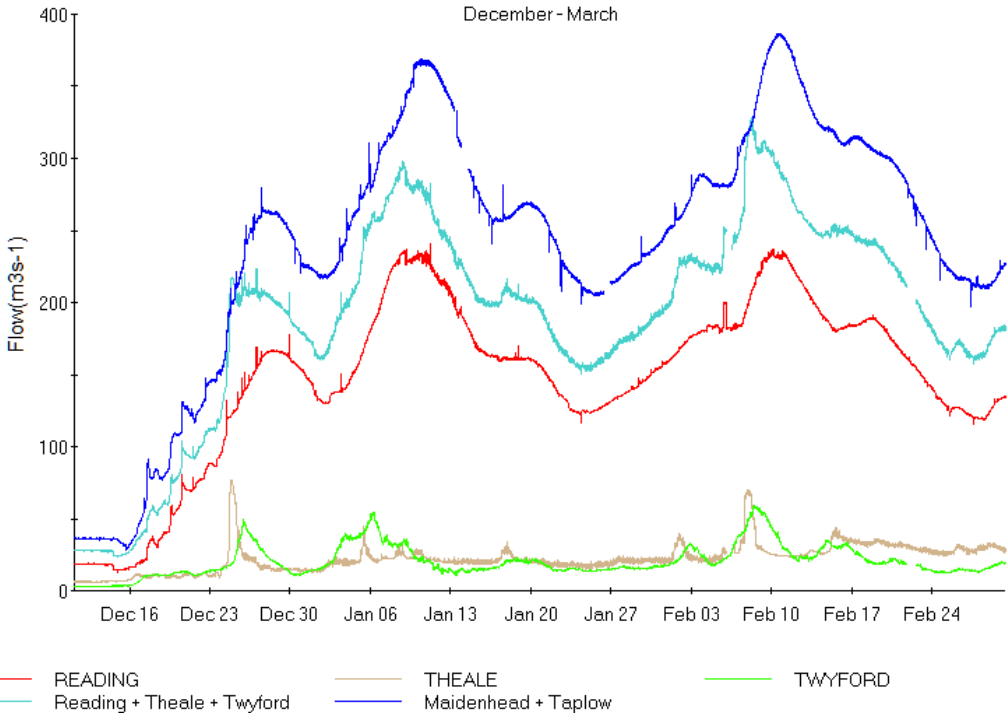
Note that the plots below use the WISKI rating at Reading and Theale and are intended to give a qualitative assessment of flow conditions only.

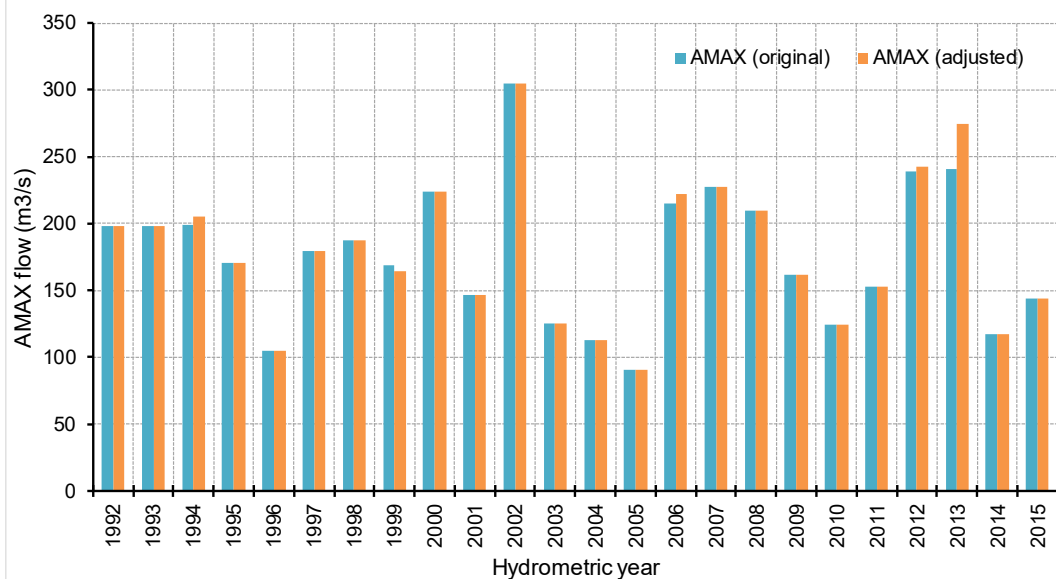
Winter 2000-2001 floods



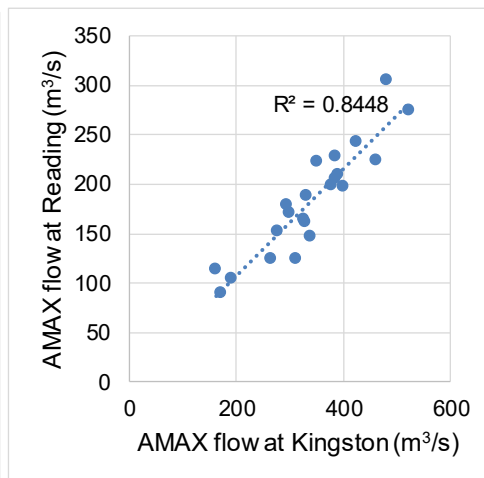
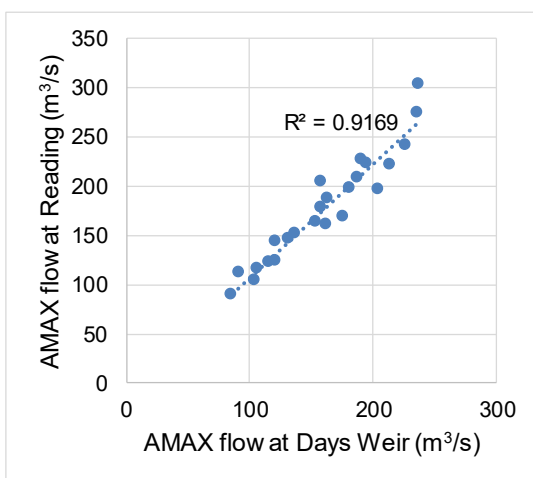
Jan 2003 flood (data is missing at several gauges)



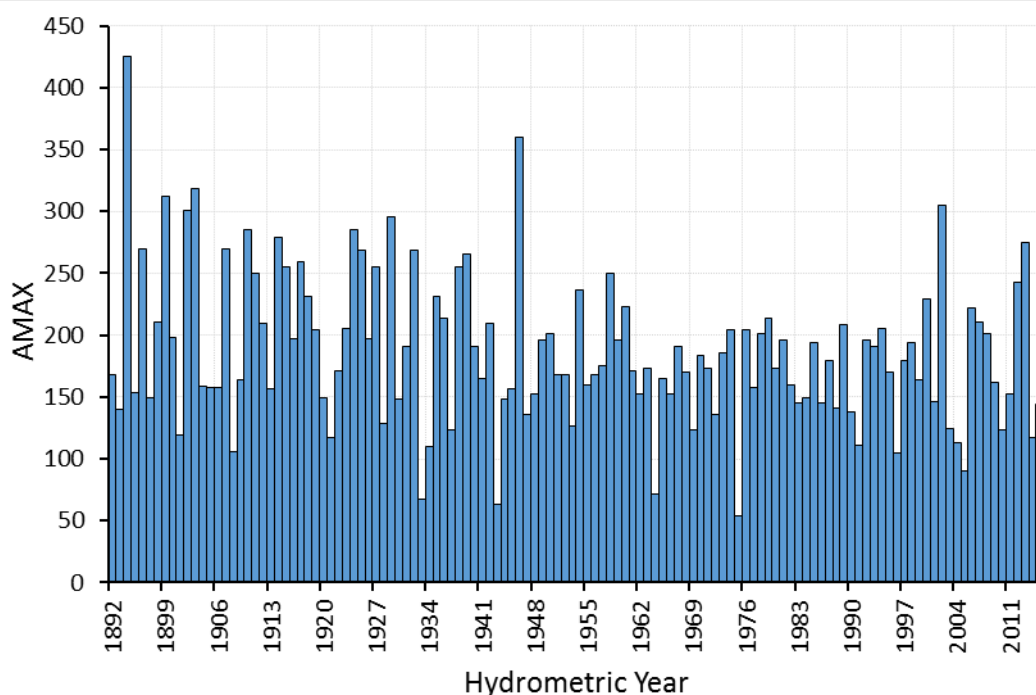
Winter 2013-14 floods	December - March  Note that the peak flow at Reading (from the ultrasonic flow series) was probably underestimated during this event: spot gaugings show a peak of about 260m³/s on 10 February 2014.
Hydrological interpretation	Floods on the Thames tend to occur in the winter in response to prolonged rainfall and/or snowmelt. They tend to be characterised by sequences of peaks, continuing weeks or months in total. High flows at Reading are typically sustained for 1-2 weeks. Flow tends to take several days to rise, or longer in some events. Inflows from the Kennet and Loddon tend to peak before the flood on the main Thames. Flood hydrographs for the Kennet show a rapid peaky response despite the dominant Chalk geology; this can be attributed to rapid runoff from Tertiary clay deposits in the lower catchment, drained by the River Enborne (where gauged flow data reveals a responsive regime) and other tributaries of the Kennet such as the Foudry Brook. Some events show multiple peaks from the Kennet and Loddon occurring during a single-peaked attenuated hydrograph on the Thames at Reading; in these circumstances it is possible for the peak flows on the tributaries to occur while the flow in the Thames is close to its maximum, reinforcing the potential for flooding downstream of Wargrave, for example at Henley. This occurred on 7-8 November 2000 and in early 2001. Depending on the relative magnitude of flows from the upper Thames and from the Kennet and Loddon, it is possible for the peak flow on the Thames downstream of Wargrave to occur either earlier or later than the peak at Reading.
Plots of flood peak data	JBA (2014) describe how AMAX flows from Reading gauge were adjusted when spot gaugings were available close to the time of the peak flow. The original and adjusted AMAX series, updated to include the two most recent years, are shown below.



The plots below illustrate the correlation between annual maximum flows at Reading and those at longer-record gauges on the Thames: upstream at Days Weir and downstream at Kingston.



It is possible to significantly extend the AMAX record at Reading, using the NFFS rating in conjunction with the Lock Keeper record at Mapledurham. Jacobs (2011) carried out a similar procedure, taking an average result from three upstream lock records, but the Mapledurham NFFS rating was not available at the time of their analysis. Data were extracted from multiple sources here, giving a complete AMAX record from 1892 to present at Reading, with data sources described in further detail in the Annex. See the AMAX plot below.



Hydrological interpretation

There are 23 years of flood peak data in the recent Reading ultrasonic dataset. In that period the January 2003 flood is the largest, with February 2014 ranking second. In the longer term there have been considerably more severe floods on the Thames, such as March 1947 and November 1894.

The scatter plots above show that annual maximum flows at Reading are closely correlated with those at Days Weir (where the catchment area is 25% smaller) and less closely with Kingston, where the catchment is a little over twice as large as at Reading.

Previous studies have considered in great detail the relationships between peak flows on the Thames and peak levels at locks, in particular relating flow at Windsor with level at Bray, Hurley, Temple and Marlow locks and flow at Reading with three upstream locks. Jacobs (2011) found that an extended flow dataset at Reading, from 1892, gave a flood frequency curve extremely similar to that estimated from single-site analysis. This result could be due to the short ultrasonic record at Reading (17 years) available at the time of the Jacobs 2011 analysis however. Similarly, JBA (2014) found that extension of the Windsor dataset using the long record of water level from Marlow Lock gave a flood frequency curve very similar to that fitted solely to annual maximum flows at Kingston.

Inclusion of historical level records from locks needs care because of the potential for the relationship between level and flow to have changed since the last 19th century as a result of changes in the conveyance of the river channel and/or floodplain. This can be seen in the Reading AMAX plot above, where there is a visible increase in the frequency of large flood events in the first half of the record. Formal trend testing confirms this pattern, indicating a statistically significant decreasing trend in the extended Reading AMAX series above. This issue was discussed with EA staff (pers. comm. with D Rylands, 18/07/2017), and was also acknowledged in the previous Jacobs (2011) study. Previous CEH studies of this issue have concluded that the trend can be attributed to more frequent flood events in the first half of the 20th century, rather than being caused by changes in conveyance of the Thames. Including the larger AMAX from the extended dataset also leads to larger design flows when carrying out flood-frequency analysis at Reading. As a result, the EA have recommended including the full dataset in this study.

Outline the conceptual model and note any unusual catchment features	As a large lowland catchment the Thames floods in response to prolonged rainfall and/or snowmelt. The size of the catchment changes considerably along the model reach, with the Kennet adding 20% to the catchment area and the Loddon another 11%. As noted above, the magnitude and timing of flow on the Thames downstream of these tributaries can be quite sensitive to the nature of the inflows, with potential for peak flows to occur at similar times. Flood duration is an important consideration given the potential for flooding from the Thames to disrupt transport networks and economic activity. The model reach also includes Berry Brook which is a heavily urbanised and low-lying catchment, with potential storage in gravel pits. Flood levels on at least part of the brook are likely to be closely linked to those on the Thames, with which it flows in parallel.
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1.10 Initial choice of approach

Is FEH appropriate?	Yes, with suitable choice of methods to account for unusual nature of catchment and wealth of data available.
Initial choice of method(s) and reasons How will hydrograph shapes be derived if needed? Will the catchment be split into sub-catchments? If so, how?	The FEH statistical method will form the basis of flood estimation in this study (the Thames catchment is too large for the ReFH rainfall-runoff method to be applicable). Flow estimation points (FEPs) Over the modelled reach, the hydrological behaviour of the Thames only significantly changes at the following locations: • Significant increase in flows at the Kennet confluence • Significant increase in flows at the Loddon confluence • Minor uniform lateral flow accretion downstream of the Loddon confluence as far as the model downstream limit at Hurley Lock. The above schematisation requires four flow estimation points on the River Thames as follows • Upstream model limit at Mapledurham (flows derived directly from the Reading gauge). FEP is labelled as “Upstream” in the below chapters. • Downstream of the Kennet confluence. FEP is labelled as “DS Kennet” in the below chapters. • Downstream of the Loddon confluence. FEP is labelled as “DS Loddon” in the below chapters. • Downstream model limit at Hurley Lock. FEP is labelled as “Downstream” in the below chapters. In each case, the additional point inflows from the Kennet and Loddon tributaries, and the minor lateral inflow between the Loddon and downstream limit, will be calculated by subtraction of the design event hydrographs at upstream-downstream pairs of the above flow estimation points. This procedure helps to conserve the volume of the T-year design flood hydrograph on the Thames. Growth curve estimation Given the dominance of the River Thames compared to the Kennet and Loddon, a single flood-frequency curve is derived from the extended Reading dataset and applied over the entire model reach. A comparison of growth curves is discussed further in the Annex. The final Reading flood-frequency curve is derived using the extended AMAX dataset described above, modified further with historic data using a Maximum Likelihood fitting procedure (see Annex). The growth curve at Reading will also be compared against an Enhanced Single Site analysis, and the previous Jacobs (2011) growth curve. Fig 9-14 in the Lower Thames report (JBA, 2014) showed the higher AMAX flows at

Reading plotting below the 95% confidence limits of the adopted growth curve. This is likely due to the influence of the Wey, Colne and Mole catchments, and indicates that the flood frequency curve previously derived at Kingston is not applicable as far upstream as Reading. However given the very long and high quality record at Kingston, transferring the growth curve from Kingston may still be useful for estimating flood flows for AEPs below 0.5%.

Peak flow estimation

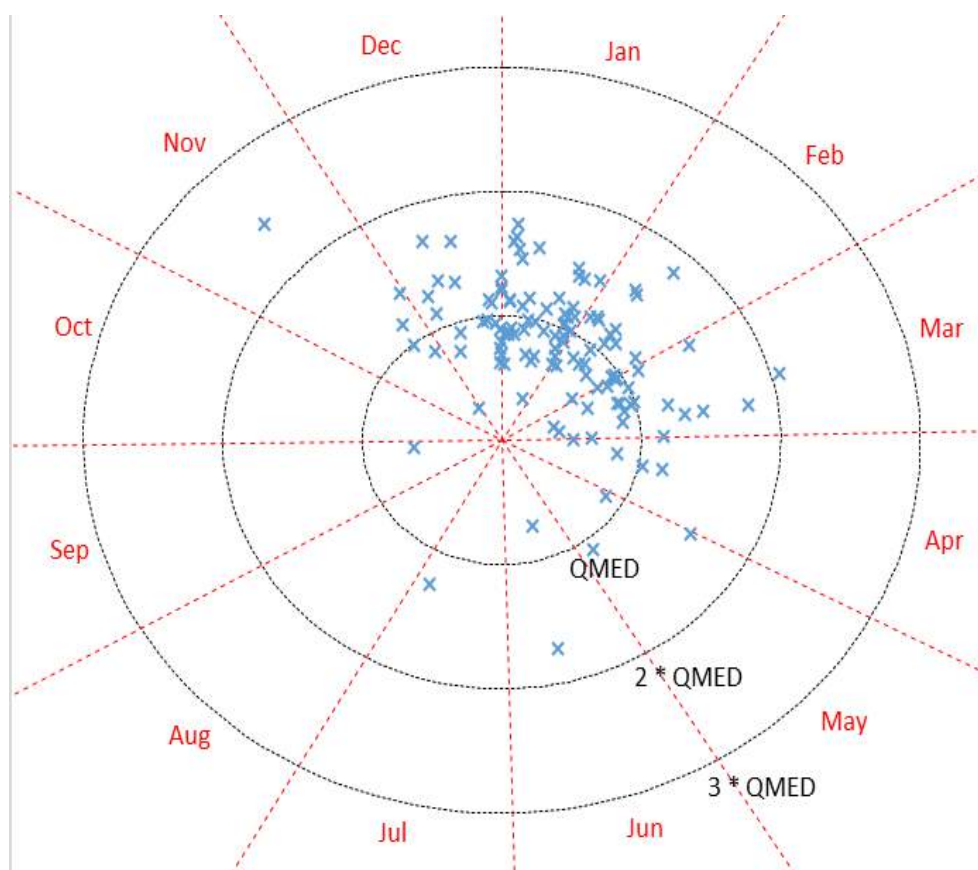
Peak flows at the upstream model limit at Mapledurham will be derived from a direct analysis of the Reading AMAX record as described in Section 1.9.

It is possible to create a “virtual” flow gauge downstream of the Kennet confluence, by adding the flow series at Reading and Theale gauges (latter from the NFFS rating as recommended by the EA). An AMAX series can then be compiled from this new dataset, allowing robust estimation of QMED and other low return-period peak flows. Using the new Marsh Lock rating curve as discussed in Section 1.7.2 allows estimation of another AMAX series downstream of the Loddon confluence. This will similarly be used to directly estimate QMED and other low return-period peak flows downstream of the Loddon confluence.

QMED at the model downstream limit at Hurley Lock will be estimated using the FEH QMED donor procedure, transferring data from the Marsh Lock dataset above (AKA “DS Loddon”) and Windsor further downstream.

Flood seasonality

A flood seasonality plot was created (see below) using the extended Reading AMAX record. Given the large catchment area and relatively permeable characteristics, as expected the majority of AMAX flood events at Reading occur in the winter/early spring season, with very few summer floods in comparison. This shows that flood events on the Thames are usually dominated by winter events.

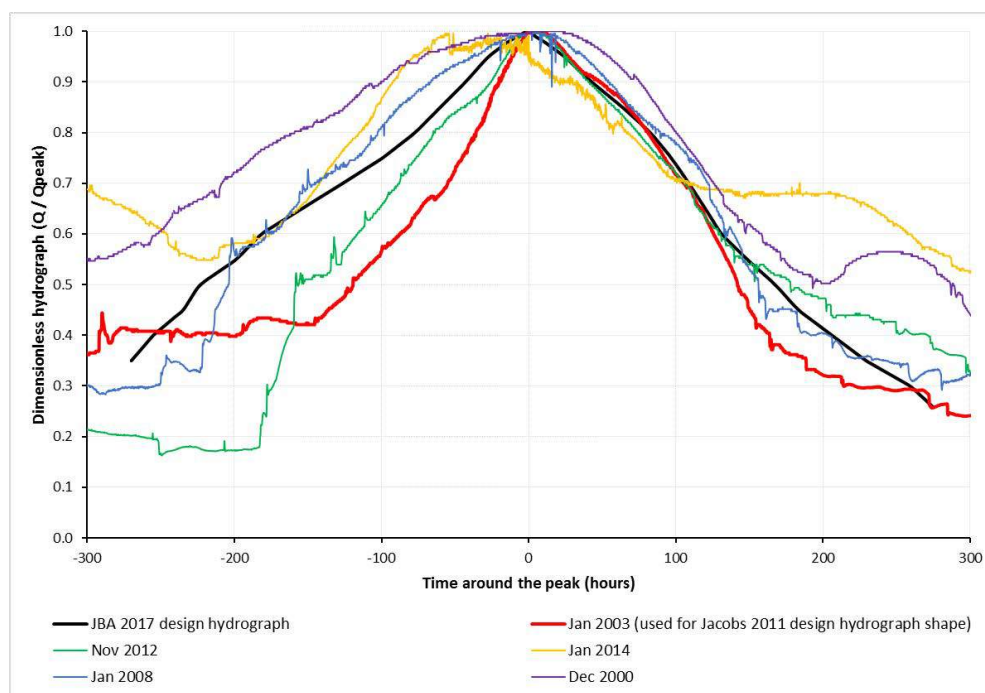


Estimation of hydrograph shapes

The Jacobs (2011) hydrological study adopted the January 2003 flow hydrograph shape for design events in their analysis. A similar approach is applied here, but instead uses an averaged hydrograph shape calculated from multiple events (taken from the previous JBA 2013 Lower Thames study, calculated using the “Hydrograph Width Analysis” technique as developed recently in the Irish Flood Studies Update programme). A comparison plot is given below, also plotting the top five flood events, all scaled by their own peak flow.

The following events were used to calculate an event-average hydrograph shape at Reading from the JBA 2013 analysis:

- December 1992
- January 1993
- January 1994
- February 1995
- January 1999
- November 2000
- December 2000
- January 2001
- February 2001
- January 2003
- March 2007
- July 2007
- January 2008
- February 2009
- November 2012
- December 2012
- January 2013
- January 2014
- February 2014

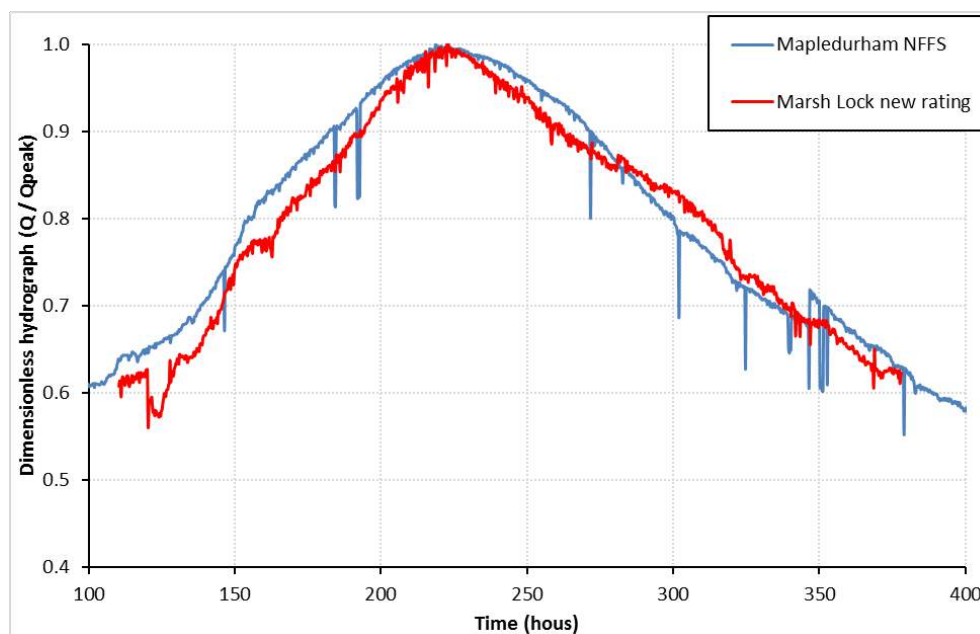


The averaged design hydrograph shape has a similar falling limb to the January 2003 event shape used in the Jacobs 2011 study, but contains a greater volume on the rising limb. The comparison against other gauged hydrographs at Reading shows that there is moderate inter-event variation on flood event volume on the rising limb. However in most cases there is a good match across events on the falling limb.

A check was carried out to ensure this hydrograph shape is also applicable downstream of the Kennet and Loddon tributaries. The analysis above was repeated, but on this occasion averaging hydrographs from the following flow series:

- Using the Mapledurham NFFS rating at Reading
- Using the new Marsh Lock rating downstream of the Loddon confluence

An average hydrograph shape was calculated from both flow series above, using the same nine flood events across both calculations (peak flows at Reading ranging between 150m³/s to 300m³/s, hence covering a wide range of flow conditions). This gives the following averaged hydrograph shapes.



Ignoring the telemetry spikes in the above plots, there appears to be a very good match in hydrograph shapes between these locations. There is no evidence of a significant change in the shape of the rising limb from an early response from the Kennet or Loddon in the Marsh Lock plot. Therefore it appears that a constant hydrograph shape along this reach of the Thames (scaling for increasing peak flows moving downstream) is a robust assumption.

Berry Brook

Inclusion of Berry Brook from a hydrological perspective is not within the scope of the project. In the context of the River Thames flood hydrology, the Berry Brook (catchment area <10km²) is insignificant, although it is noted that in a local context it could prove influential to flooding by providing an alternate flow route in extreme conditions. The response of this catchment is likely to differ notably from that of the River Thames (tending towards flooding in shorter duration intense rainfall events), although elevated water levels on the River Thames could influence flooding on Berry Brook.

No design estimate hydrology will be prepared for Berry Brook, and hydraulic simulations focused on critical durations for this watercourse will not be completed. However, it was discussed during the site visit held January 2017, that inclusion of part of the watercourse, towards the confluence of the River Thames, may be beneficial for modelling backwater effects from the River Thames, but also as a conveyance route for flood flows close to Sonning. This is discussed in the model review document prepared for this commission.

Software to be used FEH CD-ROM v3.0¹ / WINFAP-FEH v3.0.003²

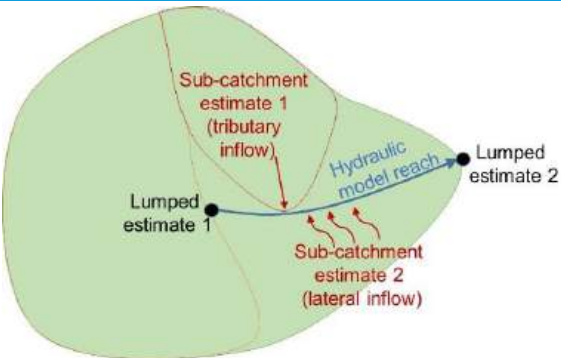
¹ FEH CD-ROM v3.0 © NERC (CEH). © Crown copyright. © AA. 2009. All rights reserved.

² WINFAP-FEH v3 © Wallingford HydroSolutions Limited and NERC (CEH) 2009.

2 Locations where flood estimates required

The table below lists the locations of subject sites. The site codes listed below are used in all subsequent tables to save space.

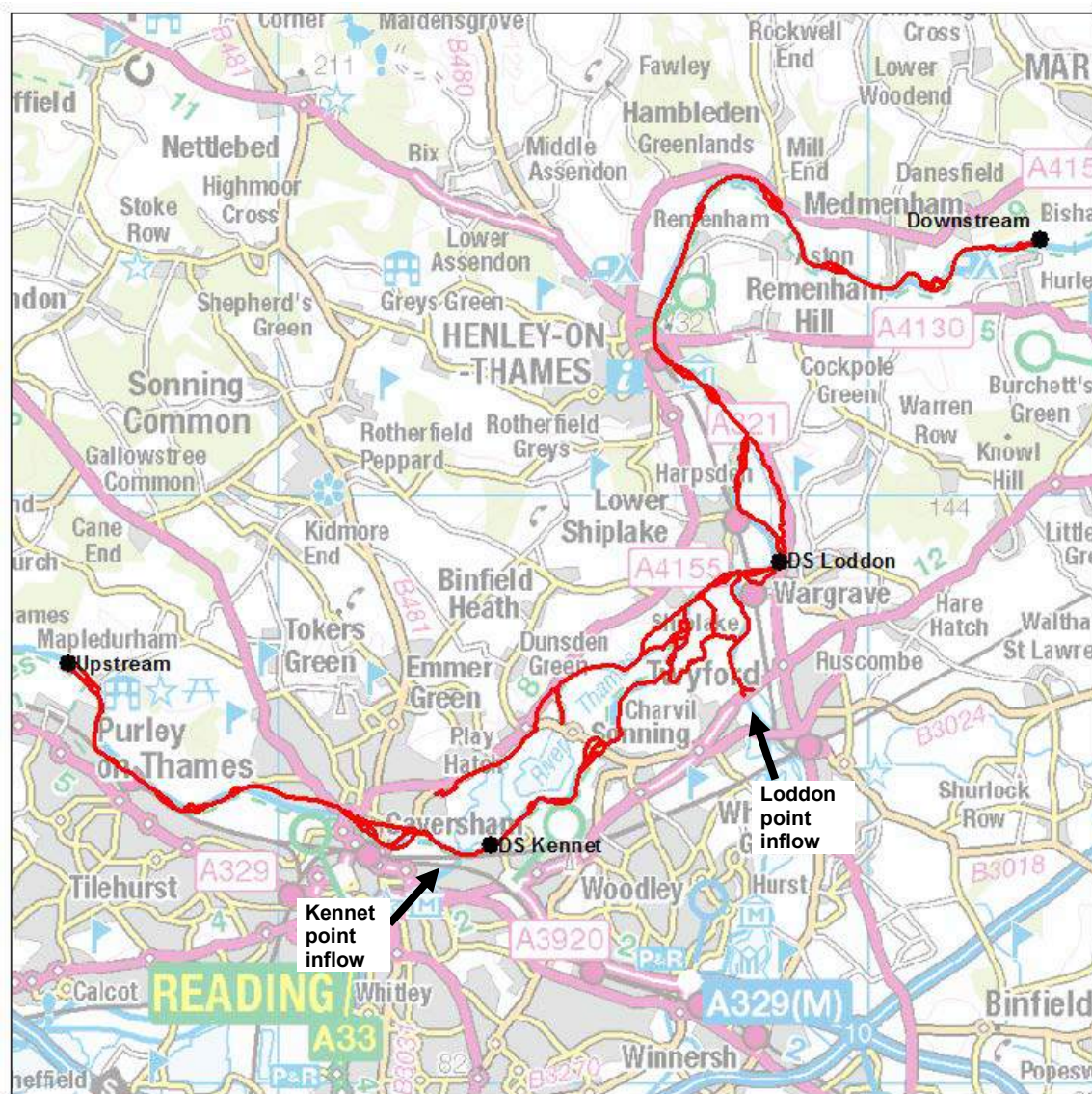
2.1 Summary of subject sites

Site code	Type of estimate L: lumped catchment S: Sub-catchment	River	Name or description of site	Easting	Northing	AREA on FEH CD-ROM (km ²)	Revised AREA if altered
Upstream	L	Thames	Upstream model extent at Mapledurham Lock	466500	177200	4575.68	
DS Kennet	L	Thames	Immediately downstream of the Kennet confluence	473100	173900	5781.35	
DS Loddon	L	Thames	Downstream of the various flow splits at the Loddon confluence	477900	178700	6497.97	
Downstream	L	Thames	Downstream model extent at Hurley Lock	482700	184450	6697.66	
Note: Lumped catchments (L) are complete catchments draining to points at which design flows are required. Sub-catchments (S) are catchments or intervening areas that are being used as inputs to a semi-distributed model of the river system. There is no need to report any design flows for sub-catchments, as they are not relevant: the relevant result is the hydrograph that the sub-catchment is expected to contribute to a design flood event at a point further downstream in the river system. This will be recorded within the hydraulic model output files. However, catchment descriptors and ReFH model parameters should be recorded for sub-catchments so that the results can be reproduced. The schematic diagram illustrates the distinction between lumped and sub-catchment estimates.							

Inflows to the model using the above flow estimation points (FEPs) will be calculated as follows:

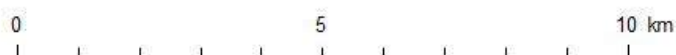
- A point inflow will be applied to the upstream limit of the model, upstream of the Mapledurham Lock site, using the flow calculated from the “Upstream” FEP.
- A second point inflow representing the River Kennet inflow is calculated by subtracting the “Upstream” and “DS Kennet” design flood hydrographs.
- A third point inflow representing the River Loddon inflow is calculated by subtracting the “DS Kennet” and “DS Loddon” design flood hydrographs.
- A final lateral inflow hydrograph representing the minor flow accretion between the Loddon confluence and the downstream model limit is calculated by subtracting the “Downstream” and “DS Loddon” design flood hydrographs (it is intended to apply this inflow uniformly between these two points).

This method aims to conserve the volume of the design flood event moving downstream. The minor lateral flow accretion between the upstream limit, Kennet confluence and Loddon confluence are ignored here, essentially lumped into the point inflows to be applied to the model as described above. A map displaying the locations of each FEP and inflow locations is given below.



Legend

- Flow Estimation Points
- River Thames



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2.2 Important catchment descriptors at each subject site (incorporating any changes made)

Site code	FARL	PROPWET	BFIHOST	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	URBEXT 2000*	FPEXT
Upstream	0.961	0.31	0.642	96.71	37.9	680	0.030	0.1694
DS Kennet	0.961	0.31	0.664	94.84	40.7	694	0.032	0.1543
DS Loddon	0.955	0.31	0.656	95.20	39.4	695	0.042	0.1544
Downstream	0.956	0.31	0.660	108.56	40.6	696	0.042	0.1517
URBEXT2000 updated to 2017 conditions using the CPRE formula from 2006 CEH report on URBEXT2000								

2.3 Checking catchment descriptors

Record how catchment boundary was checked and describe any changes (add maps if needed)	The catchment boundary was checked qualitatively against LIDAR. No discrepancies were found. Comparing the nominal and FEH CD-ROM catchment area values at gauged locations also showed no obvious errors.
Record how other catchment descriptors were checked and describe any changes. Include before/after table if necessary.	Qualitative check on FARL, SAAR, BFIHOST and URBEXT shows no obvious discrepancies: - Given that there are no major reservoirs in the Thames catchment, a FARL value of 0.95 from descriptors appears realistic. - The catchment SAAR value of just under 700mm/year is realistic for the southern region of England. Using the long-term mean annual flow for Reading as reported by the NRFA database of 38.5m³/s, the ratio of rainfall to annual runoff volume is just below 0.4, which appears realistic. - The geology of the Thames catchment consists of a mixture of chalk, limestone, sandstone and mudstone upstream of Reading. BFIHOST values around 0.6 – 0.7 appear realistic for this type of geology. - According to the NRFA database, the overall urban landcover proportion of the Thames catchment upstream of Reading is 7.3%. URBEXT2000 values around 0.03 appear realistic for this fraction.
Source of URBEXT	URBEXT2000
Method for updating of URBEXT	CPRE formula from 2006 CEH report on URBEXT2000

3 Statistical method

3.1 Overview of estimation of QMED at each subject site

Site code	QMED from CDs (m ³ /s)	Final method	Data transfer						Final estimate of QMED (m ³ /s)
			NRFA numbers for donor sites used (see 3.3)	Distance between centroids d _{ij} (km)	Power term, a	Moderate d QMED adjustment factor, (A/B) ^a	If more than one donor		
							Weight	Weighted ave. adjustment	
Upstream	180.2	AM*							174.2
DS Kennet	214.6	AM							192.0
DS Loddon	245.8	AM							219.6
Downstream	250.1	DT	DS Loddon	0.98	1.0	0.894	0.5	0.89	222.8
			39072	2.68	1.0	0.889	0.5		
Are the values of QMED spatially consistent?						Yes, QMED increase in a sensible pattern moving downstream. Ratio with catchment descriptor QMED also appears consistent around 0.9 across the reach.			
Notes Methods: AM – Annual maxima; POT – Peaks over threshold; DT – Data transfer (with urban adjustment); CD – Catchment descriptors alone (with urban adjustment); BCW – Catchment descriptors and bankfull channel width (add details); LF – Low flow statistics (add details). When QMED is estimated from POT data, it should also be adjusted for climatic variation. Details should be added below. The QMED adjustment factor A/B for each donor site is given in Table 3.2. This is moderated using the power term, a, which is a function of the distance between the centroids of the subject catchment and the donor catchment. The final estimate of QMED is (A/B) ^a times the initial estimate from catchment descriptors. If more than one donor has been used, use multiple rows for the site and give the weights used in the averaging. Record the weighted average adjustment factor in the penultimate column. Important note on urban adjustment The method used to adjust QMED for urbanisation, for both subject sites and donor sites, is that published in Kjeldsen (2010) ³ in which PRUAF is calculated from BFIHOST. The result will differ from that of WINFAP-FEH v3.0.003 which does not correctly implement the urban adjustment of Kjeldsen (2010). Significant differences will occur only on urban catchments that are highly permeable. For the QMED adjustment at the Downstream estimation point, given that the donors are in close proximity on the same river, it was decided to over-write the “a” parameter used in the adjustment procedure to 1.0. Further discussion of the sensitivity of results to this adjustment is given below. *The full extended AMAX series (1892 – present) is used to estimate QMED at the “Upstream” flow estimation point. Using the ultrasonic gauged period alone (1995 – present) gives a slightly lower QMED estimate of 167.3m ³ /s.									

Given the close proximity of flow gauges to the FEPs in this study, it was decided that the “a” term in the FEH QMED is not applicable here. The “a” term was introduced in the updated FEH guidelines when using more distant flow gauges to adjust an ungauged QMED estimate. In that research, it was found that the donor adjustment should reduce for donor sites that are further away from a target site, as there is greater uncertainty in the regional bias in the FEH QMED model over large distances.

³ Kjeldsen, T. R. (2010). Modelling the impact of urbanization on flood frequency relationships in the UK. Hydrol. Res. **41**. 391-405.

In this study, all donor gauges are located on the same river, where the bias in the FEH QMED model is expected to be consistent. This was checked by calculating the ratio of actual vs regression model QMED at the FEPs above, which gives the following values:

- 0.96 at the Reading gauge.
- 0.89 at DS Kennet.
- 0.89 at DS Loddon.
- 0.89 at the Windsor gauge.

The Thames catchment area is also quite large compared to the range of catchment areas in the dataset used in the updated FEH research to calibrate the “a” parameter. The adjustment is generally intended for smaller catchment where QMED donor information is not available on the same watercourse.

3.2 Search for donor sites for QMED (if applicable)

Comment on potential donor sites Mention: • Number of potential donor sites available • Distances from subject site • Similarity in terms of AREA, BFIHOST, FARL and other catchment descriptors • Quality of flood peak data Include a map if necessary. Note that donor catchments should usually be rural.	It is possible to estimate QMED directly at three of the FEPs: • Directly from the extended Reading AMAX dataset • From the virtual flow series downstream of the Kennet confluence • From the newly-rated Marsh Lock site downstream of the Loddon. The remaining FEP at the downstream model limit at Hurley Lock required data transfer procedures to estimate QMED. Given the proximity to the Marsh Lock rated site and the Ultrasonic Windsor gauge downstream, these two sites alone were considered suitable as QMED donors. All AMAX series mentioned above are tabulated in the Annex.
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3.3 Donor sites chosen and QMED adjustment factors

NRFA no.	Reasons for choosing	Method (AM or POT)	Adjustment for climatic variation?	QMED from flow data (A)	QMED from catchment descriptors (B)*	Adjustment ratio (A/B)
DS Loddon	Located a short distance upstream of the flow estimation point. AMAX series available from the newly rated Marsh Lock.	AM	n/a	219.6	223.4	0.894
39072	Located a short distance downstream of the flow estimation point. Data quality previously assessed in the JBA 2013 Lower Thames study and considered OK for QMED estimation.	AM	n/a	235	236.8	0.889

*The catchment descriptor value here excludes the Urban Adjustment Factor (UAF) for QMED. This is accounted for in the QMED adjustment procedure at a later stage however (the UAF values are 1.10 and 1.12 for DS Loddon and 39072 respectively)

3.4 Derivation of pooling groups

Several subject sites may use the same pooling group.

Name of group	Site code from whose descriptors group was derived	Subject site treated as gauged? (enhanced single site analysis)	Changes made to default pooling group, with reasons	Weighted average L-moments, L-CV and L-skew, (before urban adjustment)
Upstream	39130	Yes	None, apart from use of the extended AMAX record at the Reading gauge based on the calculations given in Section 1.9. (Pooling group tabulated in the Annex). A review of the pooling group, looking at record lengths, catchment properties, and data quality was carried out. This did not reveal issues with the default pooling group, hence it was retained without modification.	LCV = 0.177 LSKEW = 0.133
Notes Pooling groups were derived using the procedures from Science Report SC050050 (2008).				

It was decided to derive the pooling group using the Reading gauge as a target site, given the advantage of a very long AMAX record at this site (1892 to present) calculated from the Mapledurham NFFS rating. This gives a much more robust resulting flood-frequency curve using the ESS pooling method, as opposed to a pooling group derived elsewhere on the Thames where AMAX records are typically much shorter.

On larger catchments, it is generally more difficult to estimate representative pooling groups, due to the smaller number of large catchments available in the NRFA database. A pooling group derived at a downstream location on the Thames for instance would likely only change the order of sites in the original pooling group, rather than giving a better representation of the downstream sites' flood frequency curve. Further discussion of this point is given in Section 3.7.

3.5 Derivation of flood growth curves at subject sites

In this case the fully extended AMAX series at Reading (1892 – present) is used in these calculations. The single-site (SS) and historic-adjusted single-site (SSH) calculation below are not standardised by QMED, the final row (ESS) is standardised by QMED.

The Generalised Logistic frequency model was selected for consistency across all methods considered below, based on current FEH guidance to use this model unless there is strong evidence to the contrary. The GEV model is acceptable in some circumstances but can tend to give flood-frequency curves that are bounded-above.

Site code	Method (SS, P, ESS, J)	If P, ESS or J, name of pooling group (Error! Referenc e source not found.)	Distribution used and reason for choice	Note any urban adjustment or permeable adjustment	Parameters of distribution (location, scale and shape after adjustments)	Growth factor for 100-year return period
Upstream	SS	n/a	GLO, best fit from visual assessment of flood-frequency plot and comparison on theoretical and sample L-moment ratio plot	None	Location = 180.3 Scale = 32.6 Shape = -0.124	2.12
	SS (gauged period only 1995 – present)	n/a	GLO, for consistency in comparison below	None	Location = 169.9 Scale = 31.8 Shape = -0.119	2.15
	SSH	n/a	As above	None	Location = 180.7 Scale = 33.2 Shape = -0.137	2.18
	ESS	Upstream	GLO, result from WINFAP goodness of fit test (ZGLO value of 1.0, ZGEV also acceptable with value of -1.5)	No, catchment is classed as essentially rural (URBEXT2000 < 0.03)	Location = 1.0 Scale = 0.179 Shape = - 0.133	2.13

Notes

Methods: SS – Single site; SSH – Single site with historic adjustment, P – Pooled; ESS – Enhanced single site; J – Joint analysis
A pooling group (or ESS analysis) derived at one gauge can be applied to estimate growth curves at a number of ungauged sites.
Each site may have a different urban adjustment, and therefore different growth curve parameters.
Urban adjustments are all carried out using the v3 method: Kjeldsen (2010).
Growth curves were derived using the procedures from Science Report SC050050 (2008).

3.6 Growth curves from the statistical method

Site code	Flood peak (m ³ /s) for the following Annual Exceedance Probabilities										
	50%	20%	10%	5%	3.3%	2%	1.3%	1%	0.5%	0.2%	0.1%
Upstream (SS)	180.3	229.6	262.6	296.1	316.5	343.4	365.7	382.2	424.3	485.6	536.8
Upstream (SS gauged only)	169.9	217.9	249.8	282.2	301.8	327.5	348.9	364.7	404.8	463.0	511.3
Upstream (SSH)	180.7	231.3	265.8	301.1	322.7	351.3	375.3	393.1	438.7	505.8	562.4
Upstream (ESS)	174.5	222.1	254.2	287.1	307.2	333.7	355.9	372.4	414.5	476.2	528.1

The above results are discussed and compared graphically in Section 3.7.

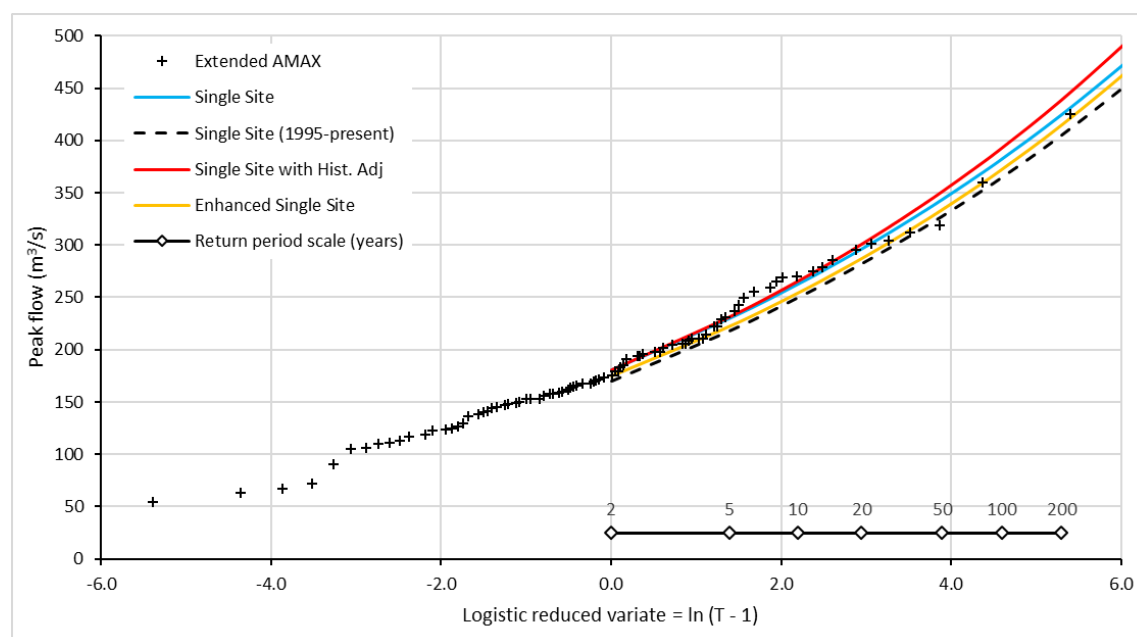
3.7 Discussion of results

3.7.1 Selection of the final flood frequency curve at Reading

Extension of the Reading AMAX series to 1892 (see Annex) gives a 124-year continuous record. These were initially used in a single-site analysis as summarised above. This calculation was then modified using further historic information for floods before 1892 (labelled as “SSH” above). This procedure uses a Maximum Likelihood fitting procedure, as outlined in the recent FEH Local research project. Information from Figure 4.4 of the Jacobs 2011 hydrology report shows that there were 4 events recorded at the Whitchurch Lock gauge that exceeded the 1947 flood (1768, 1770, 1774 and 1809). Following recommendations from the FEH Local project, it was decided to set the start of the historic period to 1700, based on average time gaps between events in the historic dataset and the start of the extended AMAX record in 1892. This resulted in a slightly steeper growth curve.

An enhanced single site approach was also applied for comparative purposes. This was built with the extended Reading AMAX series at the top of its own pooling group. This calculation resulted in a similar growth curve to the previous two calculations above, but was found to be less steep than the calculations above.

The dashed black line in the plot below shows the results of a single-site analysis at Reading if only the ultrasonic period of record is used (see second row in the table in Section 3.6). This frequency curve plots slightly below the other options analysed here, showing the effect of the inclusion of historic data in the frequency calculation (blue and red lines in the plot below). It should also be kept in mind that this ultrasonic record is relatively short (22 years) and is therefore robust for short return periods only.



It was decided to adopt the historic-adjusted single-site calculation for the dimensionless growth curve in this study, given the use of data before 1892 (standardised by the at-site QMED value of 174.5m³/s). The 1,000-year growth factor from this curve is 3.11. Current flood estimation procedures recommend a check against a hybrid rainfall-runoff procedure for estimation of this figure, but in this case given the size of the Thames catchment, it was decided that application of a rainfall-runoff procedure in this case is not suitable.

3.7.2 Spatial checks

Gauging stations on large streams are usually well established and hence have relatively long flow records, giving a much more robust picture of the flood-frequency relationship compared to the FEH pooling procedure. Using the AMAX series for the DS Kennet and DS Loddon FEPs derived in this study, it is possible to compare the final flood-frequency curve derived at Reading to single-site flood frequency estimates at these locations. This gives a useful spatial check on the applicability of the selected flood frequency curve across the reach of the Thames being modelled. This is a more robust spatial comparison method compared to the FEH pooling method, for the reasons given above.

The 5% AEP growth factor for the final flood-frequency curve is 1.67. Similar values of 1.58 and 1.63 are obtained from single-site analyses of the AMAX records at DS Kennet and DS Loddon respectively. Unfortunately, this method is only robust up to approximately the 5% AEP event, limited by the number of AMAX events that can be derived for the DS Kennet and DS Loddon sites. Extrapolation above this would add uncertainty to the comparison, but for moderately large floods up to the 5% AEP the comparison shows that the flood-frequency behaviour along this reach of the River Thames is similar to the result derived at Reading.

4 Discussion and summary of results

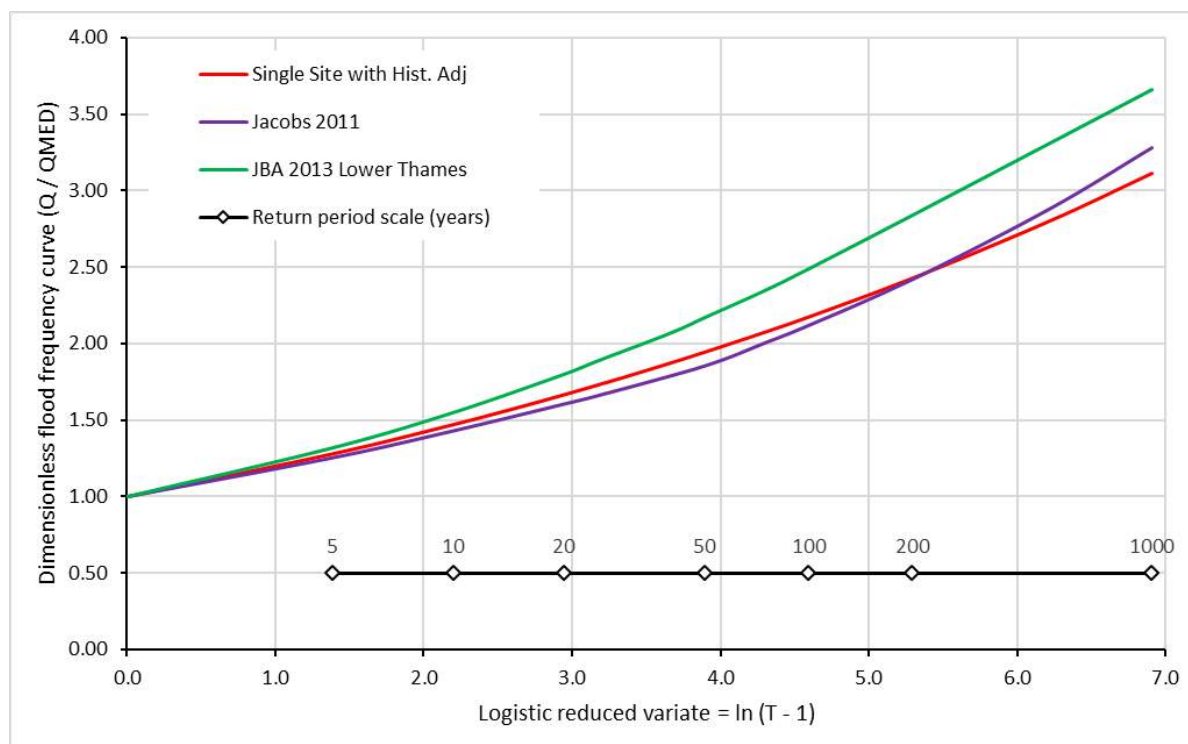
4.1 Comparison of results from different methods

This table compares peak flows from various methods with those from the FEH Statistical method at example sites for two key return periods. Blank cells indicate that results for a particular site were not calculated using that method.

Site code	Comparison against previous results			
	Return period 2 years		Return period 100 years	
	This study	Jacobs 2011	This study	Jacobs 2011
Upstream	174.2	177.0	379.0	375.0
DS Kennet	192.0	197.0 – 199.0	417.7	420.0 – 438.0
DS Loddon	219.6	201.0 – 204.0	477.8	431.0 – 452.0
Downstream	222.8	Not reported	484.9	Not reported

The Jacobs 2011 hydraulic modelling report (Table 2.3) quotes upper and lower ranges for design inflows, dependent on assumptions for the design hydrograph applied at Windsor.

A further comparison was carried out between growth curves on this reach of the Thames, that used in the Jacobs 2011 study, and the curve derived from Kingston used in the JBA Lower Thames study (2013). These curves are plotted below.



The Reading growth curve from this study (red line) gives an excellent match with the Jacobs 2011 result (purple line). This is to be expected, as the methods used to derive these curves are broadly similar. However, the Kingston growth curve (green line) is significantly steeper than the others. This indicates that it is not suitable to apply the Lower Thames growth curve on this reach of the Thames around Reading. There are numerous other significant tributaries including the Wey, Mole and Colne that enter the Thames downstream of this reach, which influence the flood-frequency behaviour on the lower reach.

4.2 Final choice of method

Choice of method and reasons	A single growth curve is applied across the entire model reach, derived from the extended AMAX series at Reading, adjusted with historic data. QMED is estimated at key locations, through a combination of “virtual” gauges (sums of upstream gauged flows), development of new ratings at existing gauged level sites, or using the FEH QMED transfer procedure. The abundance of gauged data in this case has greatly aided the accuracy of the calculations.
How will the flows be applied to a hydraulic model?	Point inflows representing the major tributaries are calculated by subtracting upstream-downstream pairs of design event hydrographs as follows: River Kennet point inflow: DS Kennet – Upstream River Loddon point inflow: DS Loddon – DS Kennet Downstream lateral inflow: Downstream – DS Loddon (to be applied uniformly from the Loddon confluence to the model downstream limit) Routing of these resulting hydrographs through a hydraulic model may lead to modelled peak flows that are less than the intended design event peak flows at the FEPs at DS Kennet, DS Loddon and Downstream. Iteration of the above model inflows may therefore be required to reach the required design event peak flow as summarised in the table in Section 4.5.

Assumptions, limitations and uncertainty	1) Addition of the gauged flow series at Reading (either WISKI or NFFS as appropriate) with the Theale (NFFS rated) is assumed to give a good approximation for flows in the Thames downstream of the Kennet confluence. 2) It is assumed the NFFS rating at Theale gives a good approximation of the total flow generated by the Kennet catchment. It is also assumed that this rating is less heavily affected by storage in nearby gravel pits compared to the WISKI rating. 3) There are gaps in the extended AMAX series at Reading where the lock keeper POT series at Mapledurham does not have a large event in a given AMAX year. In these cases, low-flow water year AMAX are instead copied from the Jacobs 2011 AMAX series to infill these gaps. These are all events significantly less than QMED and are assumed not to adversely affect the flood-frequency calculation. 4) The newly-derived rating at Marsh Lock is assumed to give a good representation of flood flows, at least up to QMED. Further hydraulic modelling of the rating at that location could be used to possibly extend the rating. The stage-discharge pairs used to derive the Marsh Lock rating contain an assumption of good quality flow data at Reading, Theale and Twyford. 5) The noted trend in the extended Reading AMAX series is assumed to be due to genuine climatic behaviour in the first half of the 20th century, as summarised by past research carried out by CEH. The inclusion of these older data at Reading lead to a larger (hence more conservative) flood-frequency analysis (the design flows would likely reduce if these older data are omitted). It is also assumed that there is no significant change to the stage-discharge relationship at Mapledurham over the 20th century. 6) It is assumed that all large events from 1700 to 1891 are accounted for in the historic adjustment procedure when adjusting the Reading flood-frequency curve. 7) It is known that the Kennet and Loddon flows tend to peak before the main Thames peak arrives during flood events, This may have a small effect on the shape of the rising limb of flood hydrograph downstream of these confluences. However in large floods the Thames flow is significantly larger than the flows from these streams. Checks described in Section 1.10 have shown that there is no overall change on average between hydrograph shapes at Reading and downstream of the Kennet. It is therefore assumed in this study that the same
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	hydrograph shape is applicable across the reach of the Thames being modelled here.
Discuss any particular limitations,	The inflows derived from subtraction of upstream-downstream pairs of event hydrographs are intended to maintain the shape/volume of the design flood event on the River Thames. These should not be viewed as corresponding T-year flood hydrographs for the individual tributaries. Iteration may be required with model inflows derived here to maintain the required design peak flow on the Thames, due to attenuation in the hydraulic model. It is recommended to use the peak flows in Section 4.5 as target peak flows.
Give what information you can on uncertainty in the results,	67% and 95% confidence intervals have been estimated for the Reading flood-frequency curve, using an in-house Monte-Carlo calculation tool. These have been calculated for a single-site analysis of the extended Reading AMAX dataset; while not matching precisely with the historic-adjusted flood-frequency method adopted in this study, given the very long AMAX record the results below are broadly indicative of the uncertainty in the historic-adjusted flood-frequency curve. A 67% confidence interval of the 100-year peak flow at Reading is within $\pm 10\%$ of the calculated value. This increases to $\pm 18\%$ for a 95% confidence interval. For typical record lengths available in the UK, these confidence intervals are usually much wider, showing the value in adding historic data.
Comment on the suitability of the results for future studies.	The new rating derived at Marsh Lock (downstream side of the lock) could be useful in future studies, or perhaps improved upon using hydraulic modelling. This might help to more accurately predict flows in the Thames, affecting downstream communities in Marlow or Henley. A longer AMAX series could be derived using the new rating at Marsh Lock using the historic Lock Keeper record (use of the recent 15-minute record was sufficient for estimating QMED in this study). This might be a useful check on the flood-frequency behaviour of the Thames downstream of the Loddon confluence. Future use of the outputs from this study can inform flood alleviation modelling on this reach of the Thames. Given the use of 1) an extended AMAX series from the Reading gauge, 2) a “virtual” AMAX series downstream of the Kennet confluence and 3) a new data-based rating at Marsh Lock used to estimate AMAX flows downstream of the Loddon confluence, the results from this study can be used to

	inform these types of analyses. In future studies, it may be a useful exercise to derive a formal modelled rating curve at Hurley Lock, or use modelling to improve the Marsh Lock rating initially derived in this study, helping to improve design flow estimates at these locations even further.
Give any other comments on the study.	It is intended to use the flow estimation points indicated in this report to check the calibration of the model, as well as at level telemetry locations at the locks and gauging stations. For example, flow hydrographs will be extracted from the model and compared to design flows / event flows from gauges. Detailed discussion of the calibration strategy is beyond the scope of this report, provided in more detail in the hydraulic modelling phase of this study.

4.3 Checks

Are the results consistent, for example at confluences?	Yes. All design peak flows increase sensibly moving downstream. Comparing the Reading growth curve with single-site growth curves derived using the AMAX series at DS Kennet and DS Loddon gives the following results: <table><tr><th>AEP</th><th>Reading growth curve</th><th>DS Kennet SS growth curve</th><th>DS Loddon SS growth curve</th></tr><tr><td>20%</td><td>1.28</td><td>1.26</td><td>1.27</td></tr><tr><td>10%</td><td>1.47</td><td>1.42</td><td>1.44</td></tr><tr><td>5.0%</td><td>1.67</td><td>1.58</td><td>1.61</td></tr><tr><td>3.3%</td><td>1.79</td><td>1.67</td><td>1.71</td></tr></table> Only short return periods can be compared here due to the length of the AMAX records at DS Kennet and DS Loddon (24 and 21 years respectively). Even so, for short return periods there appears to be a moderately good match in the shape of the growth curve.	AEP	Reading growth curve	DS Kennet SS growth curve	DS Loddon SS growth curve	20%	1.28	1.26	1.27	10%	1.47	1.42	1.44	5.0%	1.67	1.58	1.61	3.3%	1.79	1.67	1.71
AEP	Reading growth curve	DS Kennet SS growth curve	DS Loddon SS growth curve																		
20%	1.28	1.26	1.27																		
10%	1.47	1.42	1.44																		
5.0%	1.67	1.58	1.61																		
3.3%	1.79	1.67	1.71																		
What do the results imply regarding the return periods of floods during the period of record?	At Reading, the adopted growth curve implies the following return periods for floods in the period of record: November 1894 – 200-year March 1947 – 75-year January 2003 – 30-year.																				
What is the range of 100-year growth factors? Is this realistic?	2.18. This appears realistic given the size of the upstream catchment and climate in southern England.																				
If 1000-year flows have been derived, what is the range of ratios for 1000-year flow over 100-year flow?	1.43																				
How do the results compare with those of other studies? Explain any differences and conclude which results should be preferred.	The growth curve compares very well with that derived previously by Jacobs (2011). This is likely due to the similarities in the methods applied. There are differences in the design inflows for the Kennet and Loddon however, due to differences in how the downstream design hydrograph was derived at Windsor in the Jacobs 2011 analysis. The data extension at Windsor used in the Jacobs 2011 study has since been shown to be possibly affected by non-stationary conveyance behaviour of the Thames over time and should hence be treated with caution.																				
Are the results compatible with the longer-term flood history?	Yes, the return periods for the three largest events on record above appear sensible.																				
Describe any other checks on the results																					

4.4 Final results

Site code	Flood peak (m ³ /s) for the following Annual Exceedance Probabilities										
	50%	20%	10%	5%	3.3%	2%	1.3%	1%	0.5%	0.2%	0.1%
Upstream	174.2	223.1	256.3	290.3	311.1	338.7	361.9	379.0	423.0	487.7	542.3
DS Kennet	192.0	245.9	282.4	320.0	342.9	373.4	398.9	417.7	466.2	537.6	597.7
DS Lonnon	219.6	281.2	323.1	365.9	392.2	427.0	456.2	477.8	533.3	614.9	683.6
Downstream	222.8	285.4	327.8	371.4	398.0	433.3	462.9	484.8	541.1	623.9	693.7

If flood hydrographs are needed for the next stage of the study, where are they provided? (e.g. give filename of spreadsheet, hydraulic model, or reference to table below)

Spreadsheet titled "Design event inflows" provides peak flows and results of the subtraction method described in Section 4.2.

5 Annex

5.1 AMAX data

5.1.1 Extended Reading AMAX dataset

Water Year	Date	AMAX	Source
1892	01/03/1893	167.9	Lock Keeper POT record, using Mapledurham NFFS rating
1893	19/02/1894	140	Jacobs 2011 Table 3.3 (no AMAX level from Mapledurham available)
1894	16/11/1894	425.4	Lock Keeper POT record, using Mapledurham NFFS rating
1895	23/03/1896	153	Jacobs 2011 Table 3.3 (no AMAX level from Mapledurham available)
1896	08/02/1897	269.9	Lock Keeper POT record, using Mapledurham NFFS rating
1897	01/01/1898	149	Jacobs 2011 Table 3.3 (no AMAX level from Mapledurham available)
1898	12/02/1899	210.3	Lock Keeper POT record, using Mapledurham NFFS rating
1899	20/02/1900	311.8	Lock Keeper POT record, using Mapledurham NFFS rating
1900	03/01/1901	197.9	Lock Keeper POT record, using Mapledurham NFFS rating
1901	31/12/1901	119	Jacobs 2011 Table 3.3 (no AMAX level from Mapledurham available)
1902	18/06/1903	300.9	Lock Keeper POT record, using Mapledurham NFFS rating
1903	12/02/1904	318.5	Lock Keeper POT record, using Mapledurham NFFS rating
1904	17/03/1905	159	Jacobs 2011 Table 3.3 (no AMAX level from Mapledurham available)
1905	10/01/1906	158.1	Lock Keeper POT record, using Mapledurham NFFS rating
1906	04/01/1907	158.1	Lock Keeper POT record, using Mapledurham NFFS rating
1907	01/05/1908	269.9	Lock Keeper POT record, using Mapledurham NFFS rating
1908	02/01/1909	106	Jacobs 2011 Table 3.3 (no AMAX level from Mapledurham available)
1909	27/02/1910	163.8	Lock Keeper POT record, using Mapledurham NFFS rating
1910	18/12/1910	285.3	Lock Keeper POT record, using Mapledurham NFFS rating
1911	25/01/1912	249.7	Lock Keeper POT record, using Mapledurham NFFS rating
1912	31/12/1912	210	Lock Keeper POT record, using Mapledurham NFFS rating
1913	13/03/1914	156.3	Lock Keeper POT record, using Mapledurham NFFS rating
1914	03/01/1915	279.2	Lock Keeper POT record, using Mapledurham NFFS rating
1915	23/03/1916	255.4	Lock Keeper POT record, using Mapledurham NFFS rating
1916	26/12/1916	197.6	Lock Keeper POT record, using Mapledurham NFFS rating
1917	22/01/1918	259.3	Lock Keeper POT record, using Mapledurham NFFS rating
1918	23/03/1919	231.4	Lock Keeper POT record, using Mapledurham NFFS rating
1919	13/04/1920	204.2	Lock Keeper POT record, using Mapledurham NFFS rating
1920	06/01/1921	149.8	Lock Keeper POT record, using Mapledurham NFFS rating
1921	09/03/1922	117	Jacobs 2011 Table 3.3 (no AMAX level from Mapledurham available)
1922	11/01/1923	171.4	Lock Keeper POT record, using Mapledurham NFFS rating
1923	26/01/1924	205.8	Lock Keeper POT record, using Mapledurham NFFS rating
1924	04/01/1925	285.3	Lock Keeper POT record, using Mapledurham NFFS rating
1925	05/01/1926	269.1	Lock Keeper POT record, using Mapledurham NFFS rating
1926	02/03/1927	197.6	Lock Keeper POT record, using Mapledurham NFFS rating

Water Year	Date	AMAX	Source
1927	06/01/1928	255.4	Lock Keeper POT record, using Mapledurham NFFS rating
1928	30/12/1928	129	Jacobs 2011 Table 3.3 (no AMAX level from Mapledurham available)
1929	11/12/1929	295.8	Lock Keeper POT record, using Mapledurham NFFS rating
1930	03/01/1931	148	Jacobs 2011 Table 3.3 (no AMAX level from Mapledurham available)
1931	25/05/1932	191.1	Lock Keeper POT record, using Mapledurham NFFS rating
1932	02/03/1933	269.1	Lock Keeper POT record, using Mapledurham NFFS rating
1933	16/03/1934	67	Jacobs 2011 Table 3.3 (no AMAX level from Mapledurham available)
1934	30/12/1934	110	Jacobs 2011 Table 3.3 (no AMAX level from Mapledurham available)
1935	31/12/1935	231.4	Lock Keeper POT record, using Mapledurham NFFS rating
1936	19/03/1937	214	Lock Keeper POT record, using Mapledurham NFFS rating
1937	14/01/1938	123	Jacobs 2011 Table 3.3 (no AMAX level from Mapledurham available)
1938	29/01/1939	255.4	Lock Keeper POT record, using Mapledurham NFFS rating
1939	09/02/1940	265.1	Lock Keeper POT record, using Mapledurham NFFS rating
1940	26/01/1941	191.1	Lock Keeper POT record, using Mapledurham NFFS rating
1941	28/01/1942	165.3	Lock Keeper POT record, using Mapledurham NFFS rating
1942	04/02/1943	210	Lock Keeper POT record, using Mapledurham NFFS rating
1943	25/01/1944	63	Jacobs 2011 Table 3.3 (no AMAX level from Mapledurham available)
1944	14/02/1945	148	Jacobs 2011 Table 3.3 (no AMAX level from Mapledurham available)
1945	30/12/1945	156.3	Lock Keeper POT record, using Mapledurham NFFS rating
1946	17/03/1947	359.6	Lock Keeper POT record, using Mapledurham NFFS rating
1947	30/01/1948	136	Jacobs 2011 Table 3.3 (no AMAX level from Mapledurham available)
1948	03/01/1949	152.6	Lock Keeper POT record, using Mapledurham NFFS rating
1949	16/02/1950	196	Lock Keeper POT record, using Mapledurham NFFS rating
1950	10/01/1951	201.7	Lock Keeper POT record, using Mapledurham NFFS rating
1951	27/02/1952	167.6	Lock Keeper POT record, using Mapledurham NFFS rating
1952	23/12/1952	167.6	Lock Keeper POT record, using Mapledurham NFFS rating
1953	14/06/1954	127	Jacobs 2011 Table 3.3 (no AMAX level from Mapledurham available)
1954	11/12/1954	236.8	Lock Keeper POT record, using Mapledurham NFFS rating
1955	25/01/1956	160	Lock Keeper POT record, using Mapledurham NFFS rating
1956	11/02/1957	167.6	Lock Keeper POT record, using Mapledurham NFFS rating
1957	30/01/1958	175.3	Lock Keeper POT record, using Mapledurham NFFS rating
1958	23/01/1959	249.7	Lock Keeper POT record, using Mapledurham NFFS rating
1959	28/01/1960	196	Lock Keeper POT record, using Mapledurham NFFS rating
1960	06/12/1960	222.6	Lock Keeper POT record, using Mapledurham NFFS rating
1961	14/01/1962	171.4	Lock Keeper POT record, using Mapledurham NFFS rating
1962	12/03/1963	152.6	Lock Keeper POT record, using Mapledurham NFFS rating
1963	21/11/1963	173.7	Lock Keeper POT record, using Mapledurham NFFS rating
1964	22/03/1965	72	Jacobs 2011 Table 3.3 (no AMAX level from Mapledurham available)
1965	01/03/1966	165.3	Lock Keeper POT record, using Mapledurham NFFS rating
1966	02/03/1967	152.6	Lock Keeper POT record, using Mapledurham NFFS rating

Water Year	Date	AMAX	Source
1967	17/01/1968	191.1	Lock Keeper POT record, using Mapledurham NFFS rating
1968	15/03/1969	169.9	Lock Keeper POT record, using Mapledurham NFFS rating
1969	31/01/1970	123	Jacobs 2011 Table 3.3 (no AMAX level from Mapledurham available)
1970	26/01/1971	183.1	Lock Keeper POT record, using Mapledurham NFFS rating
1971	07/03/1972	173.7	Lock Keeper POT record, using Mapledurham NFFS rating
1972	08/12/1972	136	Jacobs 2011 Table 3.3 (no AMAX level from Mapledurham available)
1973	13/02/1974	185.5	Lock Keeper POT record, using Mapledurham NFFS rating
1974	23/11/1974	204.2	Lock Keeper POT record, using Mapledurham NFFS rating
1975	29/11/1975	54	Jacobs 2011 Table 3.3 (no AMAX level from Mapledurham available)
1976	25/02/1977	204.2	Lock Keeper POT record, using Mapledurham NFFS rating
1977	30/01/1978	157.8	Lock Keeper POT record, using Mapledurham NFFS rating
1978	31/03/1979	201.7	Lock Keeper POT record, using Mapledurham NFFS rating
1979	31/12/1979	214	Lock Keeper POT record, using Mapledurham NFFS rating
1980	14/03/1981	173.7	Lock Keeper POT record, using Mapledurham NFFS rating
1981	03/01/1982	196	Lock Keeper POT record, using Mapledurham NFFS rating
1982	12/12/1982	160	Lock Keeper POT record, using Mapledurham NFFS rating
1983	28/01/1984	145	Jacobs 2011 Table 3.3 (no AMAX level from Mapledurham available)
1984	27/11/1984	149.8	Lock Keeper POT record, using Mapledurham NFFS rating
1985	27/12/1985	193.5	Lock Keeper POT record, using Mapledurham NFFS rating
1986	09/04/1987	145	Jacobs 2011 Table 3.3 (no AMAX level from Mapledurham available)
1987	26/01/1988	179.2	Lock Keeper POT record, using Mapledurham NFFS rating
1988	28/02/1989	141	Jacobs 2011 Table 3.3 (no AMAX level from Mapledurham available)
1989	05/02/1990	208.1	Lock Keeper POT record, using Mapledurham NFFS rating
1990	31/12/1990	138	Jacobs 2011 Table 3.3 (no AMAX level from Mapledurham available)
1991	26/09/1992	111	Jacobs 2011 Table 3.3 (no AMAX level from Mapledurham available)
1992	06/12/1992	196	Lock Keeper POT record, using Mapledurham NFFS rating
1993	08/01/1994	191.1	Lock Keeper POT record, using Mapledurham NFFS rating
1994	02/02/1995	205.6	From JBA Lower Thames 2013 analysis (Reading ultrasonic adjusted with spot gaugings)
1995	25/12/1995	170.3	Reading ultrasonic gauge
1996	26/02/1997	104.8	Reading ultrasonic gauge
1997	13/04/1998	179	Reading ultrasonic gauge
1998	24/01/1999	194.3	Mapledurham NFFS rating (considered more reliable than ultrasonic above 180m ³ /s)
1999	28/12/1999	164.2	From JBA Lower Thames 2013 analysis (Reading ultrasonic adjusted with spot gaugings)
2000	16/12/2000	229.4	Mapledurham NFFS rating (considered more reliable than ultrasonic above 180m ³ /s)
2001	07/02/2002	146.7	Reading ultrasonic gauge
2002	04/01/2003	304.6	Mapledurham NFFS rating (considered more reliable than ultrasonic above 180m ³ /s)
2003	03/02/2004	124.8	Reading ultrasonic gauge
2004	31/03/2005	113.1	Reading ultrasonic gauge

Water Year	Date	AMAX	Source
2005	01/04/2006	90.1	Reading ultrasonic gauge
2006	26/07/2007	222	From JBA Lower Thames 2013 analysis (Reading ultrasonic adjusted with spot gaugings)
2007	20/01/2008	210.8	Mapledurham NFFS rating (considered more reliable than ultrasonic above 180m ³ /s)
2008	12/02/2009	201.7	Mapledurham NFFS rating (considered more reliable than ultrasonic above 180m ³ /s)
2009	19/01/2010	162	Reading ultrasonic gauge
2010	19/01/2011	123.9	Reading ultrasonic gauge
2011	03/05/2012	152.5	Reading ultrasonic gauge
2012	29/11/2012	242.4	From JBA Lower Thames 2013 analysis (Reading ultrasonic adjusted with spot gaugings)
2013	10/01/2014	274.9	From JBA Lower Thames 2013 analysis (Reading ultrasonic adjusted with spot gaugings)
2014	18/01/2015	117	Reading ultrasonic gauge
2015	12/02/2016	144	Reading ultrasonic gauge

5.1.2 DS Kennet AMAX dataset

Each AMAX event here was calculated by first adding the Reading and Theale gauged flow series, then calculating the maximum from the added series for each water year.

Water Year	Date	AMAX	Notes
1992	07/12/1992 20:45	232.36	Using Reading Ultrasonic (no data from Mapledurham for NFFS rating)
1993	10/01/1994 13:15	229.04	Using Reading Ultrasonic (no data from Mapledurham for NFFS rating)
1994	02/02/1995 17:00	241.58	Using Reading Ultrasonic adjusted using spot gaugings from Lower Thames study (no data from Mapledurham for NFFS rating)
1995	23/12/1995 11:45	189.64	Using Reading Ultrasonic (Below cutoff point for NFFS Mapledurham rating)
1996	27/02/1997 09:15	114.83	Using Reading Ultrasonic (Below cutoff point for NFFS Mapledurham rating)
1997	13/04/1998 18:30	192.52	Using Reading Ultrasonic (Below cutoff point for NFFS Mapledurham rating)
1998	24/01/1999 10:00	224.63	Using Mapledurham NFFS at Reading (above cutoff where ultrasonic is considered less reliable)
1999	25/12/1999 15:30	191.42	Using Reading Ultrasonic adjusted using spot gaugings from Lower Thames study
2000	13/12/2000 22:15	272.5	Using Mapledurham NFFS at Reading (above cutoff where ultrasonic is considered less reliable)
2001	05/02/2002 15:00	185.17	Using Reading Ultrasonic (Below cutoff point for NFFS Mapledurham rating)
2002	04/01/2003 10:00	350.32	Using Mapledurham NFFS at Reading (above cutoff where ultrasonic is considered less reliable)
2003	07/02/2004 15:00	139.91	Using Reading Ultrasonic (Below cutoff point for NFFS Mapledurham rating)
2004	31/03/2005 13:45	125.28	Using Reading Ultrasonic (Below cutoff point for NFFS Mapledurham rating)
2005	01/04/2006 11:45	98.53	Using Reading Ultrasonic (Below cutoff point for NFFS Mapledurham rating)

Water Year	Date	AMAX	Notes
2006	27/07/2007 00:15	238.54	Using Reading Ultrasonic adjusted using spot gaugings from Lower Thames study
2007	20/01/2008 08:30	242.41	Using Mapledurham NFFS at Reading (above cutoff where ultrasonic is considered less reliable)
2008	12/02/2009 17:30	233.31	Using Mapledurham NFFS at Reading (above cutoff where ultrasonic is considered less reliable)
2009	19/01/2010 10:30	178.15	Using Reading Ultrasonic (Below cutoff point for NFFS Mapledurham rating)
2010	19/01/2011 13:00	145.43	Using Reading Ultrasonic (Below cutoff point for NFFS Mapledurham rating)
2011	03/05/2012 11:00	165.43	Using Reading Ultrasonic (Below cutoff point for NFFS Mapledurham rating)
2012	27/12/2012 13:15	266.56	Using Reading Ultrasonic adjusted using spot gaugings from Lower Thames study
2013	10/01/2014 06:15	319.66	Using Mapledurham NFFS at Reading (above cutoff where ultrasonic is considered less reliable)
2014	16/01/2015 12:00	151.92	Using Reading Ultrasonic (Below cutoff point for NFFS Mapledurham rating)
2015	29/03/2016 11:30	177.82	Using Reading Ultrasonic (Below cutoff point for NFFS Mapledurham rating)

5.1.3 Marsh Lock (AKA DS Loddon) AMAX dataset

The Marsh Lock (downstream) level series contains some gaps, and periods where there are frequent and severe telemetry spikes. This prevents the use of automated methods for extracting an AMAX level series. Instead this process was carried out manually, comparing the Marsh Lock level telemetry against the gauged flow series from Reading to help identify each AMAX event.

Year	Date	Stage (mALD)	AMAX flow from new rating	Notes
1995	24/12/1995 11:45	3.309	213.6	
1996	26/02/1997 13:00	2.812	135.9	
1997	13/04/1998 20:00	3.35	219.6	
1998	22/01/1999 01:45	3.465	236.4	
1999	27/12/1999 00:30	3.572	252.5	
2000	14/12/2000 18:45	3.972	315.2	
2001	06/02/2002 11:30	3.397	226.4	
2002	04/01/2003 10:00	4.274	365.3	
2003	03/02/2004 00:15	2.933	161.7	
2004				Missing data over the peak. Likely less than QMED judging from the Reading dataset
2005	01/04/2006 11:15	2.655	97.4	
2006	26/07/2007 04:45	3.647	263.9	
2007	17/01/2008 19:30	3.687	270.1	
2008	12/02/2009 16:00	3.755	280.7	
2009				Missing data for most of the WY. Would have been slightly below QMED judging from other datasets
2010	19/01/2011 17:00	3.093	183.3	
2011	02/05/2012 04:15	3.153	191.6	

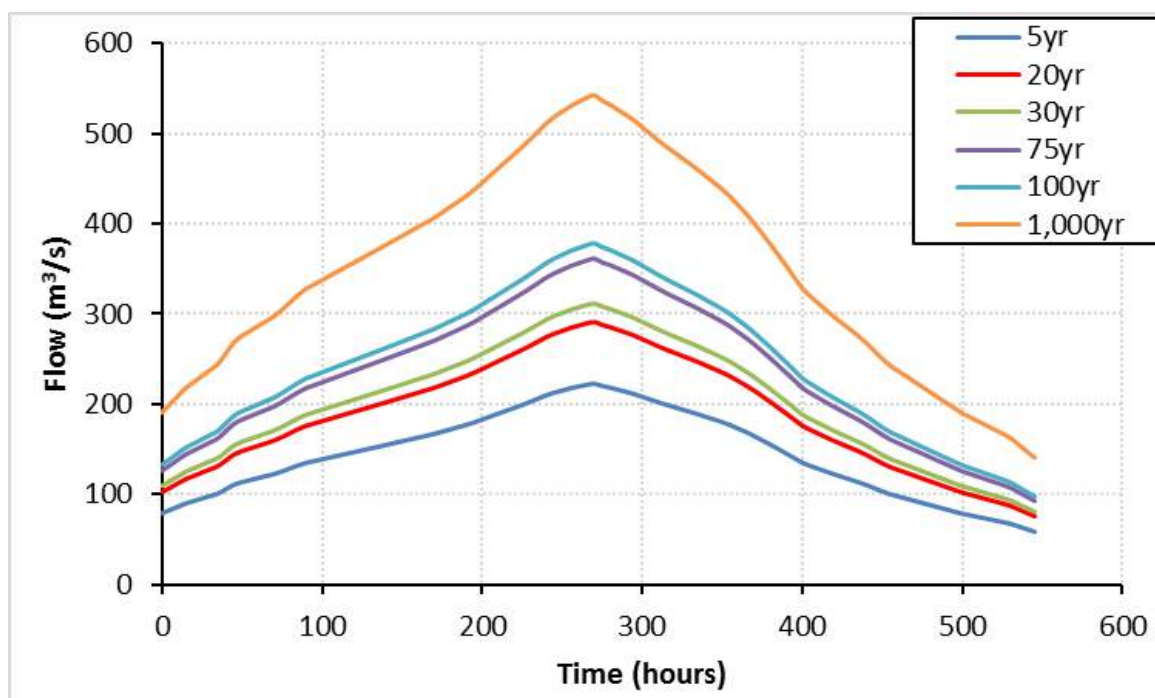
Year	Date	Stage (mALD)	AMAX flow from new rating	Notes
2012	27/12/2012 10:00	3.812	289.6	
2013	09/02/2014 02:45	4.275	365.5	Truncated hydrograph, true peak is probably even higher
2014	16/01/2015 16:45	3.128	188.1	
2015	13/01/2016 03:15	3.279	209.3	
2016	02/02/2017 11:45	2.655	97.4	

5.2 Reading ESS pooling group

Station	SDM	n	QMED	LCV	LSKEW	Disc	Area	SAAR	FPEXT	FARL
39130 (Thames @ Reading)	0	124	174.5	0.179	0.124	0.148	4599	680	0.17	0.961
39002 (Thames @ Days Weir)	0.4	77	149.6	0.195	0.096	1.316	3480	690	0.176	0.953
27009 (Ouse @ Skelton)	0.815	129	322.0	0.137	0.116	0.769	3301	899	0.136	0.983
54001 (Severn @ Bewdley)	0.919	92	336.0	0.134	0.131	0.729	4330	912	0.106	0.973
27041 (Derwent @ Buttercrambe)	1.546	42	70.7	0.139	0.321	1.648	1594	765	0.141	0.994
21021 (Tweed @ Sprouston)	1.646	36	816.9	0.188	0.127	1.391	3346	1014	0.046	0.978

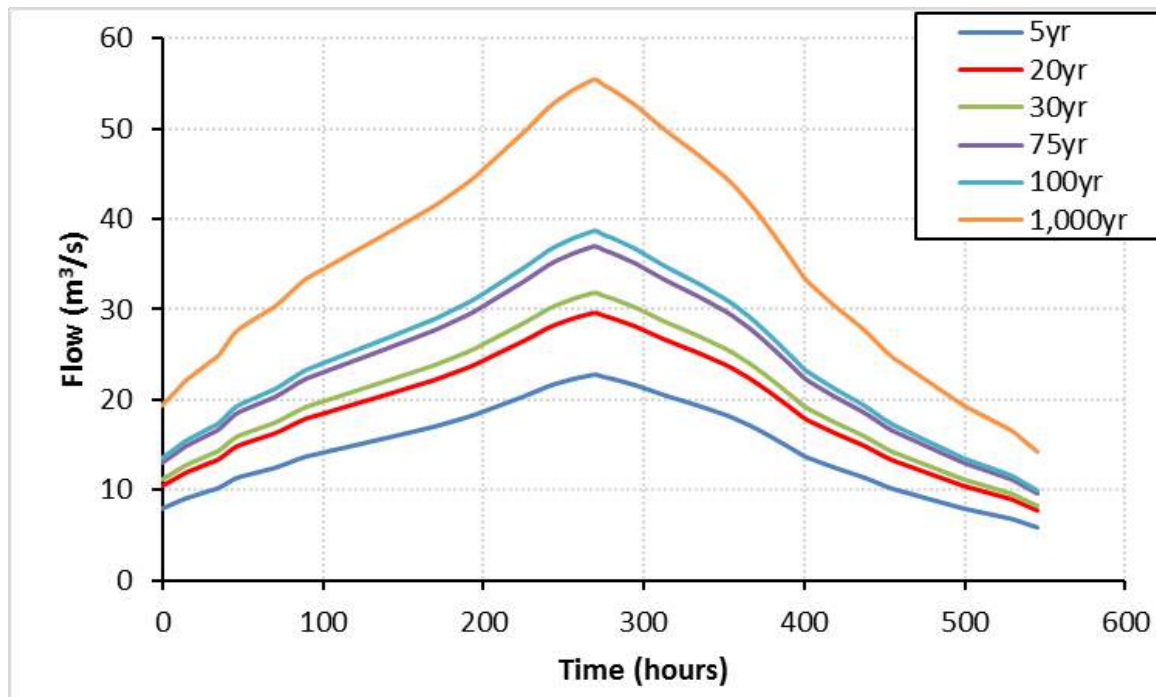
5.3 Inflow hydrographs

5.3.1 Upstream inflows



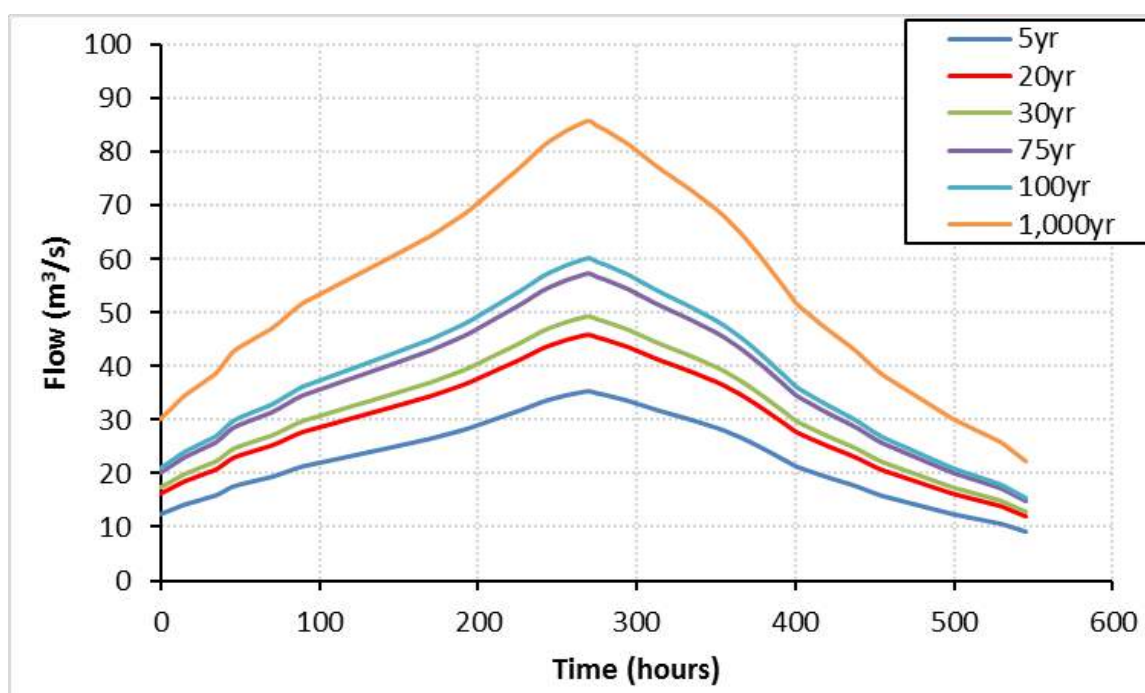
5.3.2 Kennet inflows

Calculated by subtracting design flow hydrographs at Upstream and DS Kennet



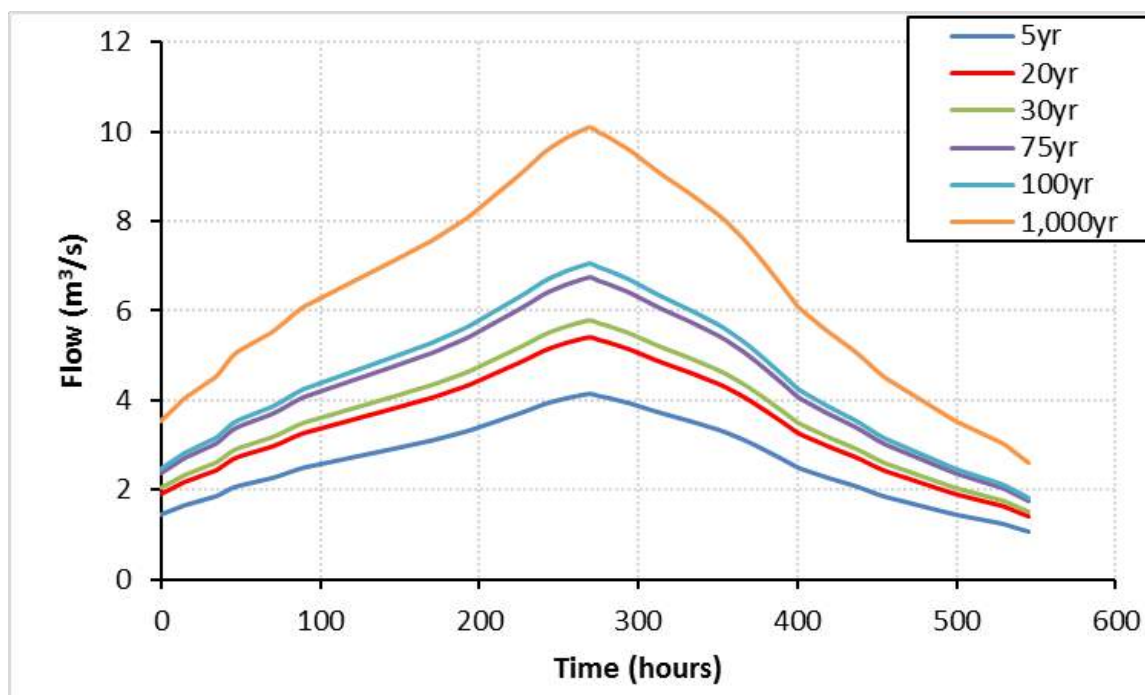
5.3.3 Loddon inflows

Calculated by subtracting design flow hydrographs at DS Kennet and DS Loddon



5.3.4 Downstream lateral inflow

Calculated by subtracting design flow hydrographs at DS Loddon and Downstream



Offices at

Coleshill
Doncaster
Dublin
Edinburgh
Exeter
Haywards Heath
Limerick
Newcastle upon Tyne
Newport
Saltaire
Skipton
Tadcaster
Thirsk
Wallingford
Warrington

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E EA Approval Letter

Emelie Persson
J B A
The Library Church Hill
Coleshill
BIRMINGHAM
B46 3AD

Our ref: WA/2022/129911/02-L01
ENVPAC/1/THM/00685

Date: 10 February 2023

Dear Ms Persson

Review Of Flood Modelling

Thames Field Retirement Villages

I'm pleased to confirm that we now deem the modelling fit for intended use.

Please see our more detailed review comments sent separately via email on 10 February 2023.

Yours sincerely,

Mr Jack Moeran
Planning Specialist

Direct dial 02030259655
Direct e-mail planning-wallington@environment-agency.gov.uk

Disclaimer

Please note that the views expressed in this report by the Environment Agency, is a response to a pre-application enquiry only and **does not represent our final view in relation to any future statutory consultations made in relation to this site**. We reserve the right to change our position in relation to any such application. You should seek your own expert advice in relation to technical matters relevant to any conditions before submission.

End

F Landscape Strategy

Thamesfield Village

Henley-on-Thames, Oxfordshire

December 2023



Landscape Strategy

Turley Design were commissioned by Retirement Villages Group (RVG) to provide landscape proposals to support a full application for the part demolition of existing building and replacement with a three-storey extension to provide extra-care units (Use Class C2), with associated soft and hard landscaping works; provision of additional vehicle parking, bin stores and ancillary structures; and alterations to existing basement at Thamesfield Retirement Village, Henley-on-Thames.

Objectives

The landscape proposals have been informed and shaped by RVG's Landscape Design Code and Vision. The overarching themes of the Vision is to create a sense of place, promote physical and mental well-being, and implement climate resilience. These themes will be achieved within the landscape proposals by meeting the following objectives:

- Integrate with the existing surrounding landscape setting, including cultural, social and historical characteristics;
- Provide an inspiring and inviting first impression to visitors by aiming to uplift the quality of the public realm;
- Identify opportunities for the enhancement of biodiversity and participation by residents in caring for the planet;
- Encourage residents and staff to exercise and experience the outdoors;
- Promote locally sourced, organic fruit and vegetables for healthy eating options;

- Provide a safe and secure environment for a community to live, work and play, reducing anxiety levels and stress;
- Providing means and spaces for social interaction between residents;
- Implement spaces for a wide range of intellectually stimulating processes, such as bird watching or bee keeping;
- Make spaces and settings for rest and relaxation, promoting physical well-being;
- Provide habitat enhancements by connecting planted systems, integrating with adjacent habitats, and maximising green spaces; and
- Maximise daylight gain in winter, shade in summer and wind protection throughout the year by strategically placing trees.

Proposals

The adjacent Illustrative Landscape Masterplan sets out the landscape proposals for Thamesfield Village. Alongside the redevelopment of extra care units, the courtyard will undergo a transformation to create a high-quality communal outdoor space which has the potential to become the heart of the village.

The courtyard will be a scenic walk between destinations with interest along the route. The courtyard will be fully accessible for all users.

The design creates outdoor rooms within the courtyard, separated by a flowering pergola, which residents would journey through. A Kitchen Garden to one end and a Residents Garden to the other. This series of social spaces would promote impromptu conversations and meetings as well as organised activities which promote mental and physical well-being.

The courtyard will be a vibrant, stimulating, inclusive and beautiful place for residents, staff and their visitors to enjoy.

The western boundary woodland walk will connect the courtyard with the wider outdoor facilities whilst providing ecological enhancements to support wildlife.

The proposals support resident engagement and participation in outdoor activities. Residents will be able to help make decisions on the gardens and be involved in it's evolution, help with gardening, grow their own food , fruit veg and herbs and share their produce from the garden as well as organise events in the gardens. This will promote a sense of ownership and encouraging participation serves to promote wellness and a healthy sociable community.

The courtyard proposals have been designed to accommodate fire vehicle access and turning. Fire vehicles will be able to overrun the hard surfaced areas as well as the grassed areas which will be reinforced with pavers to accommodate their loading capacity requirements. There are no raised kerbs or built elements, ensuring a flush surface for the extent of the turning head.



- 1 Resin bound gravel
- 2 Raised beds
- 3 Allotment beds
- 4 Greenhouse
- 5 Garden shed
- 6 Bin store (inc. fence screen)
- 7 Circular tree bench
- 8 Benches, tables and chairs
- 9 Freestanding planters
- 10 Steps to basement
- 11 Patio over basement
- 12 Private balcony/ garden
- 13 Existing trees
- 14 Proposed trees
- 15 Ornamental shrub planting
- 16 Garden mix planting
- 17 Hedgerow planting
- 18 Meadow mix planting
- 19 Native shrub mix planting
- 20 Mown grass with protection mesh for fire vehicle access
- 21 Vertical bike shed

Kitchen Garden

- Provision for growing fruit, vegetables and herbs. Raised, robust allotment beds which are sufficiently spaced for comfortable access for all to use.
- Research in environmental psychology and horticulture demonstrates that the act of gardening has a positive psychological and therapeutic effect on people. Horticulture therapy for those with dementia focuses on positive reminiscence, re-connecting with others and gentle appropriate physical exercise and stimulation of a great number of cognitive processes which reduces the anxiety of living with dementia.
- A community Kitchen Garden Team consisting of interested residents and restaurant/ RVG management staff will ensure a thriving, productive kitchen garden. A Kitchen Garden Annual Management Plan will define activities and responsibilities throughout the year.
- Enabling equipment would be required – a greenhouse (to broaden the growing season/plant propagation) and a shed (for equipment storage) as well as outdoor taps, rainwater harvesting tank, electricity points and composting bins.



Resident's Garden

- The proposed terrace will offer a vibrant space for social interaction between residents. Dementia patients with a lower mental capacity enjoy emotional participation - they take interest in their social surroundings, observe people, are friendly and talk to others but do not have the strength to actively take part or integrate in busy social situation. Dementia patients appreciate a sense of concealment and protection, yet open views of their surrounding environment.
- The Resident's Garden will offer an attractive and inviting space to linger where residents will feel encouraged to spend time outdoors, feel safe and relaxed without it being overstimulated.
- A central feature would create a focal point, this may be a large ornamental tree, a water sculpture or a piece of art.
- Seating with back and arm rests have been arranged strategically to offer sunshine and shade opportunities throughout the day.
- Planting will incorporate species of flowering and sensory interest, providing seasonal variety and change throughout the year.



Private Outdoor Space

- Patio terraces to ground floor apartments. Extending 2m from the building and providing residents with c.16-20sqm of private amenity space. Paved spaces which provide residents an outdoor place they can make their own and personalise.
- To offer a degree of separation and enclosure between ground level private amenity space and the public courtyard, a 1.1m high balustrade would define their patio with hedgerow planting for greening and visual screening. Where space permits, further planting to the communal space would separate private boundaries from communal routes.



Woodland Walk

- Ecological enhancements to boundary vegetation will establish a wildlife corridor including supplementary tree and native shrub planting. Bird and bat boxes will provide nesting and roosting opportunities, whereas bird feeders will allow residents to bird watch from their apartments.
- Provision of a continuous and looped footpath network, set entirely outdoors, to offer diverse and interesting routes to explore and promote physical well-being. This will be informal surfacing of self-binding aggregate to enhance parkland setting, avoiding steps where possible.
- Structured locations of fixed furnishings create destinations, landmarks and circulation cues that encourage movement into and through the garden. Seating will be strategically located to provide places to rest.
- Movable furnishings allow an adaptable environment, creating places for both social interaction and also private contemplation for those not wishing to be sociable at that time.

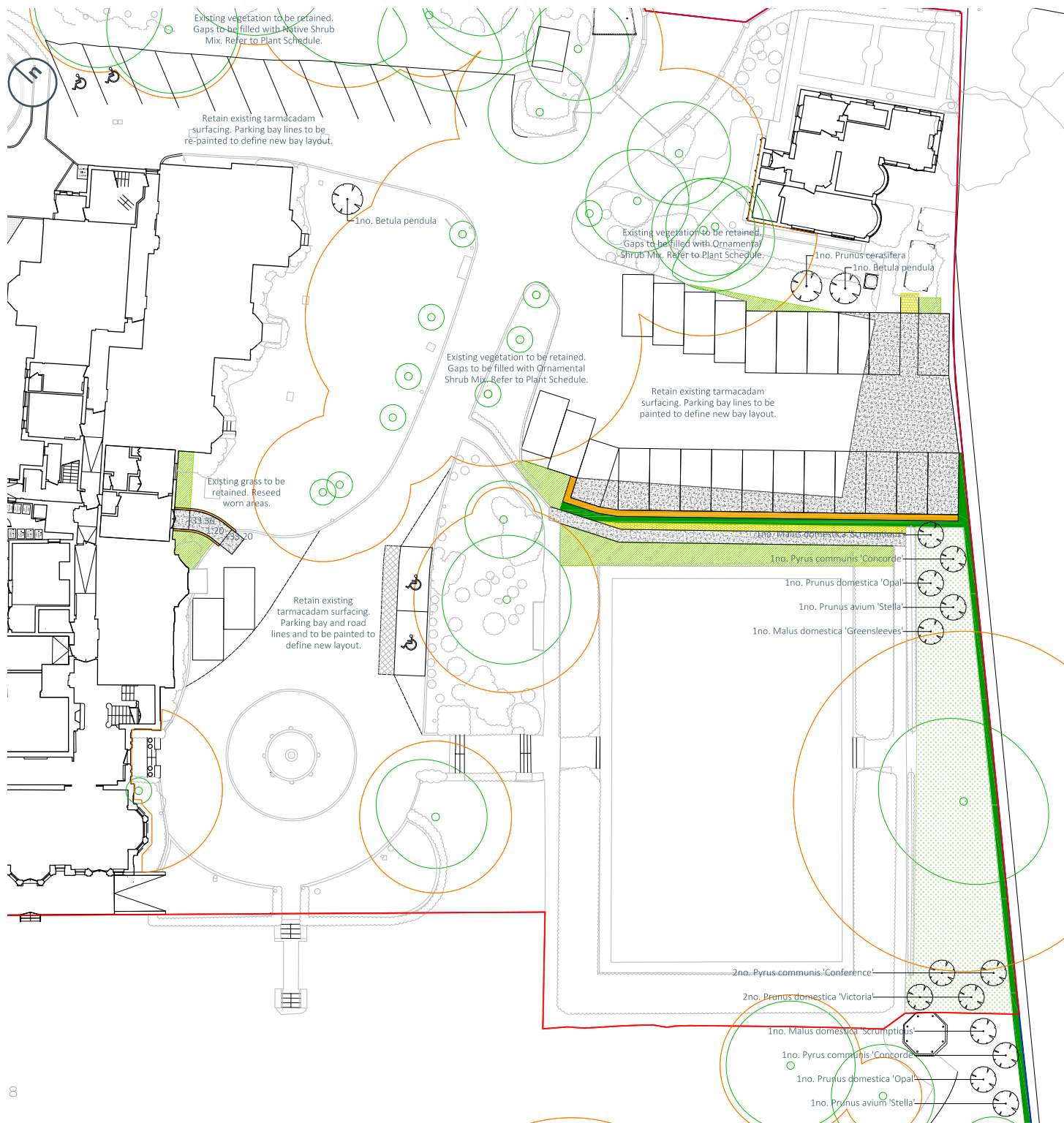




-  Application boundary
-  Ownership boundary
-  Resin Bound Gravel
Buff Colour. Permeable. Installed to product specification. Setts edging to courtyard. Aluminum edging to paths beyond courtyard and patio.
-  Setts
Single row of 100 x 100mm setts. Buff Colour. Laid flush to adjacent surfaces. Installation to engineers specification.
-  Suregreen PP40 Porous Paver Grass Finish
Or similar approved, suitable for Fire Engine overrun. Laid flush to adjacent hard surfaces. Installed to product specification.
-  Raised Beds
Height 60cm inc coping. Brick finish same as bricks to new building.
-  Allotment Beds
Height 60cm inc coping. Brick finish same as bricks to new building. To be filled with a soil/compost mix.
-  Retaining wall
Height min 1.1m above step level inc coping. Brick finish same as bricks to new building.
-  Greenhouse
6ft x 8ft. Timber or aluminum frame, apex. Concrete base. RVG product choice.
-  Garden Shed
6ft x 8ft. Pressure treated timber, tongue and groove, apex. Concrete base. RVG product choice.
-  Garden Bench
Hardwood timber. With back and arm rests. Freestanding. RVG product choice.
-  Circular Tree Bench
D.2m approx. Hardwood timber. With back rest. RVG product choice.
-  Table and Chairs
Freestanding. RVG product choice.
-  Large Planters
Freestanding. RVG product choice.
-  Small Planters
Freestanding. RVG product choice.
-  Vertical Bike Locker
Galvanised steel. RVG product choice. Installed to manufacturers specifications.
-  Fence Screen to Bin Store
6ft horizontal double slatted panels (slats mounted alternately on the front and back of the panel). Pressure treated timber. Timber or concrete posts.
-  Balustrade to patio
To match balustrades to terrace or to balconies.
-  Existing tree retained
-  Combined root protection area

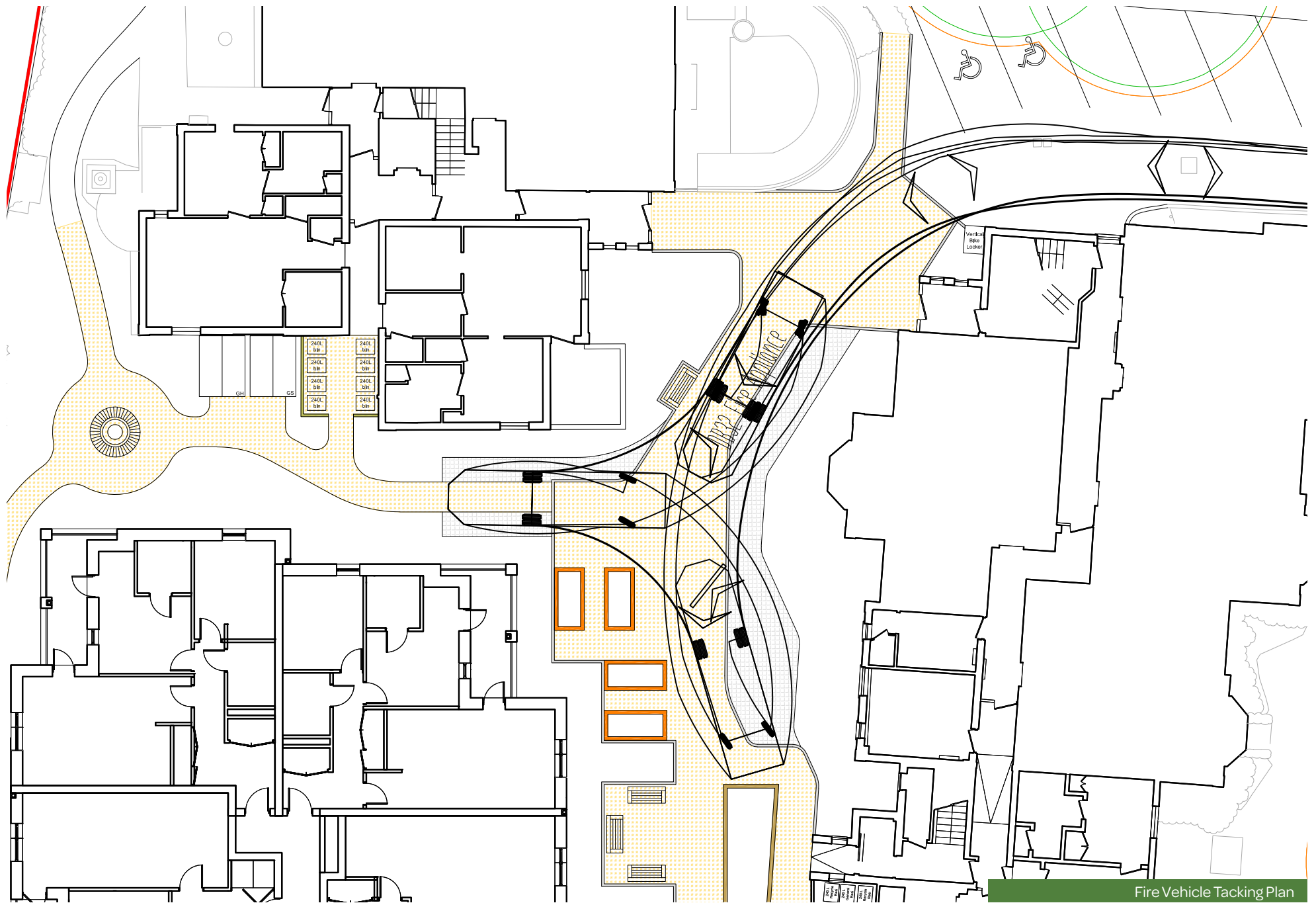


- Application boundary
- Ownership boundary
- Existing tree retained
- Combined root protection area
- Proposed tree
- Ornamental hedgerow
Planted in a single row, at 3no. plants per linear metre
- Garden Mix 1
Interspersed with Infills and Bedding Mix
- Garden Mix 2
Interspersed with Infills and Bedding Mix
- Garden Mix 3
Interspersed with Infills and Bedding Mix
- Infills and Bedding Mix
- Ornamental Shrub Mix
Interspersed with Infills and Bedding Mix
- Native Shrub Mix
Retain existing vegetation where possible and add additional plants where needed.
- Meadow Mix
- Close Mown Grass
- Close Mown Grass with Suregreen
PP40 Porous Paver Grass Finish
Product: Suregreen PP40 Pourous Pavers or similar approved. Installed to product specification.
- Allotment Bed
To be filled with a soil/compost mix. Planted contents to be decided by residents and Kitchen Garden Team.



- Application boundary
- Ownership boundary
- Tarmacadam
Continuation of existing surface materials.
Installed to product specification.
- Extent of existing tarmacadam to be retained
- Relocated garden path
New area of path to use the same or similar approved product as existing garden paths.
Installed to engineers specification.
- Retaining wall
Height min.50cm above floor level of car park inc coping. Brick finish same as bricks to new building.
- Existing tree retained
- Combined root protection area
- Proposed tree
- Native hedgerow
Planted in a double staggered row, 400mm between rows, at 5no. plants per linear metre
- Ornamental shrub mix
In areas of existing vegetation, retain existing vegetation where possible and add additional plants where needed.
- Meadow mix
- Infill and bedding mix

Hard and Soft Car Park Landscape Plan



Hard Materials

Hard materials across the proposals will look to complement or match the proposed new architecture. Colours look to be soft and neutral to create a calming environment, allowing the natural colouring of plants to animate the spaces.

High-quality surface materials have been chosen for their suitability for elderly residents. Surfaces will be smooth yet with anti-slip properties and there will be no loose stone or uneven surfaces. Small kerbs have not been used to avoid trip hazards.

Furniture with back and arm-rests for this will be provided to reflect the resident demographic. High quality, robust hardwood timber will be used to maximise lifespan and reduce maintenance costs. All timber to be FSC certified and sustainably sourced.

Surface Materials



Resin bound gravel



Aluminium edging to resin bound gravel



Setts edging to resin bound gravel



SureGreen PP40 Lawn Protection Mesh

Built Elements



Raised beds and allotments



Balustrade to patio



Fence screen to bin store

Furniture



Benches



Circular Bench



Tables and Chairs



Greenhouse



Shed



Vertical bike shed

Plant Schedule

This Planting Schedule sets out an indicative species list for the garden mixes, climbers, infill and bedding plants, wildflower grassland areas, hedgerows and trees.

Plant species have been chosen for their suitability to site conditions, in particular partial shade due to the courtyard setting, and for their seasonal interest and sensory properties. Colour, form and scent have all been important considerations as well as using more traditional varieties which residents will recognise. A mix of both evergreen and deciduous species have been chosen alongside species which are pollinators and bee-friendly or have other wildlife-benefitting properties.

Orchard & Car Park Trees	
Rootballed or container grown. Select Standard.	
Tree pit size: 900 x 900 x 750mm, backfilled with topsoil.	
Underground tree anchoring system. 0.6m dia. bark surface to pits.	
10-12cm stem girth. 3-3.5m height. Min 2m clear stem.	
Species	Common Name
<i>Betula pendula</i>	Silver Birch
<i>Malus domestica</i> 'Scrumptious'	Apple 'Scrumptious'
<i>Malus domestica</i> 'Greensleeves'	Apple 'Greensleeves'
<i>Pyrus communis</i> 'Concorde'	Pear 'Concord'
<i>Pyrus communis</i> 'Conference'	Pear 'Conference'
<i>Prunus domestica</i> 'Opal'	Plum 'Opal'
<i>Prunus domestica</i> 'Victoria'	Plum 'Victoria'
<i>Prunus avium</i> 'Stella'	Cherry 'Stella'
<i>Prunus cerasifera</i>	Cherry Plum

Courtyard Trees	
Rootballed or container grown. Select Standard.	
Tree pit size: 900 x 900 x 750mm, backfilled with topsoil.	
Underground tree anchoring system. 0.6m dia. bark surface to pits.	
10-12cm stem girth. 3-3.5m height. Min 2m clear stem.	
Species	Common Name
<i>Acer griseum</i>	Paperbark Maple
<i>Acer platanoides</i> 'Emerald Queen'	Norway Maple
<i>Betula utilis</i> var. <i>Jacquemontii</i>	Himalayan Birch 'Jacquemontii' (multi-stem)
<i>Prunus</i> 'Amanogawa'	Cherry 'Amanogawa'
<i>Prunus</i> 'Royal Burgandy'	Cherry 'Royal Burgandy'
<i>Sorbus aucuparia</i>	Rowan
<i>Sorbus aria</i> 'Lutescens'	Whitebeam

Trees



Acer griseum (Paperbark Maple)



Malus domestica 'Scrumptious' (Apple)



Sorbus aucuparia (Rowan)



Prunus avium 'Stella' (Cherry)



Betula utilis var. *Jacquemontii* (Birch)



Pyrus communis 'Conference' (Pear)

Ornamental Plant Mixes		
Garden Mix 1		
Planted at 4/m ² , except specimens planted as individuals		
Species marked * to be located to the front of beds		
groups of 3, 5 and 7no.		
Species	Stock	Size
Choisya 'Aztec Pearl' (Specimen)	C10L	40-50cm
Hebe 'White Gem'*	C5L	30-40cm
Hauchera micrantha 'Palace Purple'*	C3L	-
Kniphofia 'Royal Standard'	C3L	30-40cm
Lavandula angustifolium 'Hidcote'	C2L	20-30cm
Lobelia cardinalis 'Queen Victoria'	C3L	30-40cm
Pittosporum tenifolium 'Tom Thumb'*	C3L	20-30cm
Santolina virens*	C3L	20-30cm
Salvia officinalis 'Purpurascens'	C5L	-
Spiraea japonica 'Gold Mound'*	C3L	30-40cm
Stipa tenuissima	C2L	-

Garden Mix 2		
Planted at 4/m ² , except specimens planted as individuals		
Species marked * to be located to the front of beds		
To be planted in single species staggered informal groups of 3, 5 and 7no.		
Species	Stock	Size
Artemisia ludoviciana 'Valerie Finnis'	C2L	40-60cm
Bergenia cordifolia 'Purpurea'	C2L	20-30cm
Hebe 'White Gem'*	C5L	30-40cm
Choisya 'Aztec Pearl'	C3L	30-40cm
Philadelphus 'Belle Etoile'	C10L	Specimen
Phormium tenax 'Purpureum'	C10L	Specimen
Polystichum setiferum	C2L	30-40cm
Rosmarinus 'Miss Jessop's Upright'	C2L	40-60cm
Salvia verticillata 'Purple Rain'	C3L	30-40cm
Skimmia 'Kew Green'*	C3L	30-40cm
Spiraea japonica 'Firelight'	C3L	30-40cm

Garden Mix 3		
To be planted at 3/m ² and in single species groups of 3, 5 and 7no.		
Species marked * to be located to the front of beds		
In small beds, select species marked **, specimens as groups of 1, 3 or 5no.		
Species	Stock	Size
Bergenia cordifolia 'Purpurea'	C2L	20-30cm
Calamagrostis x acutiflora 'Karl Forester'	C10L	Specimen
Cornus alba 'Sibirica'	C10L	Specimen
Euonymus fortunei 'Emerald Gaiety'	C2L	20-30cm
Geranium macrorrhizum 'Johnson's Blue'	C2L	20-30cm
Hebe 'Champagne'	C2L	20-30cm
Hebe 'White Gem'**	C5L	30-40cm
Hydrangea macrophylla 'Lanarth's White'	C3L	30-40cm
Lavandula angustifolium	C2L	20-30cm
Perovskia 'Blue Spire'	C; 9cm	-
Stipa gigantea	C10L	Specimen
Vinca minor 'Atropurpurea'	C3L	30-40cm

Garden Mixes



Kniphofia 'Royal Standard'



Lavandula angustifolium 'Hidcote'



Artemisia ludoviciana 'Valerie Finnis'



Phormium tenax 'Purpureum'



Stipa gigantea



Euonymus fortunei 'Emerald Gaiety'

Ornamental Shrub Mix		
300mm depth of topsoil onto 300mm depth subsoil		
Ultimate plant height is above 1m. All evergreens.		
Species	Supply size	Pot size
<i>Amelanchier canadensis</i>	90-120cm	15L
<i>Choisya ternata</i> 'Sundance'	40-60cm	3L
<i>Cornus alba</i> 'Elegantissima'	90-120cm	15L
<i>Cornus alba</i> 'Sibirica'	40-60cm	3L
<i>Euonymus fortunei</i> 'Emerald Gaiety'	40-60cm	3L
<i>Photinia × fraseri</i> 'Red Robin'	40-60cm	3L
<i>Rhus typhina</i>	100-125mm	20L
<i>Skimmia × confusa</i> 'Kew Green'	40-60cm	3L
<i>Viburnum davidii</i>	20-30cm	3L
<i>Viburnum tinus</i> 'Eve Price'	30-40cm	3L

Native Shrub Mix		
Typically planted as a density of 3/m ²		
Plant Name	Common Name	Height
<i>Corylus avellana</i>	Hazel	40-60cm
<i>Crataegus monogyna</i>	Hawthorn	40-60cm
<i>Prunus spinosa</i>	Blackthorn	40-60cm
<i>Rosa canina</i>	Dog Rose	40-60cm
<i>Salix caprea</i>	Goat willow	40-60cm
<i>Ulex europaeus</i>	Common gorse	40-60cm
<i>Viburnum opulus</i>	Guelder rose	40-60cm

Native Hedgerows			
Planted in a double staggered row, 450mm between rows, at 5no. plants per linear metre.			
300mm depth of topsoil onto 600mm depth subsoil			
To be maintained at a maximum height of 2.0m			
%	Plant Name	Common Name	Height
30	<i>Corylus avellana</i>	Hazel	40-60cm
45	<i>Crataegus monogyna</i>	Hawthorn	40-60cm
5	<i>Ilex aquifolium</i>	Holly	40-60cm
5	<i>Ligustrum vulgare</i>	Wild Privet	40-60cm
10	<i>Prunus spinosa</i>	Blackthorn	40-60cm
5	<i>Rosa canina</i>	Dog Rose	40-60cm

Ornamental Hedgerow			
To perimeter of balconies on ground floor. Select single species.			
Planted in a single row, at 3no. plants per linear metre.			
%	Plant Name	Common Name	Height
100	<i>Ligustrum ovalifolium</i>	Privet	60-90cm
100	<i>Ligustrum ovalifolium</i> 'Aureum'	Golden Privet	60-90cm
100	<i>Prunus laurocerasus</i> 'Rotundifolia'	Cherry Laurel	60-90cm

Shrubs & Hedgerows



Rhus typhina



Photinia × fraseri 'Red Robin'



Skimmia × confusa 'Kew Green'



Viburnum tinus 'Eve Price'



Native mixed-species hedgerow



Ligustrum ovalifolium 'Aureum'

Infills and Bedding		
Used throughout planting areas and in containers to add initial colour and interest		
Species	Stock	Size
Campanula portenschlagiana	1L	Clump
Carex 'Ice Dance'	1L	Clump
Festuca glauca 'Elijah Blue'	1L	Clump
Geranium 'Rozanne'	2L	Clump
Narcissus - mixed	Bag	
Nepeta 'Junior Walker'	1L	Clump
Osteospermum jucundum 'Compactum'	1L	Clump
Pachysandra terminalis	1L	Clump
Phlomis russeliana	2L	5 per metre
Rudbeckia hirta 'Indian Summer'	1L	Clump
Sedum spectabile	1L	Clump
Stachys byzantina 'Silver Carpet'	1L	Clump
Verbena bonariensis 'Buenos Aires'	1L	Clump
Vinca minor mixed	1L	Clump

Meadow	
To be sown on nutrient poor soil to BS3882:2015 'Low Fertility Specification', or cultivated and screened subsoil	
Mix	Specification
Basic General Purpose Meadow Mix	Emorsgate Seeds, Mix EM1. Sown at 4g/m². 20% wildflower and 80% grasses.
Grass	
150mm depth of topsoil onto 150mm depth subsoil	
Location	Specification
Close Mown Grass Areas	Germinal Seeds, Mix A22 (Low Maintenance). Sown at 50g/m².

Infills & Bedding



Festuca glauca 'Elijah Blue'



Stachys byzantina 'Silver Carpet'



Phlomis russeliana



Verbena bonariensis 'Buenos Aires'



Rudbeckia hirta 'Indian Summer'



Sedum spectabile

Meadow



Basic General Purpose Meadow Mix

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Date of issue

November 2023

Job Reference

RETH3002

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