

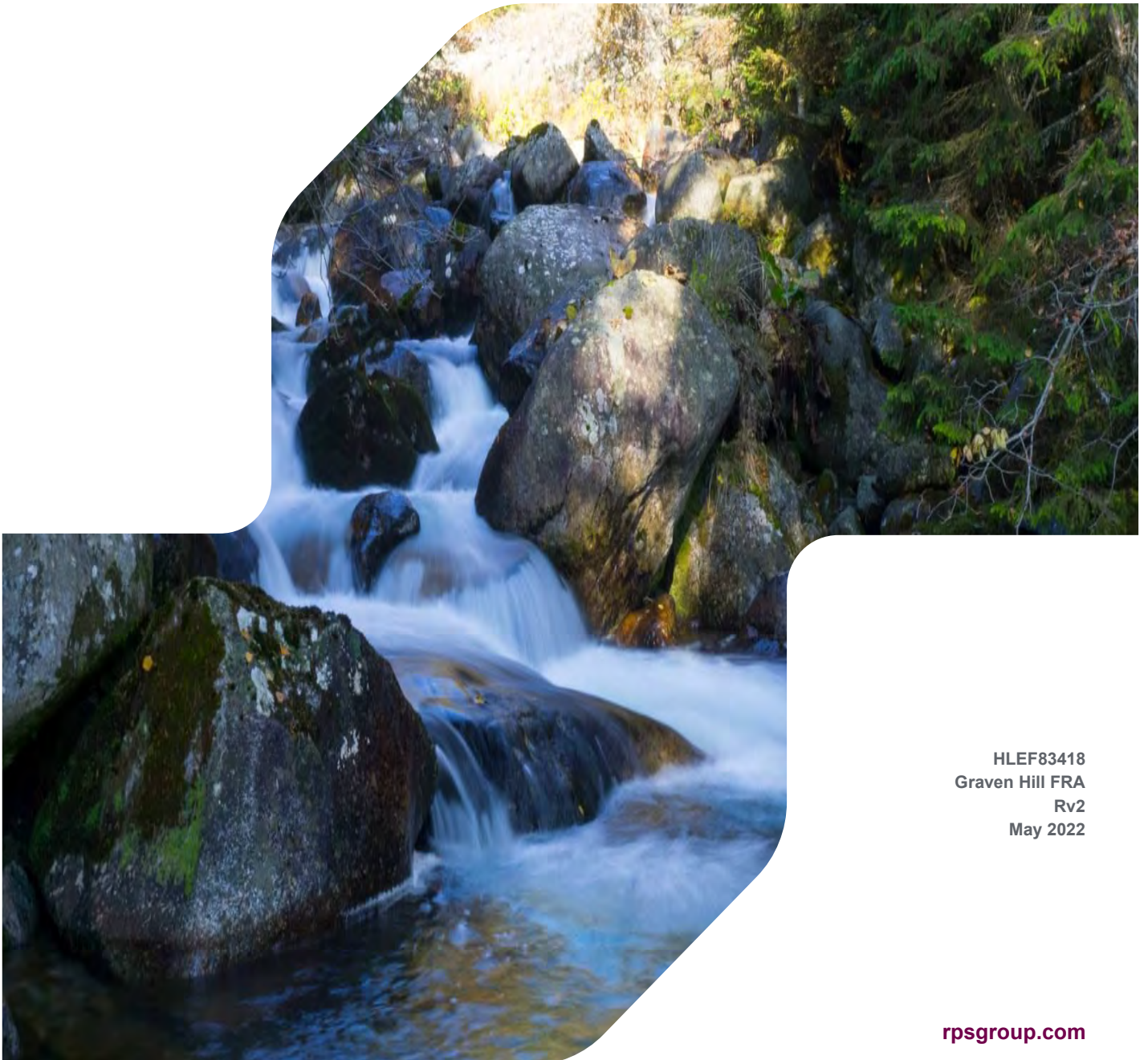
Appendix 11 Hydrology and Flood Risk

11.1 Flood Risk Report

11.2 SuDS Strategy

GRAVEN HILL, D1 SITE, BICESTER

Flood Risk Assessment Report



HLEF83418
Graven Hill FRA
Rv2
May 2022

REPORT

Quality Management

Version	Status	Authored by	Reviewed by	Approved by	Review date
1	Draft	Anna Velkov	Jonathan Morley	Jonathan Morley	16/05/2022

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Appendix D Hydraulic Modelling Report (provided separately)

1 INTRODUCTION

- 1.1 RPS was commissioned to prepare a Flood Risk Assessment to support the planning application for a demolition of existing buildings, development of B8 'Storage or Distribution' use comprising up to 104,008 sq. m (GIA), creation of open space and associated highway works, ground works, sustainable drainage systems, services infrastructure and associated works at land parcel located at the former Ministry of Defence (MoD) site at Graven Hill, Bicester.
- 1.2 It is noted that the site benefits from Outline Planning Permission (ref: 11/01494/OUT), which was Granted on 8th August 2014 (as well as subsequent consents).
- 1.3 The aim of this assessment is to outline the potential flood risk issues affecting the site and the implications for future development. The feasibility of the proposed use is assessed, and potential mitigation measures or requirements for additional work are identified, where appropriate.
- 1.4 The report has been produced in accordance with the guidance detailed in the National Planning Policy Framework (NPPF) and the associated Planning Practice Guidance (PPG). Reference has also been made to the CIRIA SuDS manual (C753), and the Cherwell District Council Strategic Flood Risk Assessment (SFRA).
- 1.5 This report has been produced in consultation with the Environment Agency (EA), Cherwell District Council (CDC) as Local Planning Authority (LPA) and Oxfordshire Council as Lead Local Flood Authority (LLFA). The site is not located within an Internal Drainage Board (IDB) District.
- 1.6 The desk study was undertaken by reference to information provided / published by the following bodies:
- Environment Agency (EA);
 - Local Planning Authority (LPA);
 - British Geological Survey (BGS);
 - Ordnance Survey (OS); and
 - Thames Water (TW).

2 PLANNING POLICY CONTEXT

National Planning Policy

- 2.1 The National Planning Policy Framework (NPPF) was released in March 2012 and was updated in July 2021. The document advises of the requirements for a site-specific Flood Risk Assessment (FRA) for any of the following cases (Planning and Flood Risk paragraph 167 (footnote 55)):
- All proposals (including minor development and change of use) located within the EA designated floodplain, recognised as either Flood Zone 2 (medium probability) or Flood Zone 3 (high probability);
 - All proposals of 1 hectare (ha) or greater in an area located in Flood Zone 1 (low probability);
 - All proposals within an area which has critical drainage problems (as notified to the Local Planning Authority by the EA);
 - Land identified in a strategic flood risk assessment as being at increased flood risk in future; and
 - Where proposed development may be subject to other sources of flooding, where its development would introduce a more vulnerable use.
- 2.2 Paragraph 169 of the updated NPPF identifies that major developments (developments of 10 homes or more and to major commercial development) should incorporate Sustainable Drainage Systems unless there is clear evidence that this would be inappropriate. The systems used should:
- a. Take account of advice from the Lead Local Flood Authority;
 - b. Have appropriate proposed minimum operational standards;
 - c. Have maintenance arrangements in place to ensure an acceptable standard of operation for the lifetime of the development; and
 - d. Where possible, provide multifunctional benefits.
- 2.3 Defra published their 'Non-statutory technical standards for sustainable drainage systems' in March 2015. The document sets out non-statutory technical standards for sustainable drainage systems and should be read in conjunction with the revised NPPF. The non-statutory technical standards advise the following:

Flood Risk Outside the Development

S1 Where the drainage system discharges to a surface water body that can accommodate uncontrolled surface water discharges without any impact on flood risk from that surface water body (e.g. the sea or a large estuary) the peak flow control standards (S2¹ and S3 below) and volume control technical standards (S4 and S6) need not apply.

Peak Flow Control

S3 For developments which were previously developed, the peak runoff rate from the development to any drain, sewer or surface water body for the 1 in 1 year rainfall event and the 1 in 100 year rainfall event must be as close as reasonably practicable to the greenfield runoff rate from the development for the same rainfall event, but should never exceed the rate of discharge from the development prior to redevelopment for that event.

¹ SE2, SE4 and SE6 relate to greenfield developments

Volume Control

S5 Where reasonably practicable, for developments which have been previously developed, the runoff volume from the development to any highway drain, sewer or surface water body in the 1 in 100 year, 6 hour rainfall event must be constrained to a value as close as is reasonably practicable to the greenfield runoff volume for the same event, but should never exceed the runoff volume from the development site prior to redevelopment for that event.

Flood Risk within the Development

S7 The drainage system must be designed so that, unless an area is designated to hold and/or convey water as part of the design, flooding does not occur on any part of the site for a 1 in 30 year rainfall event.

S8 The drainage system must be designed so that, unless an area is designated to hold and/or convey water as part of the design, flooding does not occur during a 1 in 100 year rainfall event in any part of: a building (including a basement); or in any utility plant susceptible to water (e.g. pumping station or electricity substation) within the development.

S9 The design of the site must ensure that, so far as is reasonably practicable, flows resulting from rainfall in excess of a 1 in 100 year rainfall event are managed in exceedance routes that minimise the risks to people and property.

Local Planning Policy

- 2.4 As part of the Oxfordshire Housing and Growth Deal agreement with the Government, the six Oxfordshire authorities – Cherwell District Council, Oxford City Council, Oxfordshire County Council, South Oxfordshire District Council, Vale of White Horse District Council and West Oxfordshire District Council - have committed to producing a joint statutory spatial plan (JSSP), known as the Oxfordshire Plan 2050.
- 2.5 The Adopted Cherwell Local Plan 2011-2031 (Part 1) contains strategic planning policies for development and the use of land. It forms part of the statutory Development Plan for Cherwell to which regard must be given in the determination of planning applications. The Plan was formally adopted by the Council on 20 July 2015. Policy Bicester 13 was re-adopted on 19 December 2016.
- 2.6 Cherwell Local Plan contains the following Policies relating to flood risk and drainage:

Policy ESD 6:

Sustainable Flood Risk Management: The Council will manage and reduce flood risk in the District through using a sequential approach to development; locating vulnerable developments in areas at lower risk of flooding. Development proposals will be assessed according to the sequential approach and where necessary the exceptions test as set out in the NPPF and NPPG. Development will only be permitted in areas of flood risk when there are no reasonably available sites in areas of lower flood risk and the benefits of the development outweigh the risks from flooding.

Site specific flood risk assessments will be required to accompany development proposals in the following situations:

- *All development proposals located in flood zones 2 or 3*
- *Development proposals of 1 hectare or more located in flood zone 1*
- *Development sites located in an area known to have experienced flooding problems*
- *Development sites located within 9m of any watercourses*

Policy ESD 7:

Sustainable Drainage Systems (SuDS) All development will be required to use sustainable drainage systems (SuDS) for the management of surface water run-off.

- 2.7 The Cherwell District Council Level 1 Updated SFRA (May 2017) identifies and maps flood risk from sources at a district-wide scale as well as providing guidance on producing site specific FRAs. Relevant information from the SFRA has been referenced throughout this flood risk scoping report.

3 SITE DESCRIPTION

Site Description

- 3.1 The redline boundary of the site including parts D1 and EL1 is delineated in the map below. The site is irregular in shape, centred on National Grid Reference SP 59318 19645 and occupies an area of approximately 30.5 hectares (ha). The site is located approximately 3.5km south of Bicester Town Centre and 1 km to the north west of Ambrosden Centre and Sites D1 & EL1 are located to the south of Graven Hill. Site D1 constitutes the majority of the land and Site EL1 represents a much smaller parcel of land at the northeast corner. The site location is presented in Figure 1.



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Figure 1. Site Location

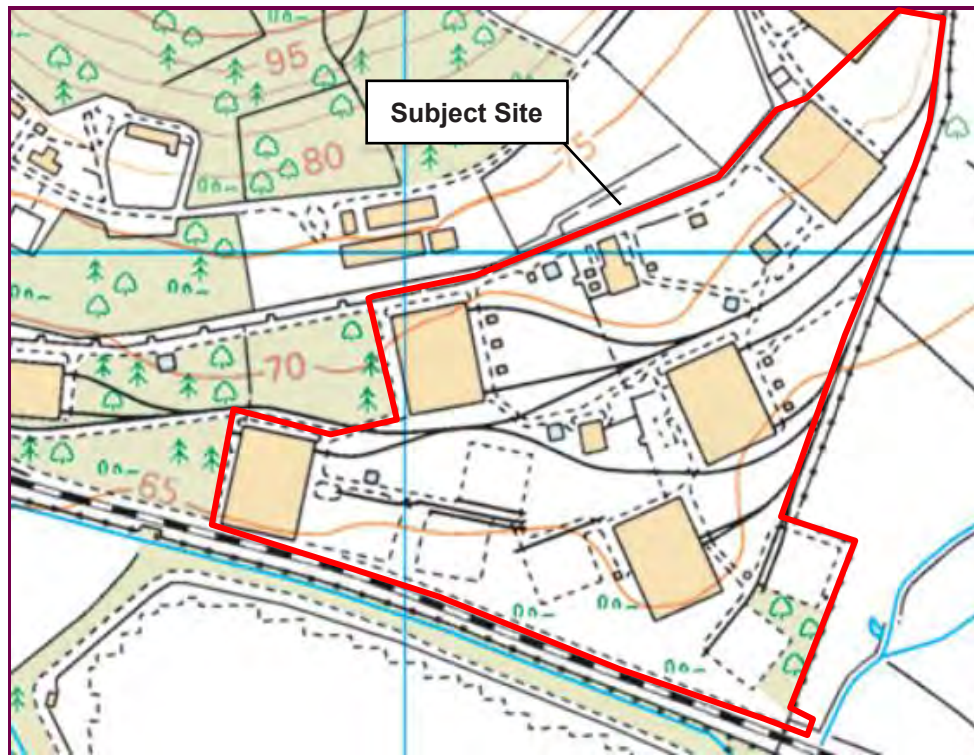
- 3.2 The site was previously occupied by the Ministry of Defence (MoD). Currently the site comprises five large vacant warehouses (Unit D1, Unit D2, Unit D4, Unit D7, Unit D10 & D20, the latter being the sub-station). and associated hardstanding areas for vehicles.
- 3.3 Existing vehicular access to the site is from Anniversary Avenue / Pioneer Road via an internal access road.
- 3.4 It appears that the site is currently occupied by approximately 60% soft landscaping (landscaped grassland) and 40% hardstanding and building footprint.

Surrounding Land Uses

- 3.5 The site is surrounded by agricultural land to the south east and south west. A solar panel farm is situated immediately to the south of the site, and the Graven Hill Woods are to the north of the site.

Topography

- 3.6 A topographical survey of the site was undertaken in May 2020. The survey indicates that ground levels along Anniversary Avenue to the north of the site are between 69m AOD and 71m AOD. The site is sloping southwards with an elevation of approximately 65m AOD in the centre of the site, dropping down to 61.5m AOD in the south corner of the site. An indicative OS mapping is presented in Figure 2 below, and the topographical survey is in Appendix A



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Figure 2. OS Map

Hydrological Setting

- 3.7 Reference to OS Mapping indicates that the nearest surface water feature is Langford Brook (Including Gagle Brook) which flows in southerly direction at about 800m to the west of the site. The Brook is classified as 'Main River' (regulated by the Environment Agency).
- 3.8 There are few drains/watercourses located to the south of the site. One of the drains is flowing along the south west boundary of the site. Another one is parallel to the south east border of the site, situated at a distance of about 200m in the north east and getting closer, at about 60m towards the south corner of the site. These drains are classed as 'Ordinary Watercourses' (regulated by the Local Authority). This was confirmed by the Building Control Manager of Cherwell District Council Tony Brummell, who stated that *"I can confirm that the ditches you have marked in blue are Ordinary Watercourses and thus fall under the control of the Local Authority."* The full response is presented in Appendix B.
- 3.9 A small pond is present approximately 500 m to the south east of the site.
- 3.10 No significant artificial watercourses (e.g. canals) have been identified within 1 km of the site.

Hydrogeological Setting

- 3.11 British Geological Survey (BGS) online mapping (1:50,000 scale) has no records of the Superficial deposits under the site. The areas surrounding the site have superficial deposits of Alluvium - Clay, Silt, Sand and Gravel. The site is underlain by bedrock of Peterborough Member – Mudstone, Sedimentary Bedrock.
- 3.12 BGS Borehole data records (SP52SE72 and SP52SE73) indicates the following:
- Dark brown topsoil with silty clay beneath;
 - Water entry between 1.7m and 2.40m.
- 3.13 The soils are described as 'Slowly permeable seasonally wet slightly acid but base-rich loamy and clayey soils' by the National Soils Research Institute.
- 3.14 The bedrock beneath the superficial deposits are characterised as being unproductive strata defined as soluble rock.
- 3.15 EA online groundwater Source Protection Zone (SPZ) mapping indicates that the site is not located within a groundwater SPZ.

Environmental Setting

- 3.16 There are no designated sensitive areas (e.g. Special Area of Conservation (SAC), or Special Protection Area (SPA) within close proximity to the site. Two Sites of Special Scientific Interest (SSSI) are located at 1.5km south east and 3.5km south west of the site respectively.

4 PROPOSED DEVELOPMENT

- 4.1 The proposal comprises development totalling approx. 104,008 sq. m (GIA) of logistics-led floorspace (1,119,529 sq. ft) at the site. The indicative Masterplan (provided in Appendix C) demonstrates how this floorspace could be provided across 9 separate units (Units 1-9). Approximately 902 parking spaces would be provided, including HGV parking yards associated with the Logistics Units as well as disabled parking. These could be arranged in a variety of layouts to best respond to market demand as well as site constraints. This will also include the associated access roads, loading areas, infrastructure and tertiary buildings on the vacant brownfield site.
- 4.2 The total site area is approximately 30.5 ha. The proposed impermeable area of approximately 23.9 ha comprises 10.4 ha of roofed area and 13.5 ha of paved area.
- 4.3 The site will be accessed from Anniversary Avenue to the north. Buildings within the site will be accessed from an internal network of roads.
- 4.4 The vulnerability classifications (in accordance with the PPG) of the proposed uses are provided in Table 1 below.

Table 1. Vulnerability of Proposed Uses

Proposed Use	Vulnerability
Employment Land/Logistics Use	Less vulnerable
Green Space	Water compatible

5 CONSULTATIONS AND REGULATORY INFORMATION

Fluvial / Tidal Flood Risk Classification

- 5.1 The EA Flood Map for Planning, which is available online, indicates that the site is located within Flood Zone 1, whereby the annual probability of flooding from fluvial or tidal sources is classified as less than 1 in 1,000. The EA Flood Map for Planning is provided in Figure 3.



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Figure 3. EA Flood Map for Planning

- 5.2 Although the site is located within Flood Zone 1, the EA has been contacted with request for information for the flood history in the area and any other flood related issues at the site. In their response from 16.11.2020 the EA have confirmed that they do not have any detailed flood risk modelling in this location and therefore they are unable to provide modelled flood levels and extents for the site.

EA Flood Warning Area

- 5.3 The EA defines a Flood Warning Area as “*geographical areas where we expect flooding to occur and where we provide a Flood Warning Service. They generally contain properties that are expected to flood from rivers or the sea and in some areas, from groundwater.*”
- 5.4 The site is not located in a Flood Warning Area.

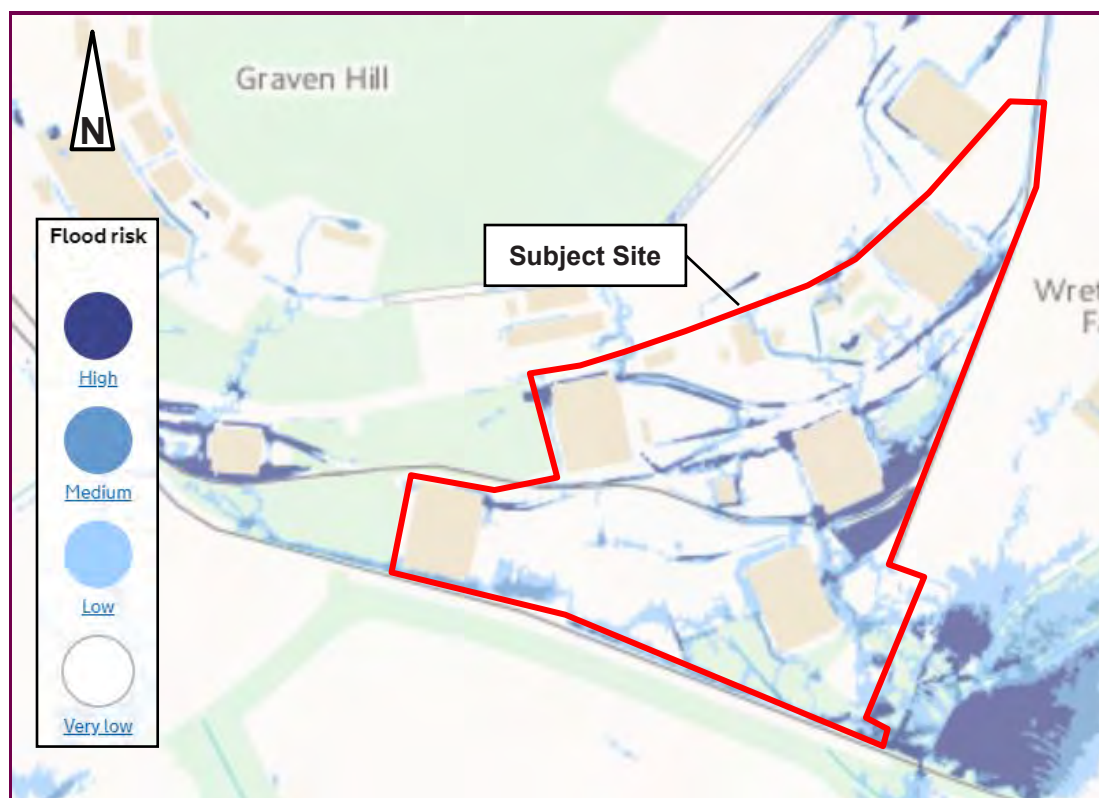
Flood Modelling

- 5.5 As mentioned above, there are two watercourses/drains designated as Ordinary Watercourses which flow along the south west and south east boundary of the site, and join upstream the culvert under the railway near the south corner of the site. The LLFA was consulted, and they have confirmed that the watercourse should be hydrologically modelled in order to assess the risk of flooding to the site from this source. RPS has undertaken hydrological modelling of the two watercourses, which is detailed in full in the Graven Hill hydraulic modelling report reference HLEF82585 (see Appendix D).
- 5.6 The model was run for the 1 in 20, 1 in 100 and 1 in 100 year fluvial event plus 15% climate change allowances, which is the required climate change allowance for the Cherwell and Ray Management Catchment in the River Thames Basin District.
- 5.7 The modelling results indicate that for all modelled return periods the water in the south- west ditch remains within banks. Whilst the capacity of the culverts along the ditch is exceeded, the water overtopping the culverts still remains within the extent of the channel profile.
- 5.8 With regards to the watercourse running to the south-east of the site, the results indicate that water overtops the riverbanks along a 180m stretch of the stream upstream the railway culvert and the maximum predicted water levels for the 1 in 100 and 1 in 100 +CC flood events are 62.4m AOD and 62.3m AOD respectively. However, it is noted that these are in-channel water levels resulting from a 1D model. The model doesn't take into account the loss of momentum and volume of water once it spills into the floodplain. In reality the flood level into the floodplain will be considerably lower, the flooding will be shallow and is not expected that it will extend much and reach the site boundary which is 60m to the north west of the watercourse.
- 5.9 In order to demonstrate the above, a quick estimate was performed for the volume of water, during the 1 in 100+CC event, above the bank level between the cross section RS20 (the location where the flow starts to overflow the banks) and RS22, just upstream of the culvert. This volume was estimated to be approximately 400m³. Considering that it will spill over both banks, the volume spilling onto the floodplain between the watercourse and the Site is expected to be approximately 200m³. The area enclosed between this river reach and the site was measured to be approximately 8,300m². Such an area can accommodate 200m³ volume at 0.02m depth. Considering that the flood depth would be bigger near the watercourse, it could be concluded that the floodplain is big enough to accommodate the water overtopping the banks of the watercourse, without reaching the site boundaries. 2D hydraulic modelling will be performed at the design stage to further demonstrate that the development site is not at risk of fluvial flooding from this source.
- 5.10 In addition, it was noted during the site visit that when joining upstream of the culvert the watercourses form a small pond which to some extent will accommodate the excess water resulting from the insufficient capacity of the culvert. This is illustrated in the photographs below.
- 5.11 Based on the above, it could be concluded that whilst the capacity of the culvert under the railway will be exceeded during the modelled flood events and it will create a backup effect upstream the watercourse, it is not expected that the floodplain will reach the site boundary and flood the site.
- 5.12 The long section profiles of the watercourses and the predicted water levels for the different events are presented into the modelling report (Appendix D).



Surface Water Flood Risk Classification

- 5.13 The EA's updated Flood Map for Surface Water, which is available online, indicates that a large area in the south east of the site is at high risk of surface water flooding. In addition, there are several localised linear areas, associated with existing rail tracks within the site, which are at low to high risk of flooding from surface water.
- 5.14 During a 1 in 100 year rainfall event, the majority of the site would be unaffected by surface water flooding and the linear areas across the site which are at risk of flooding will be flooded with depth of approximately 300mm. However, the area in the south east of the site will be flooded with depth of between 300mm and 900mm and at places exceeding 900mm. During a 1 in 1000 year event (which can be considered as a proxy for the 1 in 100 year plus climate change event) the flood outline is slightly wider, but the flood depths remain in the same magnitude for the respective areas. The updated Flood Map for Surface Water is presented in Figure 4.



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Figure 4. Updated Flood Map for Surface Water

- 5.15 It is noted that there is a large area to the south east and outside the site boundary, which is at 'high' risk of surface water flooding. This is associated with a defined flow path which follows the drain present at this location. The area at 'high' risk of flooding is in topographical low in comparison to the site and is separated from the site with raised strip of land. Therefore, it is not considered that it presents a flood risk to the site.

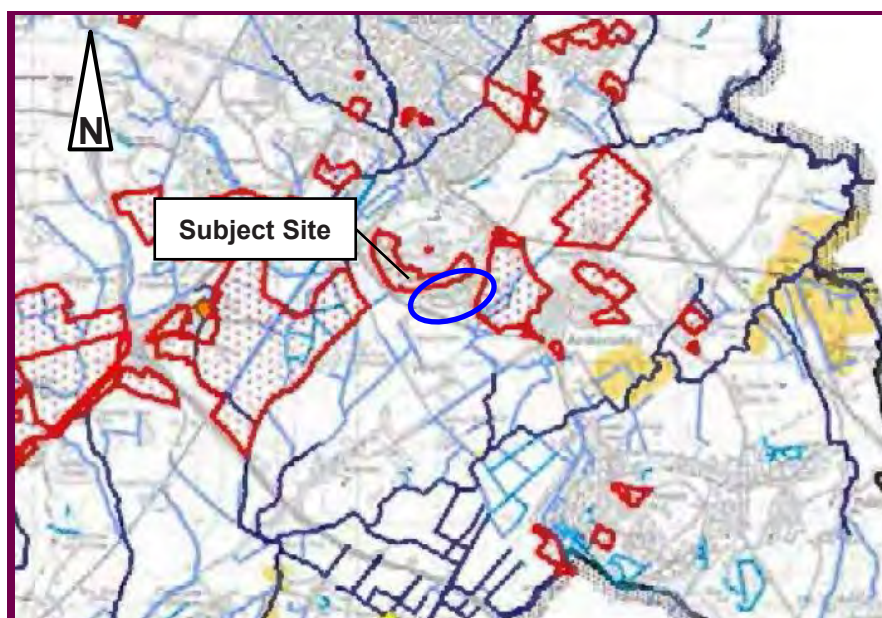
Reservoir Flood Risk Classification

- 5.16 EA mapping also indicates that the site is not located within an area potentially at risk from reservoir flooding.

Local Authority Flood Risk Assessment

- 5.17 The Cherwell District Council (CDC) Updated SFRA was published in May 2017. It provides an overview of flood risk from various sources within the District. Information relevant to this assessment is summarised below:
- The predominant risk of flooding within the CDC boundary is from rivers (fluvial flooding).
 - The SFRA states that there has been a total of 973 flood incidents in the district related to pluvial flood sources reported; however, this does not denote the specific types of pluvial flooding (i.e. surface water, highway, and drainage). Notwithstanding the above RPS notes that none of the reported incidents are recorded at or in close proximity to the site. Extract of the historic flood map is presented in Figure 5 below. The areas with red contour represent the Level 1 SFRA Sites, and the areas in yellow indicate the EA historic flood.
 - One of the key issues with pluvial flooding is that even in areas with no history of surface water flooding, relatively small increases in usage of impermeable hard surfacing and surface gradients can cause flooding (garden loss and reuse of brownfield sites for example).

- The site is in an area with no reported historic flooding incidents by the EA of the Canal and River Trust.
- The site is located in an area with 5 to 10 sewer flooding incidents recorded by TW DG5 register². None of these incidents are recorded close to the site.
- The site is located within an area which is defined as being at $\geq 50\%$, $< 75\%$ susceptibility of groundwater flooding.



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Figure 5 - Map of historic flood incidents

Lead Local Flood Authority / Local Planning Authority

5.18 The site is within the administrative boundary of Cherwell District Council. Consultation has been undertaken with the Council regarding surface water management schemes and acceptable surface water run-off rates. The Building Control Manager at Cherwell District Council, (Tony Brummell) has advised the following:

- *The ground in this locality is highly impermeable and there is clearly a surface water flood risk. When operating as a military establishment this risk was reduced by cutting deep wide drainage ditches. As far as the Council is aware these were generally well maintained by the military and they are not aware of any historic flooding. That said, Graven Hill was a restricted site and the Council would probably not have known if there had been flooding.*
- *It is essential that these drainage ditches are retained, or if needing to be diverted, are replaced by ditches or culverts with no less conveyance capacity.*
- *It is suggested that the flood risk assessment is approached on an incremental basis. A comparison of the proposed impermeable area with the existing at the site would inform the*

²A water-company held register of properties which have experienced sewer flooding due to hydraulic overload

approach to the Flood Risk Assessment. If impermeable area is increasing, the Council would expect attenuation to be provided according to the greenfield rate.

- *The Council is not aware of any hydraulic modelling that has been done for this site, and they would expect one to support your Flood Risk Assessment.*

Water Authority

- 5.19 The sewer network in the wider area surrounding the site is operated by Thames Water. Thames Water was consulted for any available flood history and drainage network information at the site. TW have confirmed that according to their flooding records there have been no incidents of flooding in the requested area as a result of surcharging public sewers.
- 5.20 In addition, Drainage and Water search was undertaken by Farrer & Co in November 2020. According to the information provided by TW foul sewer trunk are running along the south west and south east periphery of the site. There are three connections from the buildings within the site to the foul sewer network. It is likely that the remaining buildings within the site boundary are served by a local drainage system but no drainage plans were available at the time of the assessment.

Internal Drainage Board

- 5.21 The site is not located within an IDB District.

6 FLOOD RISK AND MITIGATION

- 6.1 The key flood risk implications for the development are discussed below. Key recommendations are underlined for clarity.

Fluvial / Tidal Flooding

- 6.2 The EA Flood Map for Planning, as seen in Figure 2, indicates that the site is located within Flood Zone 1. The annual probability of flooding is classified as less than 1 in 1,000 in the absence of any defences.
- 6.3 Hydraulic modelling was undertaken for two ordinary watercourses running along the south-west boundary of the site and to the south east of the site respectively. The modelling results predict that the site would not be flooded from these watercourses during the 1 in 100 +15% CC allowance design flood event.
- 6.4 Overall, the proposed development is determined to be at low risk of flooding from fluvial sources.

Surface Water Flooding (Overland Flow)

- 6.5 This can occur during intense rainfall events, when water cannot soak into the ground or enter drainage systems.
- 6.6 According to the information outlined within Section 5, the surface water flood risk map shows that there is a large area in the south east part of the site, immediately to the south of one of the existing buildings, which is indicated to be at high risk of surface water flooding. This is not associated with any ordinary watercourse, but rather with water following the topography of the site and ponding in lower areas. Currently this area is not occupied, and it appears that the overland flow is blocked by the existing building to the north and the raised level of the rail embankments crossing the site. The predicted flood depth at this location at places exceeds 900mm during both 1 in 100 and 1 in 100 plus climate change storm events.
- 6.7 The linear areas throughout the site, which are also indicated to be at medium to high risk of surface water flooding also appear to be related to lower topography, where the overland flow is stopped by the railway embankments and ponds in these areas. The predicted depth of flooding at these locations is predominantly between 300mm and 900mm. However, providing that these areas are immediately surrounded by depth of up to 300mm, it is likely that overall, the depth is around the 300mm mark.
- 6.8 According to the information provided by the Cherwell District Council, the previous owners of the site (MoD) have cut deep wide drainage ditches across the site to mitigate the risk of surface water flooding. The Council are not aware of any historic flooding at the site; however, as military site, Graven Hill is a restricted site and it is possible that even if flooding had occurred in the past, this information has not been provided to the authorities.
- 6.9 It is noted that the provided indicative layout plan indicates that two buildings are proposed in the area at high risk of surface water flooding. However, the site will be levelled up during construction, and the lower topographic spots at this location, where the surface water runoff is ponding, will be eliminated. To compensate for the displaced flood volume, the drainage strategy (report ref "Draft ABA SuDS Note for Planning - 21-04-22") proposes, amongst the other SuDS features, several attenuation basins across the site which will provide sufficient volume to compensate for the displaced water and mitigate the risk of surface water flooding at the site. These measures will ensure that the proposed buildings will not be at risk of flooding, and do not increase the flood risk elsewhere.
- 6.10 With the exception of the linear areas along the railway tracks and the area in the south east corner of the site, the majority of the rest of the site is indicated to be at a 'very low' and 'low' surface water

flood risk, associated mainly with areas prone to ponding. As stated above, redevelopment of the site and the installation of the proposed surface water drainage scheme are likely to control this.

Flooding from Sewers

- 6.11 Sewer flooding can occur during periods of heavy rainfall when a sewer becomes blocked or is of inadequate capacity. The site is currently served by Thames Water, and they have advised that no record of sewer flooding have been recorded in the vicinity of the site. The SFRA also confirms that there are no sewer flooding records at or in the vicinity of the site.
- 6.12 Overall the risk of sewer flooding at the site is considered to be low.

Groundwater Flooding

- 6.13 This can occur in low-lying areas when groundwater levels rise above surface levels, or within underground structures. The SFRA states that the site is located within an area which is defined as being at $\geq 50\%$, $< 75\%$ susceptibility of groundwater flooding. However, no basements are proposed at the site and the elevation of ground floor levels by 150mm is likely to mitigate the risk of groundwater flooding.

Other Sources of Flooding

- 6.14 There is a limited risk of flooding occurring as a result of a break in a water main. In the event of a burst in a water main, water is likely to follow the topography of the area and flow into the proposed attenuation basins and swales. The risk of flooding associated with reservoirs, canals and other artificial structures is considered to be low given the absence of any such structures in the site vicinity.
- 6.15 EA mapping indicates that the site is not located within an area potentially at risk from reservoir flooding.

Finished Floor Levels

- 6.16 In accordance with Building Regulations, it is generally considered good practice to raise the ground floor levels of all properties, even those located outside the flood risk areas, at least 150mm above external site levels and / or to ensure that external ground levels slope away from building thresholds.

7 SEQUENTIAL TEST

- 7.1 The NPPF requires the Local Authority to apply the Sequential Test in consideration of new development. The aim of the Test is to steer new development to areas at the lowest probability of flooding. The site is identified as being within the wider '*Policy Bicester 2: Graven Hill*' from the Adopted Cherwell Local Plan 2011-2031, and therefore it is identified as a strategic or allocated site.
- 7.2 In addition, the proposed development is in Flood Zone 1 and is at low risk of fluvial flooding. There is identified localised risk of surface water flooding at the site. However, as the surface water flood is mainly related to ponding in lower topography points, redeveloping of the site would help alleviate the flood risk in these areas as result of on-site surface water attenuation.
- 7.3 No significant risks have been identified in relation to other sources of flooding.
- 7.4 The development is classified as "Less vulnerable" and according to "flood risk vulnerability and flood zone 'compatibility' (NPPF, Table 3), "Less vulnerable" developments are permitted in all zones (Except Zone 3b) without a requirement for Exception Test. The development is therefore considered to meet the requirements of the Sequential Test.

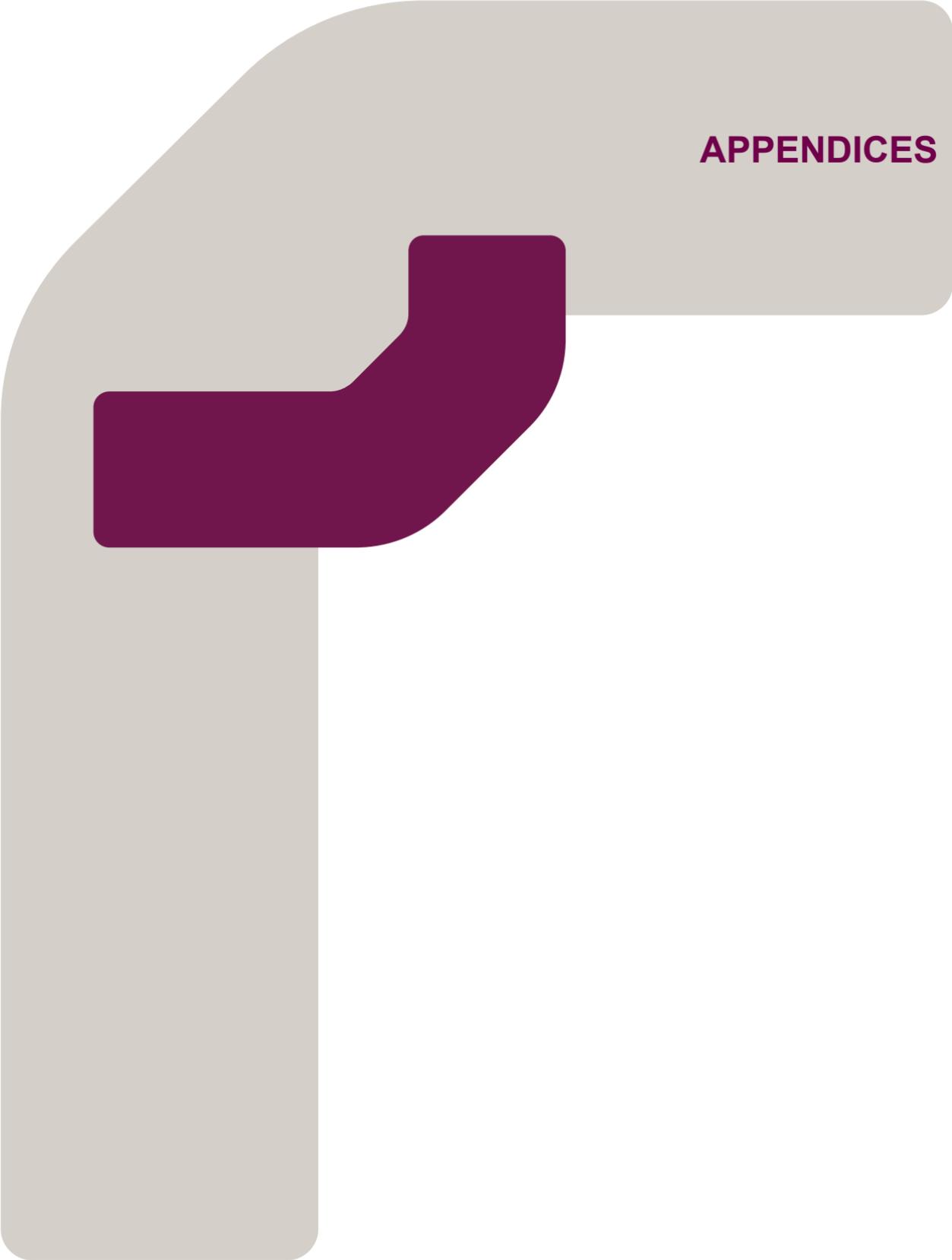
8 SUMMARY AND CONCLUSIONS

- 8.1 The aim of the FRA is to outline the potential for the site to be impacted by flooding, the potential impacts of the development on flooding both onsite and in the vicinity, and the proposed measures which can be incorporated into the development to mitigate the identified risks. The report has been produced in accordance with the guidance detailed in the NPPF. Reference has also been made to the CIRIA SUDS manual (C753), the SFRA and the PFRA and following consultation with the LLFA.
- 8.2 The potential flood risks to the site, and the measures proposed to mitigate the identified risks, are summarised in Table 1.

Table 2. Proposed mitigation

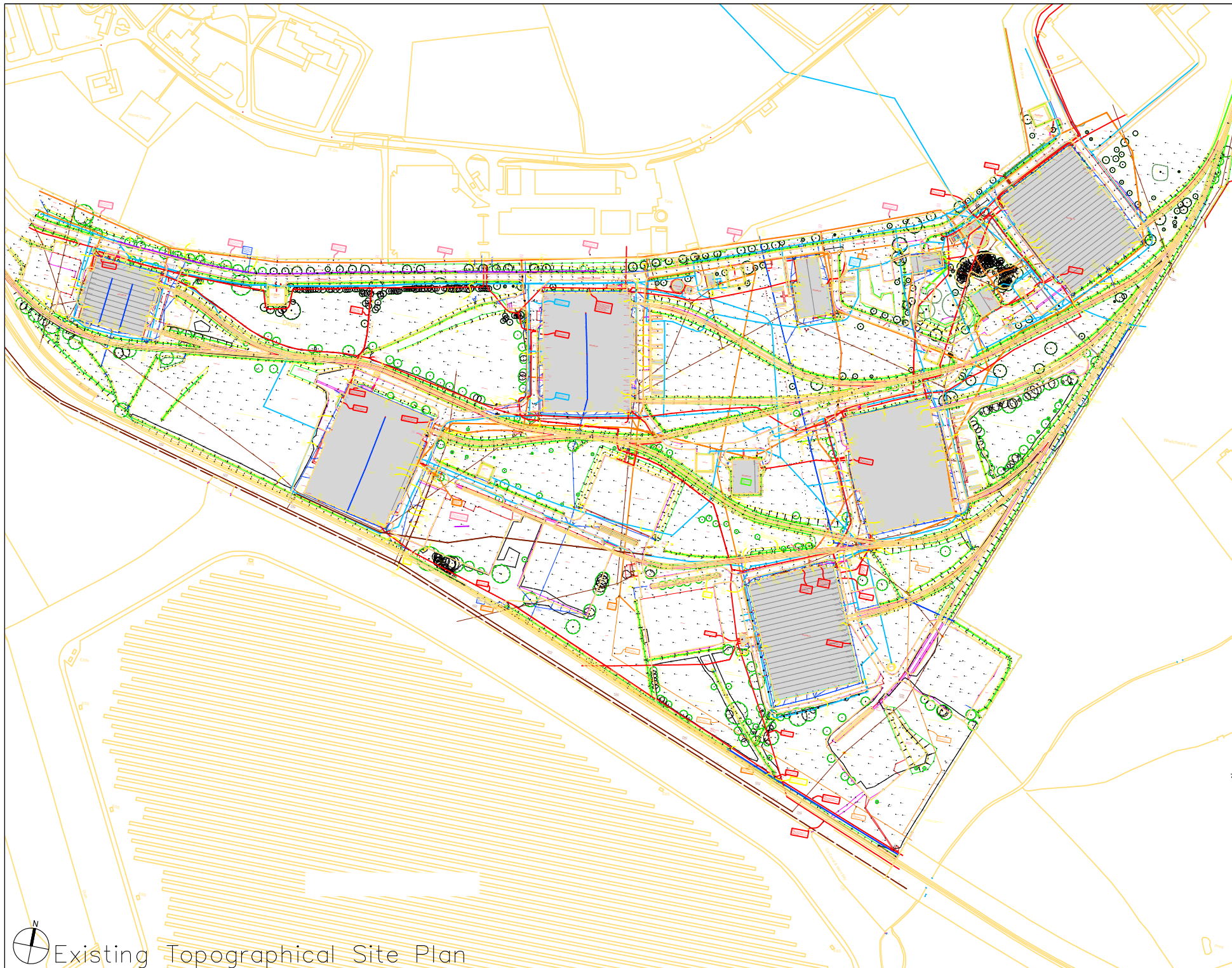
Source of Flooding	Identified Risk			Mitigation Proposed	Residual Risk		
	L	M	H		L	M	H
Fluvial	✓			None considered to be required	✓		
Tidal (actual)	✓				✓		
Sewers	✓				✓		
Surface Water		✓		Installation of a surface water drainage scheme and raising the floors by 150mm above ground	✓		
Groundwater	✓			None considered to be required	✓		
Other Sources (e.g. reservoirs, water mains)	✓				✓		

- 8.3 The site is located in Flood Zone 1 which corresponds with an annual risk of fluvial/tidal flooding that is less than 1 in 1000. The surface water flood mapping indicates that parts of the site are at risk of surface water flooding. However, the areas indicated to be at risk of flooding are associated with water ponding in lower topographical spots, and redevelopment of the site including the installation of the proposed surface water drainage scheme will alleviate this.
- 8.4 No flood risk has been identified from any of the other sources assessed.
- 8.5 It has been demonstrated that the development meets the Sequential Tests imposed under the NPPF.
- 8.6 Overall, it has been demonstrated that the development would be safe, without increasing flood risk elsewhere.



APPENDICES

Appendix A
Topographical Survey



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Notes
NOTE
Area Beyond Red Site Boundary indicated by OS map obtained by OWA Architects.
Area within Red Site Boundary taken from: Graven Hill Topographical survey carried out by MK Surveys (Rev 3 Nov 2019).
Red Site Boundary based on Inc Design Associates LTD's drawing BIC-SA(20)0030 Rev P03 issued April 2020.
All Design and DD information must be extracted from DWG format.
New road to North boundary TBC by Landowner.

Revisions

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Client
Graven Hill Purchaser LLC
Project
BB Film Studios
Graven Hill

Drawing Title
Existing Topographical Site Plan

Status	Drawn	Checked
INFORMATION	JH	GO
Scale	Date	
1:2500 @A1	May 2020	
Drawing Number	Revision	
410_S-EX-01		

Appendix B

LPA Response

Anna Velkov

From: Tony Brummell <Tony.Brummell@Cherwell-DC.gov.uk>
Sent: 26 October 2020 07:04
To: Anna Velkov
Subject: Land at Graven Hill Bicester

Follow Up Flag: Follow up
Flag Status: Flagged

CAUTION: This email originated from outside of RPS.

I have received your enquiry of 14 October.

I agree that the site is in Flood Zone 1. However, the ground in this locality is highly impermeable and there is clearly a surface water flood risk. When operating as a military establishment this risk was reduced by cutting deep wide drainage ditches. So far as we are aware these were generally well maintained by the military and we are not aware of any historic flooding. That said, Graven Hill was a restricted site and we would probably not have known if there had been flooding.

It is essential that these drainage ditches are retained, or if needing to be diverted, are replaced by ditches or culverts with no less conveyance capacity.

I would suggest you approach assessing flood risk on an incremental basis. Are you able to compare your proposed impermeable area with the existing at the site? That would inform your approach to the Flood Risk Assessment. If increasing, we would expect attenuation to be provided according to the greenfield rate.

I am not aware of any hydraulic modelling that has been done for this site. I would expect one to support your Flood Risk Assessment.

Tony Brummell MSc CEng FICE FCIWEM MCIHT MCMI
Building Control Manager

Cherwell Building Control Service
Place and Growth Directorate
Cherwell District Council

Direct Dial: 01295 221909
tony.brummell@cherwell-dc.gov.uk
www.cherwell.gov.uk

www.facebook.com/cherwelldistrictcouncil
Twitter @Cherwellcouncil

Coronavirus (COVID-19): In response to the latest Government guidance and until further notice, the Building Control Service has been set up to work remotely from home. Customers are asked not to come to Bodicote House but instead to phone or email the Building Control Service on 01295 227006: building.control@cherwell-dc.gov.uk. For the latest information about how the Building Control Service is impacted by COVID-19, please check the website: www.cherwell-dc.gov.uk

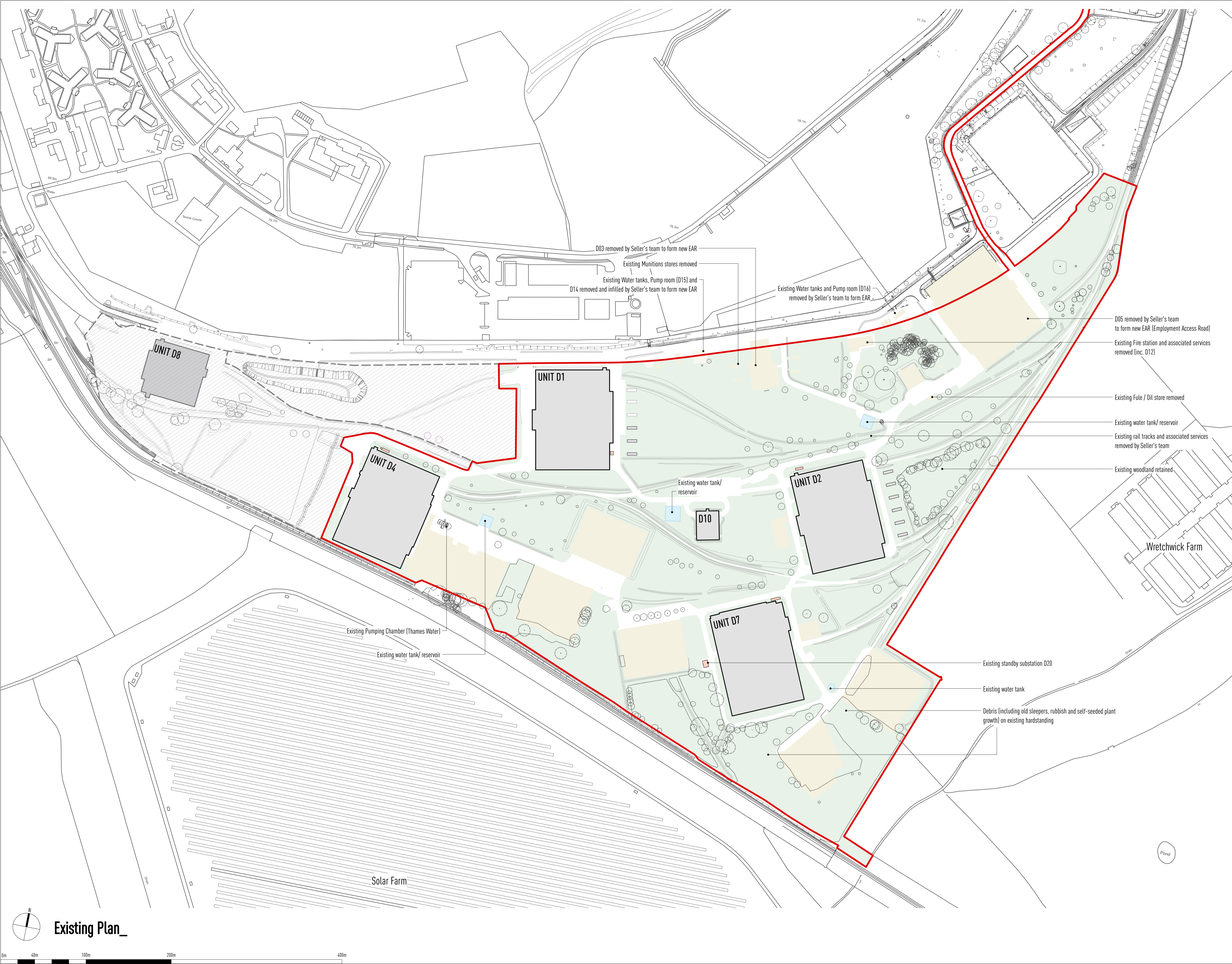
This e-mail (including any attachments) may be confidential and may contain legally privileged information. You should not disclose its contents to any other person. If you are not the intended recipient, please notify the sender immediately.

Whilst the Council has taken every reasonable precaution to minimise the risk of computer software viruses, it cannot accept liability for any damage which you may sustain as a result of such viruses. You should carry out your own virus checks before opening the e-mail(and/or any attachments).

Unless expressly stated otherwise, the contents of this e-mail represent only the views of the sender and does not impose any legal obligation upon the Council or commit the Council to any course of action..

Appendix C

Development Plans



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Key Plan

KEY

- Site Boundary
- Site by others
- Buildings to be retained
- Existing Water tanks/ Reservoirs
- Existing Concrete hardstanding
- Existing Services subject to survey (Substation, Generators, Thames water pump)

GENERAL NOTE

Site Area : 311,088m2 (76.87 Acres / 31.11 Hactare)

P12	28/04/2022	DRAFT FOR PLANNING (OUTLINE)
P11	10/03/2022	FOR PLANNING (DEMO)
DRAFT	09/03/2022	DRAFT FOR COMMENTS
P10	17/01/2022	FOR PRE-APP
P9	17/12/2021	DRAFT FOR PRE-APP
P8	17/09/2021	DRAFT FOR PRE-APP
P7	24/02/2021	PRE-APP - E11 SITE ADDED; SCALE CHANGED; DRAWING RENAMED
P6	04/11/2020	UPDATED TO SUIT CURRENT LAYOUT
P5	17/06/2020	SITE BOUNDARY UPDATED
P4	02/06/2020	UPDATED TO SUIT CURRENT LAYOUT

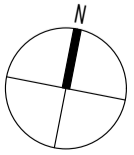
Revisions

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studio@ateliergooch.com
ateliergooch.com

Client	Graven Hill Purchaser Ltd	Project No.
Project	Graven Hill D1 Site, Bicester	410

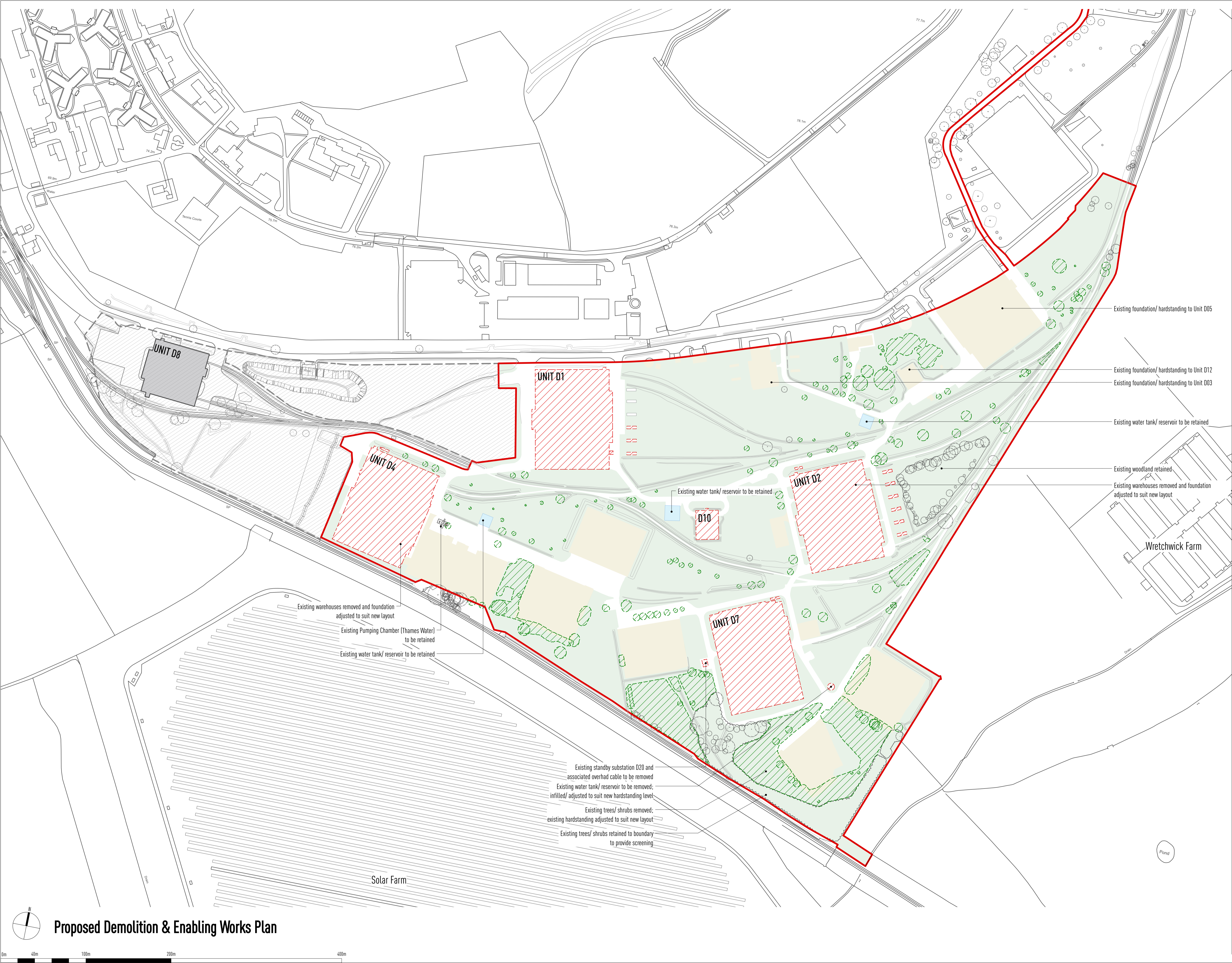
Drawing Title
EXISTING PLAN

Status	Drawn	Checked
PLANNING	JH	GO
Scale	Date	
1:2000 @A1	May 2020	
Drawing Number	Revision	
410_S-10	P12	



Existing Plan_





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KEY

- Site Boundary
- Site by others
- Existing Concrete hardstanding
- Existing Building to be removed
- Existing Reservoirs to be retained
- Proposed Bat Barn
- Existing Trees to be removed
- Existing Dense Shrubs to be removed

P2 09/05/2022 DRAFT FOR PLANNING (OUTLINE)
P1 10/03/2022 FOR PLANNING (DEMOL)
DRAFT 09/03/2022 DRAFT FOR COMMENTS

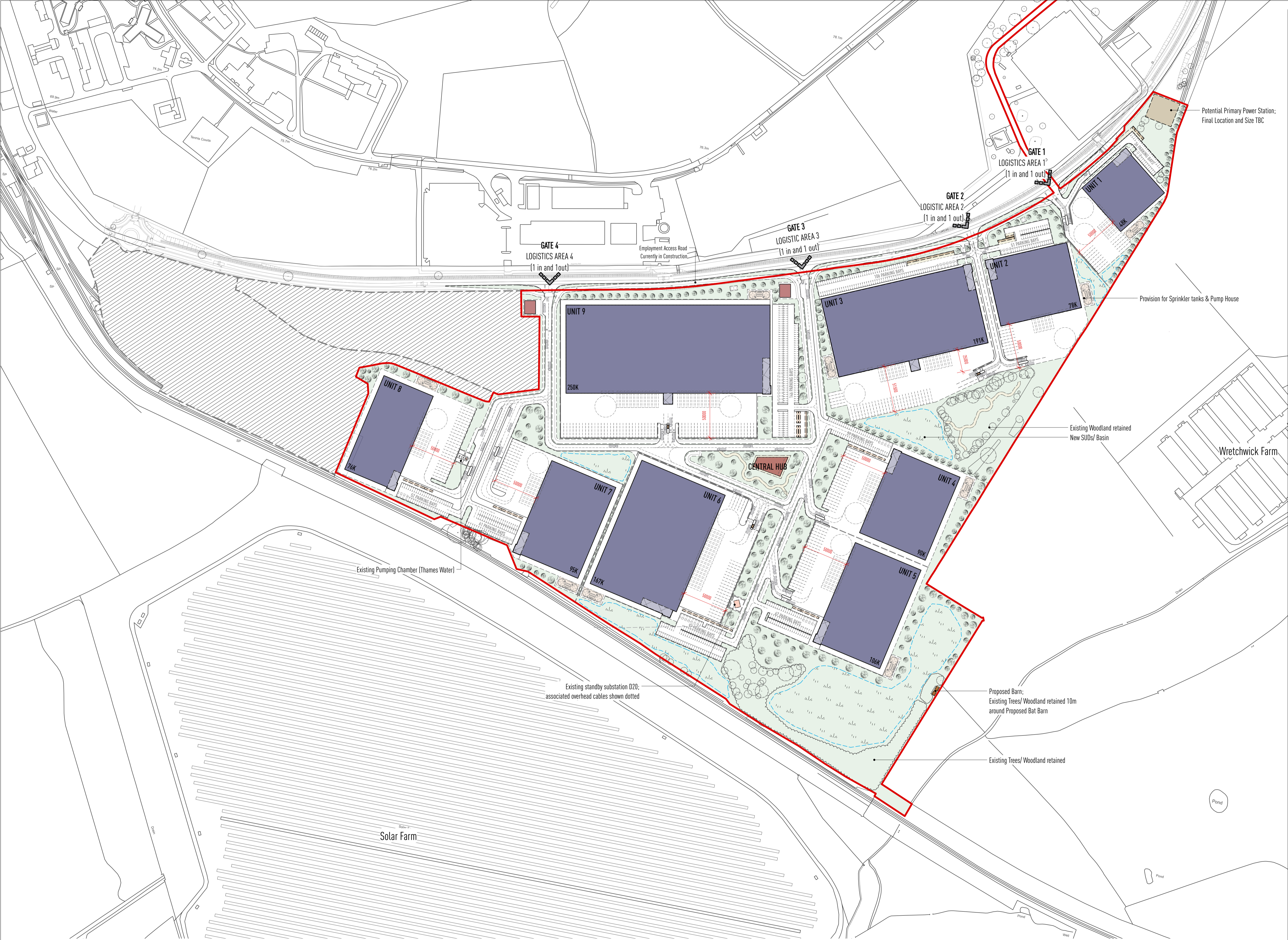
Revisions

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Client
Graven Hill Purchaser Ltd
Project
Graven Hill D1 Site, Bicester
Project No.
410

Drawing Title
Proposed Demolition Plan

Status	Drawn	Checked
PRELIMINARY	JH	GO
Scale	Date	
1:2000 @A1	May 2020	
Drawing Number	Revision	
410_S-12	P2	



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KEY

- Site Boundary
- Site by others
- Proposed Cafe / Plants / Bins
- Proposed Logistics Warehouse
- Proposed Logistics Office
- Existing D20 Substation
- Green spaces
- Proposed Basin
- Potential Primary Power Station
- Existing Trees
- Proposed Trees

P2 09/05/2022 DRAFT FOR PLANNING (OUTLINE)
P1 28/04/2022 DRAFT FOR PLANNING (OUTLINE)

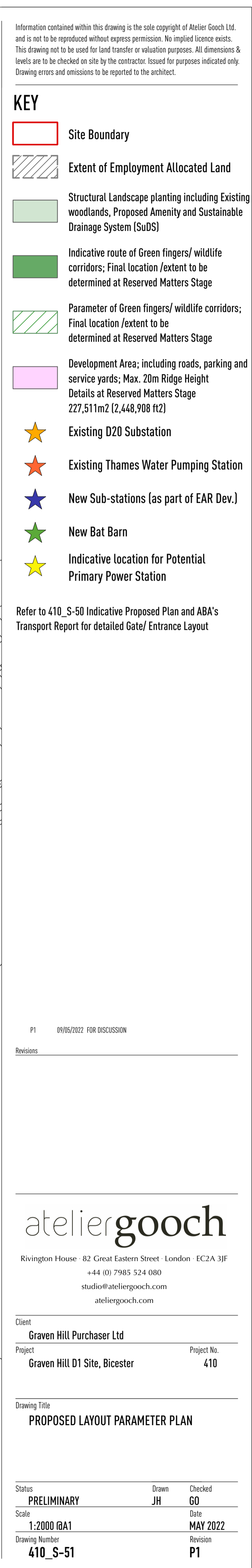
Revisions

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Client
Graven Hill Purchaser Ltd
Project
Graven Hill D1 Site, Bicester
Project No.
410

Drawing Title
INDICATIVE PROPOSED PLAN

Status	Drawn	Checked
PLANNING	JH	GO
Scale	Date	Revision
1:2000 @A1	APR 2022	
Drawing Number		
410_S-50		P2



Appendix D

Hydraulic Modelling Report (provided separately)

HYDRAULIC MODELLING REPORT

GRAVEN HILL, BICESTER

HLEF 82785
27th April 2022

Quality Management

Version	Status	Authored by	Reviewed by	Approved by	Review date
00	Draft	Minhaj Ahmed Mohammed Mamun	Anna Velkov		20.04.2022

RPS Consulting Services Ltd. General Notes

1. This report contains available factual data for the site obtained only from the sources described in this report. The site location has been determined by the client and forms the basis of the assessment and associated data searches.
2. The assessment of the site is based on information supplied by the client. Relevant information was also obtained from other sources.
3. The report reflects both the information provided to RPS in documents made available for review and the results of observations and consultations by RPS staff.
4. Where data have been supplied by the client or other sources, including that from previous site audits or investigations, it has been assumed that the information is correct but no warranty is given to that effect. While reasonable care and skill has been applied in review of this data no responsibility can be accepted by RPS for inaccuracies in the data supplied.
5. This report is prepared and written in the context of the proposals stated in the introduction to this report and its contents should not be used out of context. Furthermore new information, changed practices and changes in legislation may necessitate revised interpretation of the report after its original submission.
6. The copyright in the written materials shall remain the property of the RPS Company but with a royalty-free perpetual licence to the client deemed to be granted on payment in full to the RPS Company by the client of the outstanding amounts.
7. This report contains Environment Agency information © Environment Agency and database right.

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1 INTRODUCTION AND BACKGROUND..... 2

2 MODELLING APPROACH 4

3 MODEL RUNS AND PERFORMANCE 7

4 MODEL RESULTS..... 9

5 CONCLUSIONS 12

Appendices

- Appendix A Hydrology report
- Appendix B Surveyed Section
- Appendix C Photographs

1 INTRODUCTION AND BACKGROUND

- 1.1 RPS Consulting Services Ltd (RPS) was commissioned to undertake a hydraulic modelling exercise to assess the fluvial flood risk at Graven Hill, Bicester. The results of the modelling exercise will be used to support the Flood Risk Assessment (FRA) for the proposed development. The proposed model extends, along with the site boundary is shown in Figure 1.



Figure 1: Hydraulic Model Extend

- 1.2 The northern boundary of the site is located south of Aylesbury Road. The southern boundary is just north of the railway embankment. The Local Planning Authority (LPA) is Cherwell District Council, and the Lead Local Flood Authority (LLFA) is Oxfordshire County Council. The site is not located within an Internal Drainage Board (IDB) area.
- 1.3 The EA Flood Zone map shows that the proposed site is in Flood Zone 1, having a fluvial flood risk of greater than 0.1%, i.e., greater than 1 in 1000 year. However, the EA flood map did not consider the ordinary watercourse and the drain. The purpose of this modelling exercise is to investigate the impact of the ordinary watercourse and the drain on the flooding near the site.
- 1.4 EA flood zone map with respect to the site boundary and the cross section survey locations is shown in Figure 2

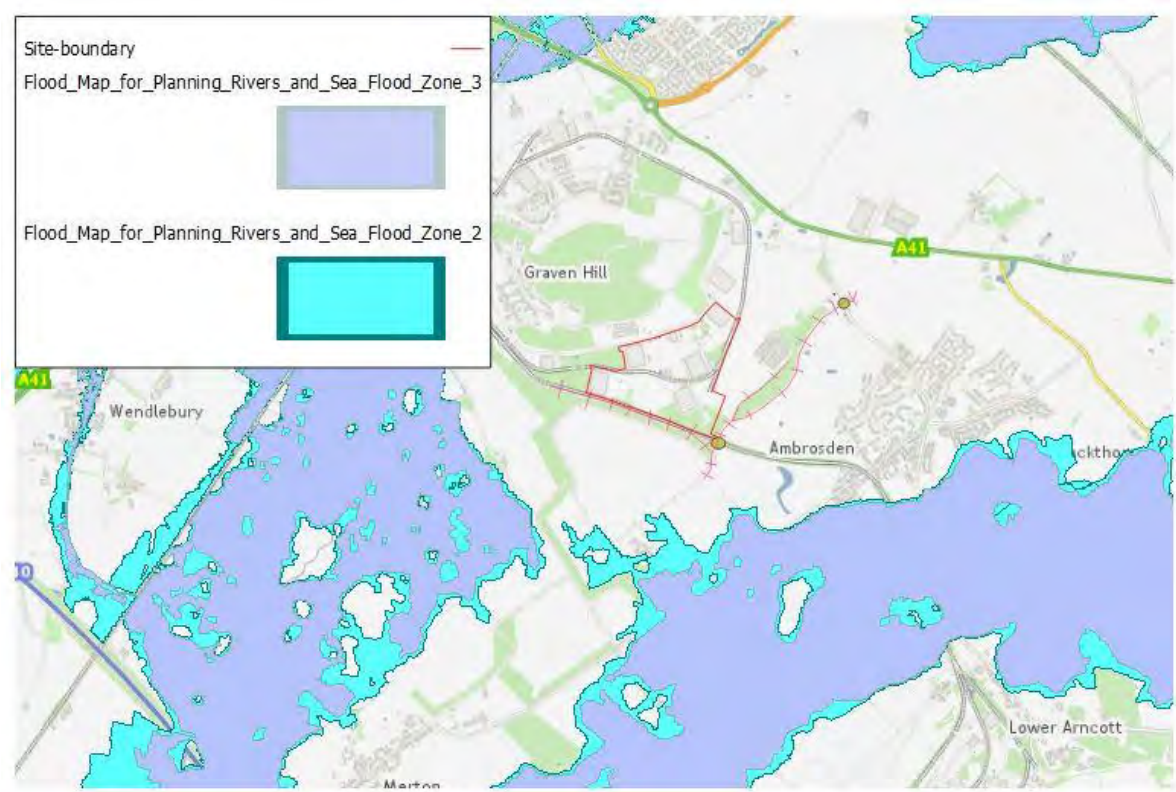


Figure 2: Environmental Agency flood map for planning

2 MODELLING APPROACH

- 2.1 Given the short length of channel required to be modelled adjacent to the site, it was considered that 1D Flood Modeller Pro (FMP) model would be suitable in order to simulate flood risk from the ordinary watercourse and the drain.
- 2.2 The 1D hydrodynamic model comprises a one-dimensional (FMP Version: 4.5.1.6163) open channel network model (based on surveyed channel cross-sections). The surveyed sections were extended using LiDAR data downloaded for this area.

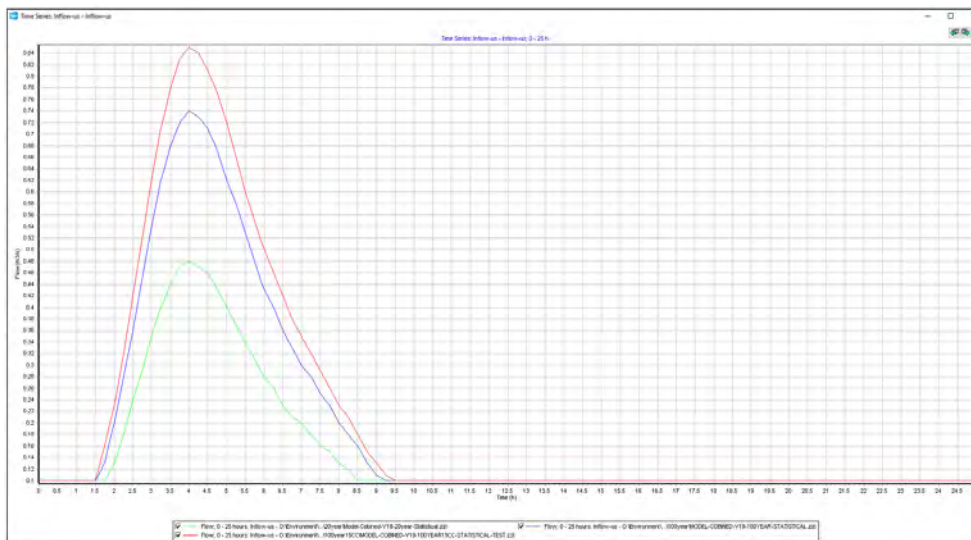
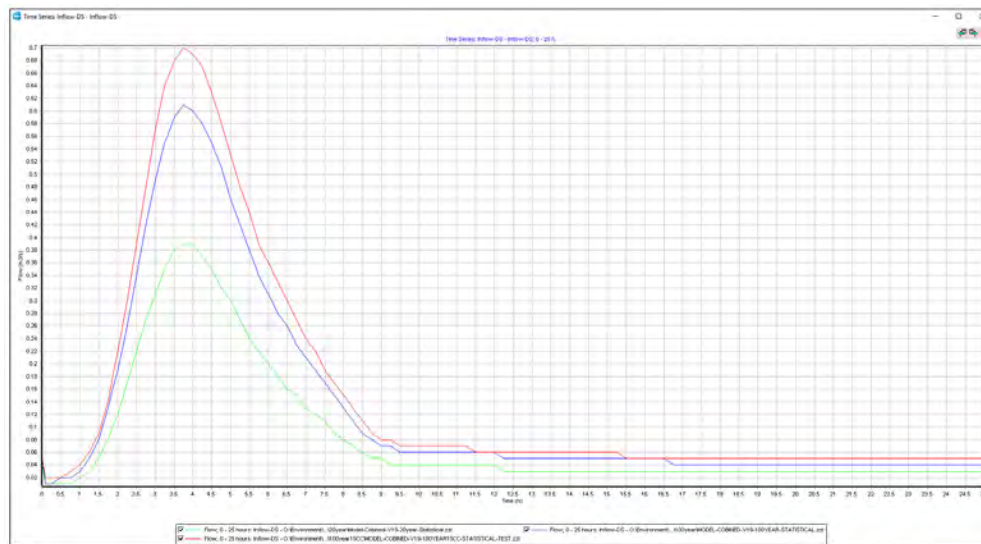
Model extents and boundaries

- 2.3 An approximate 995m length of the ordinary watercourse flowing from north to south and 838m of drains flowing from west to east have been represented within the model and can be seen in Figure 1. The upstream extent of the watercourse is located approximately 450m south from the Aylesbury Road just south of the footpath. The upstream extent of the drain is about 95 m west from the western side boundary. The drain joins the watercourse at the upstream of railway culvert.
- 2.4 However, the combined flow from the drain and the watercourse, passes through a small pond before entering the twin conduit under the Railway embankment. The survey section does not include this small pond. To include this storage in the model two additional cross sections have been added before the twin conduit under the railway embankment. The section data for this small reach has been copied from the upstream section.
- 2.5 A separate hydrology report (included as Appendix A) details the methodology adopted in deriving the inflow hydrographs for the hydraulic model. The model hydrology is based on the latest Environment agency (EA) Flood Estimation Guidelines v2 July 2020.
- 2.6 There are 3 Inflows applied to the model as point inflows. The inflow at the most upstream modelled extents of the watercourse is the inflow contributing from the northern catchment. The contribution from the southern catchment has been added as lateral point inflow about 286m downstream at structure 9. The inflow from the west has been added to the upstream end of the drain. The sub-catchment area for this inflow has been adjusted as per site boundary. The locations at which the point inflows are applied are shown on Figure 1.
- 2.7 The downstream boundary of the of the model is a normal depth unit (using a slope of 0.002).
- 2.8 There are six circular conduits within the model. Two of them are within the drain and the other four are within the watercourse. All the structures have been modelled as circular conduit. The diameters of the conduits have been taken from the survey section.
- 2.9 Manning's 'n' value coefficients have been used to represent the roughness of the open channel and floodplain. Established reference works (Chow, 1959) and experienced hydraulic modeller judgement has been used to select appropriate values. Estimates of the channel roughness coefficients were made using information from site visit and photographs from the channel survey undertaken for the commission. A manning's n value of 0.04 has been considered for the watercourse and the drain and 0.05 for the floodplain. It was considered as a conservative value.
- 2.10 Due to a lack of gauged data and limited anecdotal evidence it has not been possible to calibrate or validate the results of the hydraulic modelling against any recorded flood events.
- 2.11 The maximum inflow and the corresponding model nodes are shown in Table 1.

Table 1: Maximum Flow in the model

Hydrological Event	Maximum Flow m3/s		
	Inflow-us(East US)	Inflow-DS (EAST DS)	RS01(West)
20 year Event	0.48	0.39	0.41
100 year Event	0.74	0.61	0.63
100 year + 15%CC Event	0.85	0.70	0.72

The inflow hydrographs in the model are shown in Figure 3, Figure 4 and Figure 5.

**Figure 3 : Inflow at the upstream of Watercourse****Figure 4 : Inflow at the downstream of the watercourse**

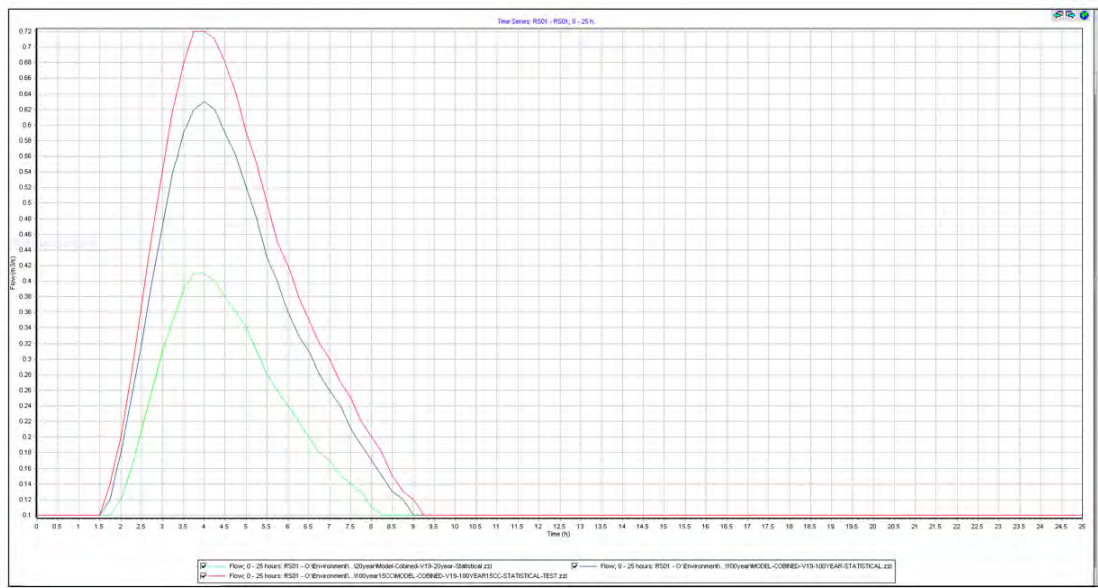


Figure 5 : Inflow at upstream end of the drain

3 MODEL RUNS AND PERFORMANCE

- 3.1 The model has been run for the following events:
- 1 in 20 year
 - 1 in 100 year
 - 1 in 100 year +15% Climate Change Allowance
 - 1 in 1000 year
- 3.2 The Climate Change Allowance scenario reflects Central scenario provided within the Environment Agency guidance for the Thames basin district.
- 3.3 The model shows acceptable stability and convergence in the 1D elements.
- 3.4 The 1D Flood Modeller convergence plots for all events show acceptable performance. Diagnostics plots are shown in Figure 6, Figure 7. There are no periods of non-convergence on the simulation.

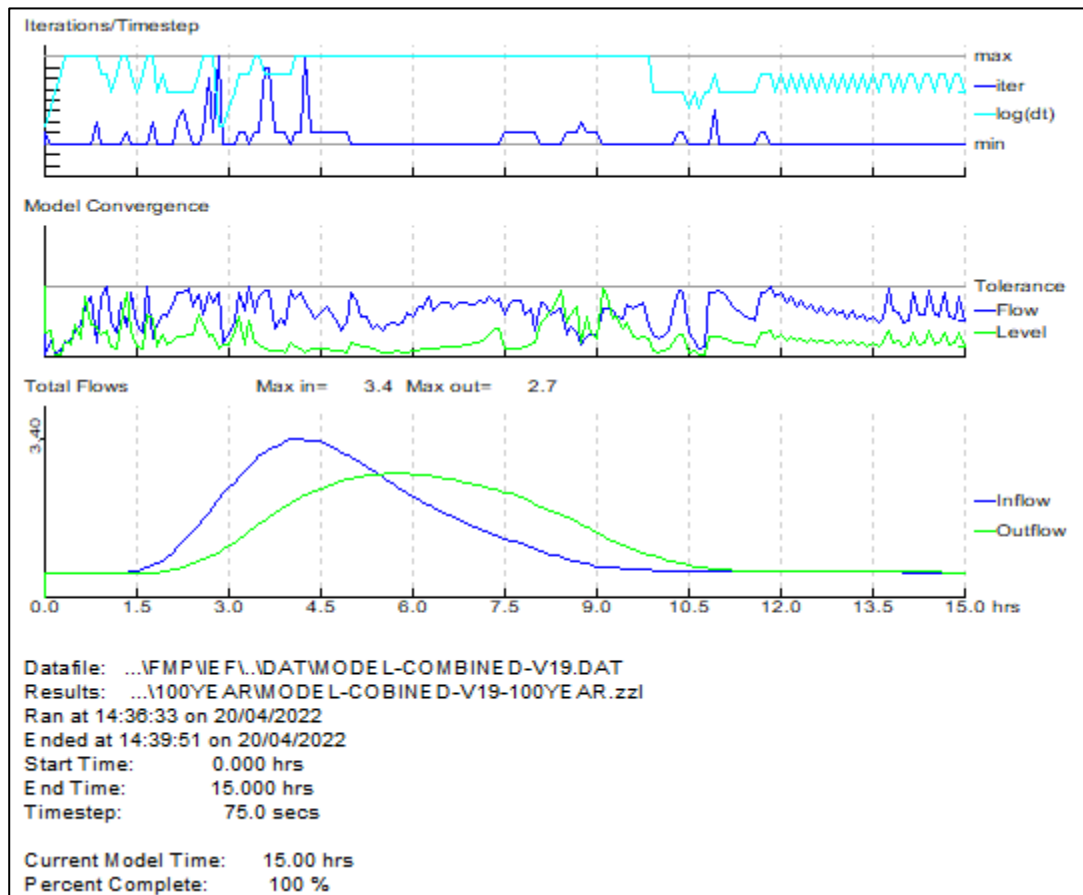


Figure 6: Convergence Plot for 100- year event run

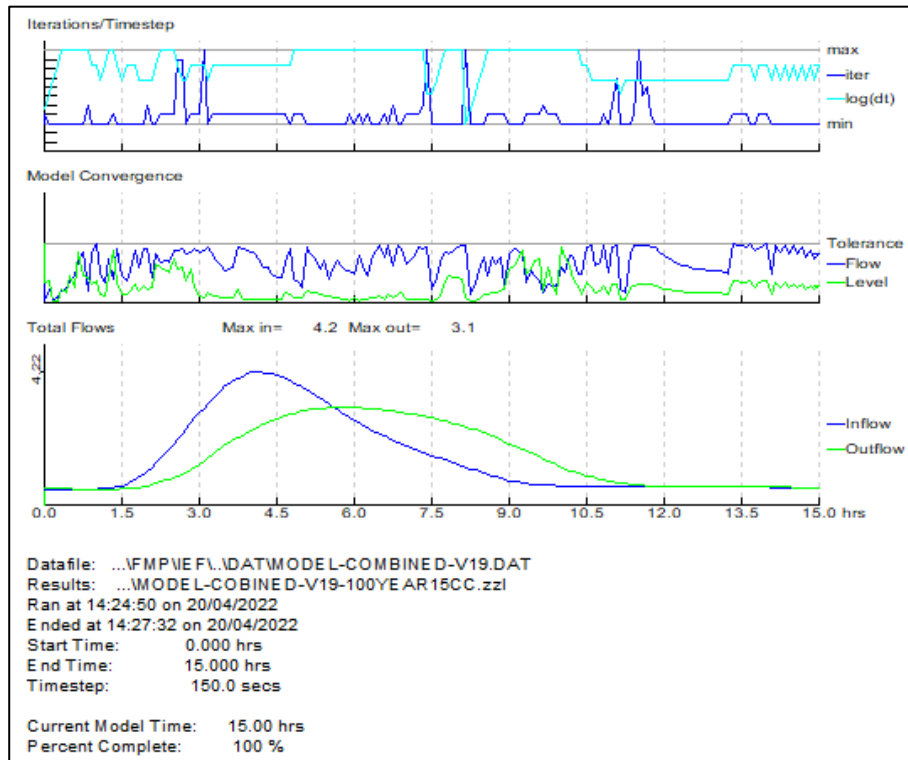


Figure 7: Convergence plot for 100 year +15%CC event

4 MODEL RESULTS

- 4.1 The output from the 1D model are water levels and flows at the model nodes. The water level profiles along the drain and the watercourse for different events are shown in Figure 9 and Figure 10. The maximum water levels at different cross sections along the reaches are shown in Table 2.

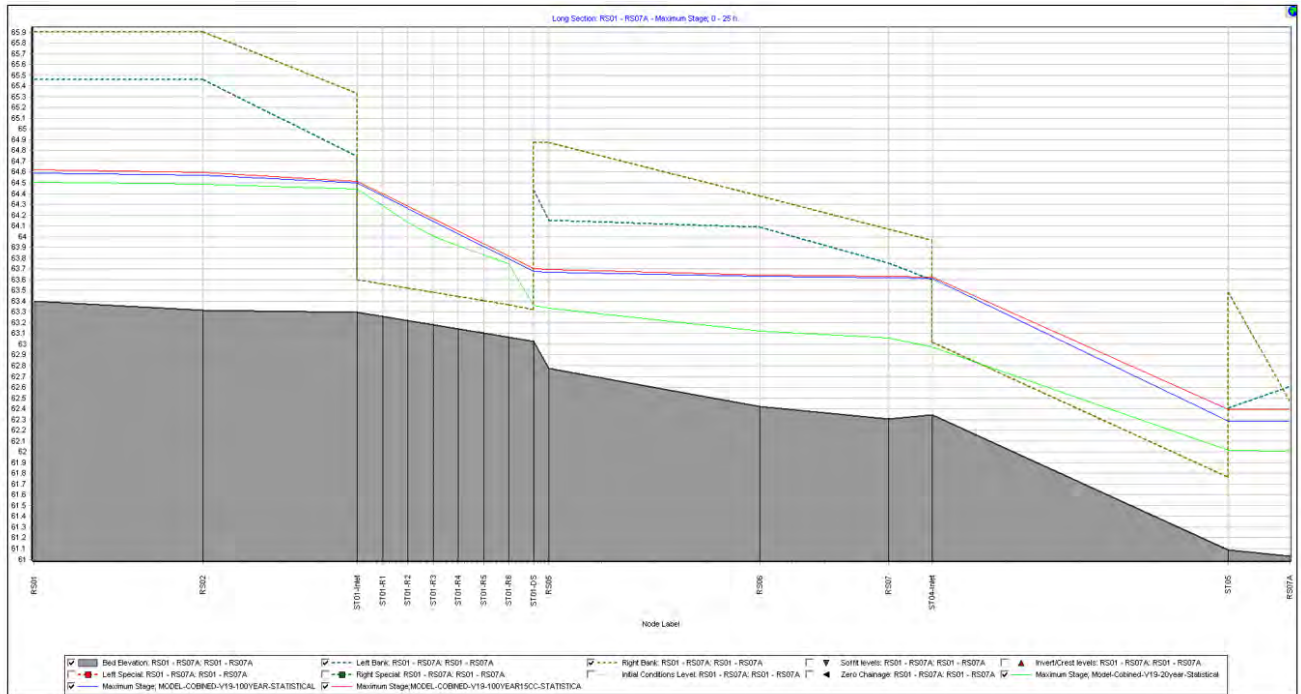


Figure 8: Long profile of maximum water level along the drain

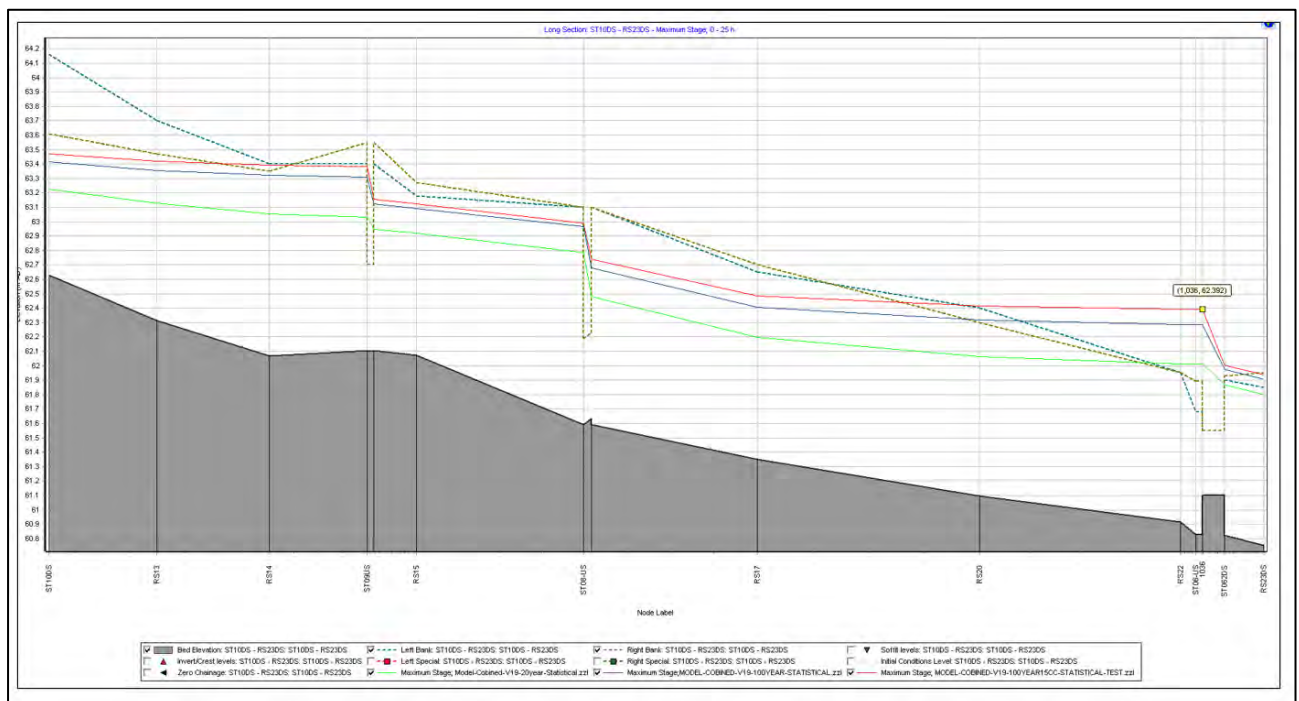


Figure 9: Long profile of maximum water level along the watercourse

- 4.2 A review of the modelling results revealed that there is “glass wall” effect along both the drain and the watercourse. In order to remove that, surveyed sections were extended using the Lidar data downloaded from Defra data service. However, The Lidar data shows that the ground levels along the watercourses are flat and extending the cross sections did not help in removing the “glass wall” effect. Thus, the “glass wall” effect still remains at the locations where the water levels exceed the bank level of the channel and for this reason the model results are considered to be conservative.
- 4.3 It is also observed that there is a back water effect due to the railway culvert. The water ponded at the upstream of the railway culvert. The water cannot spill over the railway up to 100 year +15%CC event.
- 4.4 The backwater effect diminishes at section RS05 in the drain and at RS13 in the watercourse.
- 4.5 The maximum water level at the upstream of the railway embankment are 62.011mAOD, 62.285mAOD and 62.394mAOD for 20year, 100year+15%CC and 100+15%CC year respectively. The railway embankment crest level is 63.354mAOD. It is observed that the water level does not exceeds the embankment crest level up to 100year+15%CC event.

Table 2: Maximum water level from model

Model nodes	Max Water level 20year	Max Water level 100 year	Max Water level 100 year+15%CC	Comments
ST10DS	63.226	63.413	63.471	Upstream of watercourse
RS13	63.126	63.352	63.417	
RS14	63.053	63.32	63.393	
ST09US	63.032	63.309	63.384	
ST09-Inlet	63.032	63.309	63.384	
Sp-ST09US	63.032	63.309	63.384	
Sp-ST09DS	62.949	63.122	63.154	
ST09-Down	62.949	63.122	63.154	
RS14DS	62.949	63.122	63.154	
RS15	62.921	63.093	63.125	
ST08-US	62.783	62.967	62.989	
ST08-Inlet	62.783	62.967	62.989	
ST08-Outlet	62.48	62.68	62.741	
RS16	62.48	62.68	62.741	
RS17	62.195	62.406	62.484	
RS20	62.065	62.318	62.417	
RS22	62.011	62.285	62.394	
ST06-US	62.011	62.285	62.394	
ST06	62.011	62.285	62.394	
ST07	61.868	61.973	62.004	
RS23	61.868	61.973	62.004	
RS23DS	61.801	61.907	61.938	
Inflow-us	63.226	63.413	63.471	Upstream end of drain
RS01	64.504	64.593	64.625	
RS02	64.486	64.568	64.598	
ST01-Inlet	64.444	64.498	64.519	

REPORT

ST01-U1	64.444	64.498	64.519	Junction with watercourse
ST01-U2	64.444	64.498	64.519	
Sp-ST01US	64.444	64.498	64.519	
Sp-ST01DS	63.358	63.675	63.704	
ST01-R1	64.288	64.376	64.397	
ST01-R2	64.131	64.259	64.282	
ST01-R3	64.002	64.142	64.166	
ST01-R4	63.916	64.025	64.051	
ST01-R5	63.83	63.908	63.935	
ST01-R6	63.745	63.791	63.82	
ST01-DS	63.358	63.675	63.704	
ST01-U2-R1	64.288	64.376	64.398	
ST01-U2-R2	64.131	64.259	64.282	
ST01-U2-R3	64.002	64.142	64.166	
ST01-U2-R4	63.916	64.025	64.051	
ST01-U2-R5	63.83	63.908	63.935	
ST01-U2-R6	63.745	63.791	63.82	
ST01-DS2	63.358	63.675	63.704	
ST02-Outlet	63.358	63.675	63.704	
RS05	63.332	63.672	63.702	
RS06	63.125	63.628	63.651	
RS07	63.054	63.618	63.639	
ST04-Inlet	62.975	63.609	63.629	
ST04	62.975	63.609	63.629	
Sp-ST04US	62.975	63.609	63.629	
Sp-ST04DS	62.014	62.286	62.394	
ST05	62.014	62.286	62.394	
ST05-Outlet	62.014	62.286	62.394	
RS07A	62.011	62.285	62.394	
Inflow-DS	62.949	63.122	63.154	
Sp-ST8US	62.783	62.967	62.989	
Sp-ST8DS	62.48	62.68	62.741	
ST062US	62.011	62.285	62.394	
ST062DS	61.868	61.973	62.004	
Sp-ST06US	62.011	62.285	62.394	
ST06-EXT1	62.011	62.285	62.394	
ST06-EXT2	62.011	62.285	62.394	
Upstream of rail embankment				

5 CONCLUSIONS

- 5.1 The purpose of this modelling exercise is to assess the water level for the Drain and the watercourse flowing near the site.
- 5.2 A 1D hydraulic model using industry standard Flood Modeller Pro- software has been used to simulate flood risk along drain and the watercourse.
- 5.3 Design peak flow estimates have been derived for the 1 in 20 year, 1 in 100 year, 1 in 100 year +15% climate change event. The flows are based on the latest Environment agency (EA) Flood Estimation Guidelines v2 July 2020.
- 5.4 The 1D element of the hydraulic model has been based upon 12 surveyed cross sections of the existing drain and 17 sections for the watercourse.
- 5.5 There are 6 circular conduits in the model. Two of them are in the drain and the other four are in the watercourse.
- 5.6 The depth of the model sections for the drain varies from 0.5m to 1.0m and the width of the drain is around 7m meters. The depth of the watercourse varies from 0.4m to 1.0m and the width is 5m to 10m.
- 5.7 The initial model runs showed there was “glass walling” at both the watercourse and the drain. Efforts were made to extend the cross section using Lidar data. However, the Lidar data demonstrates the floodplain is flat along these reaches and extending the cross sections did not result in removing this modelling artefact. The model results are still “glass walling” at certain locations. However, it was considered that the model results are conservative and still could be used for the purpose of the FRA.
- 5.8 No sensitivity runs were made for the model. Roughness value was considered conservative and reasonable.

Appendix A

Hydrology report

Flood estimation report: MOD Graven Hill

Introduction

This report template is a supporting document to the Environment Agency's Flood Estimation Guidelines. It provides a record of the hydrological context, the method statement, the calculations and decisions made during flood estimation and the results. This document can be used for one site or multiple sites. If only one site is being assessed, analysts should remove superfluous rows from tables.

Guidance notes (in red text) are included throughout this document in column titles or above tables. These should be deleted before finalising the document. Where relevant, references to specific sections of the Flood Estimation Guidelines document are included to indicate where further useful information can be found.

Note: Column size / page layout can be adapted, where necessary, to best present relevant information, for example, maps do not need to be within the tables if they would be better as a separate page.

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Approval

Revision stage	Analyst / Reviewer name & qualifications	Amendments	Date
Method statement preparation	Anna Velkov	N/A	N/A
Method statement sign-off			
Initial calculations preparation	Anna Velkov		N/A
Initial calculations sign-off			

Abbreviations

AEP	annual exceedance probability
AM.....	Annual Maximum
AREA	Catchment area (km ²)
BFI	Base Flow Index
BFIHOST	Base Flow Index derived using the HOST soil classification
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
OS	Ordnance Survey
POT.....	Peaks Over a Threshold
QMED	Median Annual Flood (with return period 2 years)
ReFH	Revitalised Flood Hydrograph method
ReFH2	Revitalised Flood Hydrograph 2 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 SUMMARY OF ASSESSMENT

1.1 Summary

This table provides a summary of the key information contained within the detailed assessment in the following sections. The aim of the table is to enable quick and easy identification of the type of assessment undertaken. This should assist in identifying an appropriate reviewer and the ability to compare different studies more easily.

Catchment location	SP 59393 19484 at the downstream end
Purpose of study and scope e.g. for scope just include whether it is simple, routine, moderate, difficult, very difficult	To derive inflow hydrographs for input into the 1 D hydraulic model, to assess the fluvial flood risk from an unnamed watercourse and a drain which joins the watercourse just upstream a railway culvert.
Key catchment features e.g. permeable, urban, pumped, mined, reservoir	The catchment of the watercourse is predominantly rural with moderate permeability. The catchment of the drain covers the development site and is also moderately permeable. The catchment is not pumped.
Flooding mechanisms e.g. fluvial, surface water, groundwater	The flood risk is fluvial.
Gauged / ungauged State if there are flow or level gauges and a very brief indication of quality if there are	The catchment is ungauged.
Final choice of method	Statistical.
Key limitations / uncertainties in results	

1.2 Note on flood frequencies

The frequency of a flood can be quoted in terms of a return period, which is defined as the average time between years with at least one larger flood, or as an annual exceedance probability (AEP), which is the inverse of the return period.

Return periods are output by the Flood Estimation Handbook (FEH) software and can be expressed more succinctly than AEP. However, AEP can be helpful when presenting results to members of the public who may associate the concept of return period with a regular occurrence rather than an average recurrence interval. Results tables in this document contain both return period and AEP titles; both rows can be retained or the relevant row can be retained and the other removed, depending on the requirement of the study.

The table below is provided to enable quick conversion between return periods and annual exceedance probabilities.

Annual exceedance probability (AEP) and related return period reference table

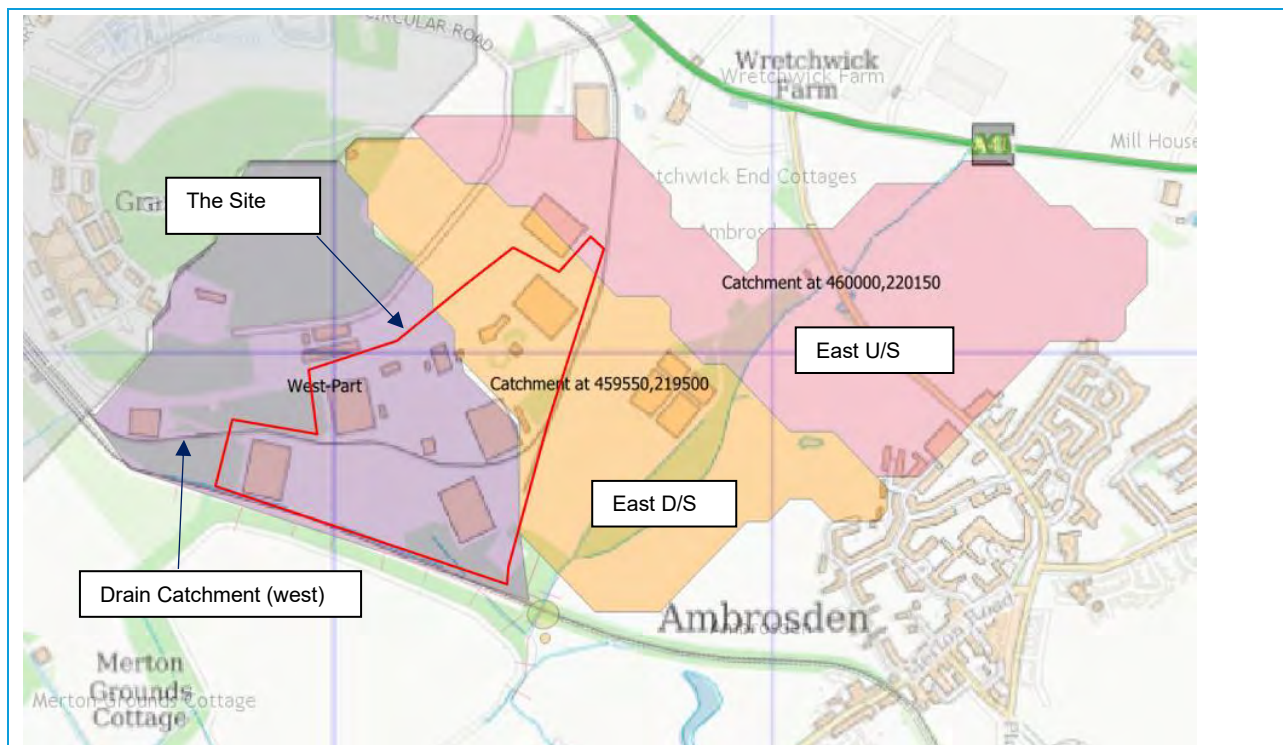
AEP (%)	50	20	10	5	3.33	2	1.33	1	0.5	0.1
AEP	0.5	0.2	0.1	0.05	0.033	0.02	0.0133	0.01	0.005	0.001
Return period (yrs)	2	5	10	20	30	50	75	100	200	1,000

2 METHOD STATEMENT

2.1 Requirements for flood estimates

<p>Overview</p> <p>The content and level of detail provided in this section will depend on the scope of the study. The following should be included as a minimum:</p> <ul style="list-style-type: none"> • Purpose of study • Peak flows or hydrographs? • Design events for which flow estimates are to be made given as AEP (%) • Climate change allowances with reference to relevant guidance • Potential number of locations for flow estimation • The purpose of the document 	<p>The purpose of this study is to estimated peak flows and derive inflow hydrographs for input into the 1 D hydraulic model of the unnamed water course and the drain which run to the south east of the site and along the south western perimeter of the site respectively. The model will be used to assess the potential flood risk to a proposed development at MOD Graven Hill, (nearest Postcode OX25 2BA).</p> <p>Design peak flow estimates will be derived for the 5%, 1%, and 1%+Climate Change (CC) allowance and 0.1% AEP events (1 in 20, 100, 100 year+CC and 1 in 1000 return periods). The flow hydrographs will be estimated at three locations as explained further in this report.</p> <p>The latest EA Flood Estimation Guidelines v2 July 2020 and the Flood estimation: technical guidance of Natural Resource Wales has been used.</p>
<p>Project scope</p> <p>What is the complexity of the study – simple, routine, moderate, difficult, very difficult?</p> <p>What analyses need to be included within the study, for example:</p> <ul style="list-style-type: none"> • Review of existing studies? • Rating reviews / updates? • Simple / detailed flood history review? • ReFH model parameter estimation? • Joint probability? 	<p>This is a routine study, which will include a simple flood history review and flood estimation based on the standard FEH methods – Statistical and ReFH2.</p>

2.2 The catchment



Description

Include topography, climate, geology, soils, land use and any unusual features (e.g. reservoirs, historic mining) that may affect the flood hydrology. In some cases, it may be useful to include reference to things such as amount of modelled reach that is culverted but remember that this is not a hydraulic modelling report and detail on hydraulic features, such as weir and culvert sizes, is not required. Think about what features are going to affect runoff from the contributing catchment reaching the watercourse.

The subject site has an area of approximately 30.5ha. It is located approximately 3.5km south of Bicester Town Centre and 1 km to the north west of Ambrosden Centre and 500m south west of A41.

The study area and the contributing catchments are shown in the figure above. The Unnamed watercourse is about 1.5km long and drains the area to the south west of A41. The area to the north of A41 drains in northerly direction. The catchment of the drain to the south west of the site covers part of the development site. Both catchments are predominantly rural with some buildings which are part of the development site. The urbanisation level of the catchments is reflected in the FEH URBEXT2000 values which are 0.044, 0.053 (for the watercourse catchment) and 0.030 for the drain catchment.

It is noted that the FEH webservice divides the catchment of the watercourse in 2 parts as shown in the figure above. The catchment of the upstream part is 0.59km² and of the downstream part is 0.51km². The catchment area of the drain is 0.56km².

The FARL value for the catchment is 1.0. A revision of the OS mapping confirms that there are not major storages in the catchment, and the FARL value was deemed appropriate.

A review of the Soilsmap of the area has identified that the soil types across the catchment are predominantly *Slowly permeable seasonally wet slightly acid but base-rich loamy and clayey soils*. The improved soils descriptor, BFIHOST19 for the U/S and D/S catchments is 0.26 and 0.319 respectively which indicate not very permeable catchment. The Catchment of the drain was not defined in the FEH website. Its catchment area was defined as the area between the neighbouring catchment to the north (in gray in the figure above), the catchment of the Unnamed watercourse and the railway which is on elevated embankment and acts as catchment boundary. The catchment descriptors for a small catchment further downstream the watercourse, which contain the area of the drain were used.

The value of the BFIHOST19 is outcome of a comprehensive revision of the BFIHOST calculation process, which provided a set of revised BFIHOST coefficients for each of the 29 HOST classes (Griffin and others, 2019). Some coefficients are very different from those in the original HOST classification. The guidance recommends the use of BFIHOST19 descriptor, as it has been found to improve the estimation of QMED. BFIHOST19 is also recommended for use in the ReFH 2.3 method, because it provides improved predictions of model parameters, particularly on some clay and peat catchments.

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2.3 Source of flood peak data

Source	NRFA peak flows dataset – Version 9 (September 2020).
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2.4 Gauging stations (flow or level)

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
There are no gauges at or very near to the sites of flood estimates						

2.5 Data available at each flow gauging station in Table 2.4

N/A

2.6 Rating equations

N/A

2.7 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	No	No		
Historical flood data	Yes	No		
Flow or river level data for events	No	No		
Rainfall data for events	No	No		
Potential evaporation data	No	No		
Results from previous studies	Yes	No		
Other data or information	No	No		

2.8 Hydrological understanding of catchment

<p>Conceptual model</p> <p>Include information on factors such as:</p> <ul style="list-style-type: none"> Where are the main sites of interest? What is likely to cause flooding at those locations? (peak flows, flood volumes, combinations of peaks, groundwater, snowmelt, tides...) Might those locations flood from runoff generated on part of the catchment only, e.g. downstream of a reservoir? Is there a need to consider temporary debris dams that could collapse? 	<p>The main area of interest is the area of the study site, along the south west boundary, parallel to the drain and the south corner of the site, which is close to the junction of the two watercourses and the railway culvert .</p> <p>The main source of potential flooding is fluvial from overtopping of the banks of the drain and from water backing upstream of the railway culvert as a result of the culvert's restricted capacity or blockage. The high levels in the drain are most likely to be as a result of runoff from the site.</p>
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<p>Unusual catchment features</p> <p>Include information on factors such as:</p> <ul style="list-style-type: none"> highly permeable heavily urbanised pumped watercourse major reservoir influence (FARL<0.90) flood storage areas, particularly those which are normally dry historical mining or operational mining activities <p>Guidance on methods for unusual catchments is contained in Section 7 of the Flood Estimation Guidelines</p>	<p>Both catchments are categorised as predominantly rural (URBEXT₂₀₀₀ = 0.05 and 0.03 respectively).</p> <p>The catchments have moderate permeability (BFIHOST = 0.26 and 0.32 for the upstream watercourse catchment and the drain catchment respectively). The SPRHOST=50.7 and 48.3 respectively (>20%) and no permeable adjustments were required.</p> <p>The watercourses are not pumped.</p> <p>The FARL value for the catchment upstream of the site is 1.0 which indicates that no reservoirs are present in the catchments. A review of the OS map confirms that.</p>
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2.9 Initial choice of approach

<p>Is FEH appropriate? (it may not be for extremely heavily urbanised or complex catchments). If not, describe other methods to be used.</p>	<p>The catchment is not extremely urbanised or complex and it is suitable for both FEH methods (Statistical and ReFH2).</p>
<p>Initial choice of method(s) and reasons</p> <p>Think about: (i) the type of problem, (ii) the type of catchment, and (iii) the type of data available. Which methods are appropriate? If more than one method is appropriate will all be applied, and the results compared before a final decision is made?</p> <p>How will hydrograph shapes be derived if needed?</p> <p>e.g. ReFH1 / ReFH2 shapes, average hydrograph shape from gauge data</p> <p>Will the catchment be split into sub-catchments? If so, how?</p> <p>If the hydrological assessment is being undertaken to supply inflows to a hydraulic model, it is likely that a distributed approach will be taken, with the catchment split into sub-catchments and design flows routed from each sub-catchment.</p>	<p>The above information indicates that all factors are suitable for use of the FEH statistical method.</p> <p>A hybrid method will be used, where the ReFH2 will be used to generate design hydrographs and will be scaled to the FEH statistical (pooled analysis) peak flow.</p> <p>Flows will be derived for the catchment of the drain and applied as upstream boundary for this watercourse. Flows will also be derived for the upstream catchment of the Unnamed watercourse and applied as upstream boundary condition for this part of the model. In addition flows will be derived for the downstream part of this catchment (as defined in the FEH website) and applied as lateral flows.</p>
<p>Software to be used (with version numbers)</p> <p>Delete entries in the column on the right as appropriate</p>	<p>FEH Webservice</p> <p>WINFAP5</p> <p>ReFH2 Design Flood Modelling Software Version 2.3</p>

3 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.

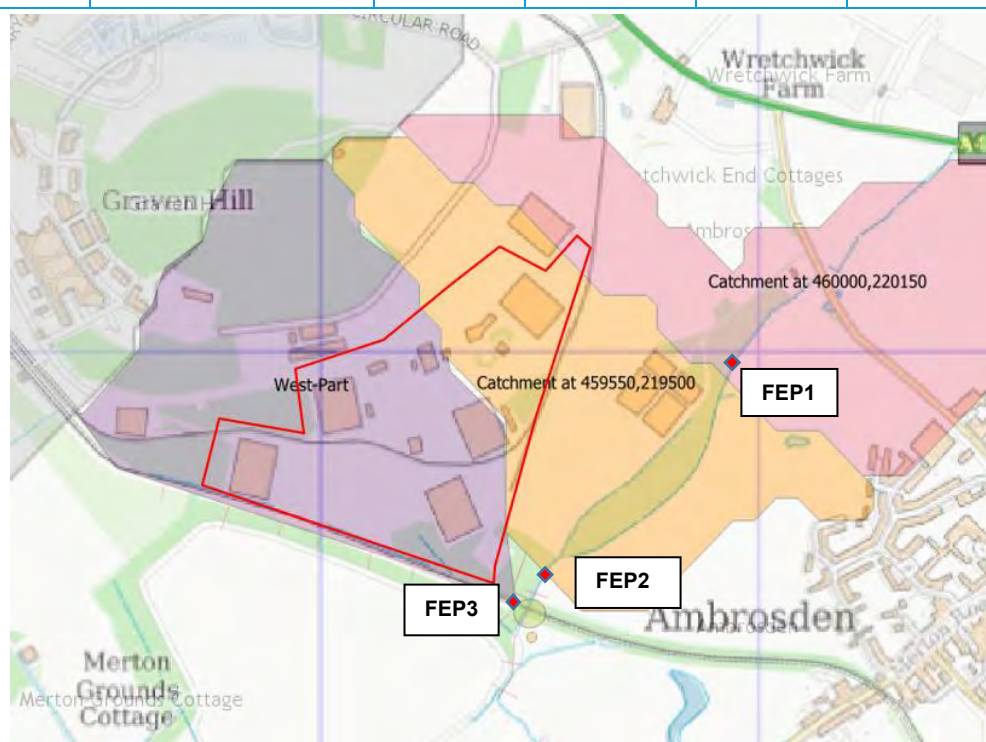
3.1 Summary of subject sites

Site code	Type of estimate L: lumped catchment S: Sub-catchment	Watercourse	Name or description of site	Easting	Northing	AREA on FEH CD-ROM (km ²)	Revised AREA if altered
FEP1 (East US)	L	Unnamed Tributary	Flows at the u/s end of the Unnamed watercourse. model. The flow was estimated at the downstream poin of the catchment as delineated in the FEH website. This is locate approximately in the middle of the watercourse. This flow was the applied at the upstream end of the model	460000	220150	0.59	Not revised
FEP2 (East DS)	L	Unnamed Tributary	Downstream catchment of the unnamed watercourse. Flows applied as laterat in the downstream section of the watercourse	459550	219500	0.515	Not revised
FEP3 (West)	L	The Drain	Cathcment area of the Drain			N/A	0.56

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.



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

Site code	FARL	PROPWET	BFIHOST	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	URBEXT 1990 Delete if not required	URBEXT 2000	FPEXT
FEP1	1.0	0.32	0.26	0.62	16.1	620		0.0446	0.116
FEP2	1.0	0.32	0.313	0.59	21.7	620		0.0534	0.0583
FEP3	1.0	0.32	0.328	0.73	26.0	620		0.0303	0.0964

3.3 Checking catchment descriptors

<p>Record how catchment boundary was checked and describe any changes</p> <p>Add maps if needed to aid explanation of any changes</p> <p>If changes are made to the catchment boundary (and hence AREA), identify if any other descriptors will be updated and how</p>	<p>Catchment boundary were checked using contour information from OS mapping and LiDAR data obtained from the EA's free data download service. No adjustment to the catchment boundary shown on the FEH CD-ROM for the Unnamed watercourse was considered necessary.</p> <p>As explained in Section 2.2 above, the catchment of the drain was not defined in the FEH website and therefore it was defined as the area between the neighbouring catchments and the railway embankment.</p>
<p>Record how other catchment descriptors were checked and describe any changes.</p> <p>Include before/after table if necessary.</p>	<p>The SAAR values are the same for all catchments and providing that the area of the catchments is very small is considered to be appropriate</p> <p>PROPWET seems suitable based on the <i>Slowly permeable seasonally wet slightly acid but base-rich loamy and clayey soils</i>, which are present across the catchment.</p> <p>DPSBAR and DPLBAR seem appropriate based on topography of catchment.</p> <p>The catchment is characterised as moderately permeable.</p>
<p>Source of URBEXT</p> <p>Delete as needed. URBEXT1990 is only used for ReFH1</p> <p>An alternative is the URBAN50k method if URBEXT values need to be substantially revised due to discrepancies between the FEH urban extent layers and current mapping</p>	<p>URBEXT1990 / URBEXT2000</p>
<p>Method for updating of URBEXT</p> <p>Delete as needed (CPRE formula from FEH Volume 4 is for URBEXT1990)</p> <p>An update to the current year is not required when the URBAN50k method is used as it will be implicitly accounted for in the latest mapping</p>	<p>CPRE formula from FEH Volume 4 / CPRE formula from 2006 CEH report on URBEXT2000</p>

4 STATISTICAL METHOD

4.1 Application of Statistical method

<p>What is the purpose of applying this method?</p> <p>Brief summary of the reasons, specific to this study, for applying the method. For example, lumped estimates at key locations for the purpose of checking modelled peak flow estimates.</p>	<p>Estimates of peak flow at key locations and deriving growth curves for a range of return periods.</p>
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4.2 Overview of estimation of QMED at each subject site

Site code	QMED (rural) from CDs (m ³ /s)	Final method	Data transfer					Urban adjustment factor UAF	Final estimate of QMED (m ³ /s)
			NRFA numbers for donor sites used (see 4.3)	Distance between centroids d _{ij} (km)	Moderated QMED adjustment factor, (A/B) ^a	If more than one donor			
						Weight	Weighted ave. adjustment		
FEP1	0.21	CD						1.033	0.217
FEP2	0.17	CD						1.047	0.178
FEP3	0.18	CD						1.030	0.183
Are the values of QMED spatially consistent?						Yes			
Method used for urban adjustment for subject and donor sites (delete method in the column to the right as needed)						Urban adjustment to QMED, using the Kjeldsen (2010).			
Parameters used for WINFAP v4 urban adjustment if applicable (these are 'standard' values and should be revised if alternative values have been applied)									
Impervious fraction for built-up areas, IF			Percentage runoff for impervious surfaces, PR _{imp}			Method for calculating fractional urban cover, URBAN			
0.3			70%			From updated URBEXT2000			
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).									
The QMED adjustment factor A/B for each donor site 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 (rural) estimate from catchment descriptors.									
Important note on urban adjustment									
The method used to adjust QMED for urbanisation published in Kjeldsen (2010)Error! Bookmark not defined. in which PRUAF is calculated from BFIHOST is not correctly applied in WINFAP-FEH v3.0.003. Significant differences occur only on urban catchments that are highly permeable. This is discussed in Wallingford HydroSolutions (2016)Error! Bookmark not defined..									

4.3 Search for donor sites for QMED (if applicable)

<p>Comment on potential donor sites</p> <p>Provide details regarding how potential donors were selected and the reasons why they were chosen / rejected.</p> <p>Include a map if necessary, which shows the location of the study catchment and donor stations under consideration.</p> <p>Section 4 of the Flood Estimation Guidelines provides guidance on selecting a donor(s) for data transfer.</p>	<p>The catchments are very small and no suitable donor sites were available.</p>
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4.4 Donor sites chosen and QMED adjustment factors

NRFA no.	Method (AM or POT)	Adjustment for climatic variation?	QMED from flow data (A)	QMED from catchment descriptors (B)	Adjustment ratio (A/B)

4.5 Derivation of pooling groups

Name of group	Site code from whose descriptors group was derived	Subject site treated as gauged?	Changes made to default pooling group, with reasons	Weighted average L-moments L-CV and L-skew, (before urban adjustment)
MOD Pooling WINFAP5	D/S of FEP3 (grid reference SP 59450 19300) – the catchment from which the descriptors group was derived was a catchment to a point d/s of the railway culvert which includes the Unnamed watercourse catchment and the majority of the drain catchment.	no	Station 7011 (Black Burn @ Pluscarden Abbey) was removed since it has only 7 years of data. With this station removed, the total number of years was 544, and no other stations were added.	L-CV - 0.275 L-skew - 0.254

Note: Pooling groups were derived using the procedures from Science Report SC050050 (2008).

4.6 Derivation of flood growth curves at subject sites

Site code	Method (SS, P, ESS, J)	If P, ESS or J, name of pooling group	Distribution used and reason for choice	Note any urban adjustment or permeable adjustment	Parameters of distribution	Growth factor for 100-year return period / 1% AEP
D/S FEP3	P	MOD Pooling WINFAP5	The GL distribution was selected with goodness of fit 0.1396. It has the best goodness of fit and in addition the GL distribution is the preferred distribution for the pooling analysis.	No permeable adjustments were made. No urban adjustment to the growth curves, only to QMED, using the Kjeldsen (2010).	L-CV - 0.275 L-skew - 0.254	3.421

Notes

Methods: SS – Single site; P – Pooled; ESS – Enhanced single site; J – Joint analysis
Urban adjustments are all carried out using the method of Kjeldsen (2010).
Growth curves were derived using the procedures from Science Report SC050050 (2008).

4.7 Flood estimates from the statistical method

Site code	Flood peak (m ³ /s) for the following return periods (in years)									
	2	5	10	20	50	100	200	1000		
	Flood peak (m ³ /s) for the following AEP (%) events									
	50	20	10	5	2	1	0.5	0.1		
FEP1 (U/S)	0.22	0.32	0.39	0.48	0.62	0.74	0.89	1.3		
FEP2 (D/S)	0.18	0.26	0.32	0.39	0.51	0.61	0.73	1.1		
FEP3 (West)	0.18	0.27	0.33	0.41	0.52	0.63	0.75	1.1		

5 REVITALISED FLOOD HYDROGRAPH (REFH) METHOD

N/A

6 REVITALISED FLOOD HYDROGRAPH 2 (REFH2) METHOD

6.1 Application of ReFH2 method

What is the purpose of applying this method?	Lumped estimates at key locations for the purpose of checking and comparing modelled peak flow estimates obtained from the Statistical method and deriving hydrograph shapes.
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6.2 Catchment sub-divisions for ReFH2 model

This section can be deleted if the catchment is essentially rural.

6.3 Parameters for ReFH2 model

Site code	Method	T _p _{rural} (hours)	T _p _{urban} (hours)	C _{max} (mm)	PR _{imp}	BL (hours)	BR
FEP1 (U/S)	CD	2.21		221.8		20.78	0.501
FEP2 (trib)	CD	1.95		258.53		23.27	0.912
FEP3 (West)	CD	2.08		267.41		24.98	1.016
Brief description of any flood event analysis carried out (further details should be given in the annex)							
Methods: OPT: Optimisation, BR: Baseflow recession fitting, CD: Catchment descriptors, DT: Data transfer (give details)							

6.4 Design events for ReFH2 method: Lumped catchments

This table can be deleted if ReFH2 is not being applied for lumped catchments. Note: ReFH2 may be applied for both lumped catchments and sub-catchments in a study; if this is the case both this table and the next should be completed.

Storm durations detailed here should be the values for the individual catchments. Lumped flows should be generated using the storm duration relevant to each lumped catchment for comparison with Statistical estimates.

Site code	Urban or rural	Season of design event (summer or winter)	Storm duration (hours)
FEP1 (U/S)	Rural	Winter	3*
FEP2 (D/S)	Rural	Winter	3
*The critical duration was selected by estimating the time to peak using the Formula updated as per the "FEH Supplementary Report No1", pg 19, Sec 3.3.2.			

6.5 Design events for ReFH2 method: Sub-catchments and intervening areas

This table can be deleted if ReFH2 is not being applied for sub-catchments.

6.6 Flood estimates from the ReFH2 method

Note: This table is for recording results for lumped catchments. There is no need to record peak flows from sub-catchments or intervening areas that are being used as inputs to a semi-distributed model of the river system.

Site code	Flood peak (m ³ /s) for the following return periods (in years)									
	2	5	10	20	50	100	200	1000		
	Flood peak (m ³ /s) for the following AEP (%) events									
	50	20	10	5	2	1	0.5	0.1		
FEP1	0.39	0.56	0.69	0.81	0.99	1.14	1.32	1.85		
FEP2	0.30	0.43	0.53	0.61	0.77	0.89	1.03	1.45		
FEP3	0.29	0.43	0.52	0.62	0.76	0.87	1.00	1.42		

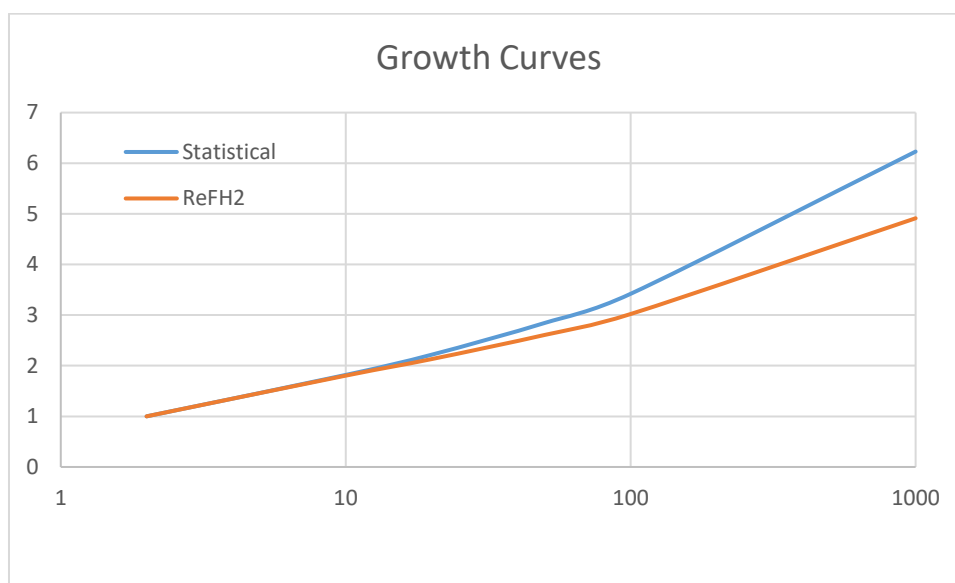
7 DISCUSSION AND SUMMARY OF RESULTS

7.1 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 / AEP events. Delete columns which are not required.

Site code	Ratio of peak flow to FEH Statistical peak					
	Return period 2 years / 50% AEP			Return period 100 years / 1% AEP		
	ReFH	ReFH2	Statistical	ReFH	ReFH2	Statistical
FEP1		0.39	0.22		1.14	0.74
FEP2		0.30	0.18		0.89	0.61
FEP3		0.29	0.18		0.87	0.63

Growth Curves for the different methods investigated



7.2 Final choice of method

Choice of method and reasons

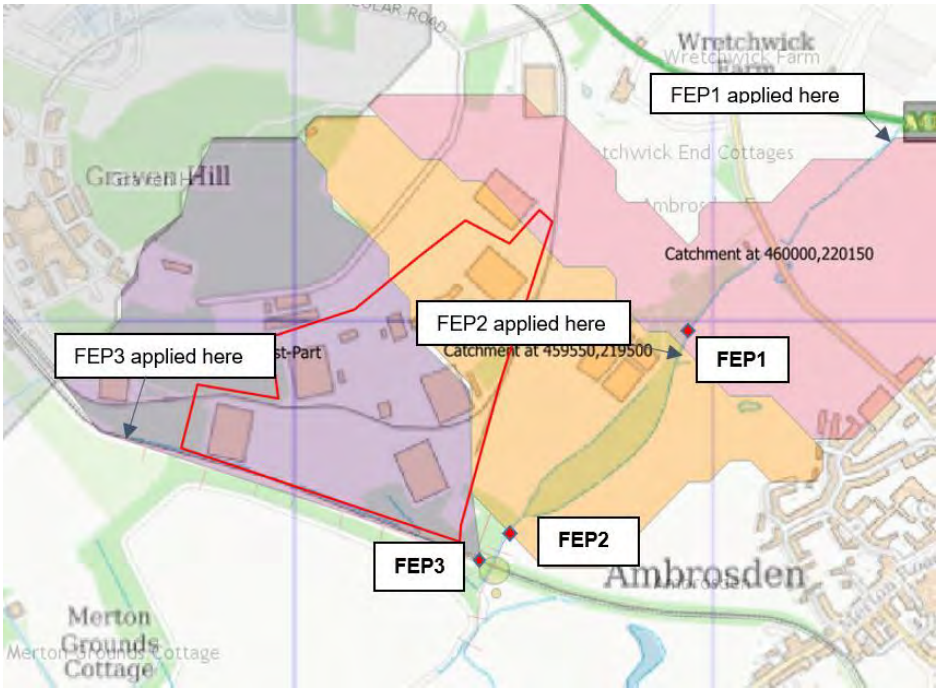
Include reference to type of study, nature of catchment and type of data available.

Statistical method – Moderate confidence can be placed on the QMED estimated using the Statistical method based on catchment descriptors only. The catchments are ungauged and there was no suitable donor gauge in a nearby catchment. In addition the catchment of the drain was not defined in the FEH website and it was delineated using the boundaries of the neighbouring catchments. However, the three catchment assessed are very small and next to each other and the catchment descriptors are similar, which give confidence in the used parameters.

ReFH2 - Peak flows based on catchment descriptors alone produced growth curves similar in shape to the FEH statistical method (pooled analysis) growth curves for the low flows. But approximately around the 100 year event and towards the higher flows, the values decrease and the curve becomes flatter. At the same time the resulting peak flows are significantly higher in comparison to the Statistical method flows and are unrealistically big for such a small catchments.

Conclusion

The growth curves from the Statistical Method and the ReFH2 method follow a similar shape up to the 1 in 80 year return period events. However, the resulting peak flows from the ReFH2 method for all events are significantly higher in comparison to the Statistical method flows and are unrealistically big for such a small catchments. In addition the EA guidance advises that the FEH

	<p>statistical method is based on much larger database of flood events and has been more directly calibrated to reproduce flood frequency on UK catchments and is therefore preferred to other rainfall run-off approaches.</p> <p>A method was used for this study, where the peak flow from the statistical method was fit to a ReFH2 derived hydrograph shape.</p>
<p>How will the flows be applied to a hydraulic model?</p> <p>If relevant. Will model inflows be adjusted to achieve a match with lumped flow estimates, or will the model be allowed to route inflows?</p>	

7.3 Assumptions, limitations and uncertainty

List the main assumptions made (specific to this study)	<p>FEH Statistical estimates are derived using catchment descriptors and not from directly gauged flows/rainfall records. It is assumed that the catchment descriptors reflect the nature of the catchments and are reliable to be used for flow derivation.</p> <p>It is assumed that the empirical equations and the pooling groups derived from the catchment descriptors provide a good estimate of the flows in the subject watercourses.</p>
Discuss any particular limitations, e.g. applying methods outside the range of catchment types or return periods for which they were developed.	No gauged data for the study site was available and thus the accuracy of the calculations depends on the CD only.
<p>Provide information on the uncertainty in the design peak flow estimates and the methodology used</p> <p>Uncertainty in the peak flow estimates should always be provided. The default is the 95-percentile upper and lower bounds, but other estimates may need to be provided depending on the requirements of the study. Further information can be found in Section 5.4 of the Flood Estimation Guidelines.</p>	<p>It is almost always preferable to obtain Qmed from flood data if at all possible; however, no such information was available for the study site.</p> <p>The degree of uncertainty for a design flow Q based on a QMED estimated from catchment descriptors has a 95% confidence limit of 0.49Q, 2.04Q which in this case is 0.196 and 0.816 m³/sec for the combined upstream and downstream catchments of the Unnamed Watercourse.</p> <p>It is important to note that a wide confidence interval does not necessarily mean that the best estimate is wrong. It is much more likely to be correct than are the values at the upper and lower confidence limits.</p>
Comment on the suitability of the results for future studies, e.g. at nearby locations or for different purposes, would a project for scheme design require	The results from this study are consistent at different node locations and catchment areas.

additional detail, etc.	
Give any other comments on the study, e.g. suggestions for additional work, such as flow monitoring, rating reviews, etc.	It is considered that the distribution of the estimated flows within the model is appropriate and no adjustments are required.

7.4 Checks

Are the results consistent, for example at confluences? <i>This will not be relevant for a study where there is only a single flow estimation point.</i>	Yes
What do the results imply regarding the return periods / frequency of floods during the period of record? <i>This will only be relevant where there is flow gauge data.</i>	The results show that with increased return period there is increased flow, proportionally, according to the growth curves in which there is good confidence.
What is the range of 100-year / 1% AEP growth factors? Is this realistic?	Growth factors are: Statistical method – 3.4 ReFH2 method – 3.02 And they are considered realistic.
If 1000-year / 0.1% AEP flows have been derived, what is the range of ratios for 1000-year / 0.1% AEP flow over 100-year / 1% AEP flow?	Statistical method – 1.82 ReFH2 method – 1.62
How do the results compare with those of other studies? Explain any differences and conclude which results should be preferred. <i>This will not be relevant if there are no previous hydrological assessments.</i>	N/A
Are the results compatible with the longer-term flood history? <i>This will not be relevant if there is no flow gauge data or historical flooding information.</i>	N/A
Describe any other checks on the results, e.g. sense-checking hydraulic model results	No flood history for the study area was available.

7.5 Final results

Site code	Flood peak (m ³ /s) for the following return periods (in years)									
	2	5	10	20	50	100	200	1000		
	Flood peak (m ³ /s) for the following AEP (%) events									
	50	20	10	5	2	1	0.5	0.1		
FEP1 (U/S)	0.22	0.32	0.39	0.48	0.62	0.74	0.89	1.35		
FEP2 (D/S)	0.18	0.26	0.32	0.39	0.51	0.61	0.73	1.11		
FEP3 (West)	0.18	0.27	0.33	0.41	0.52	0.63	0.75	1.14		

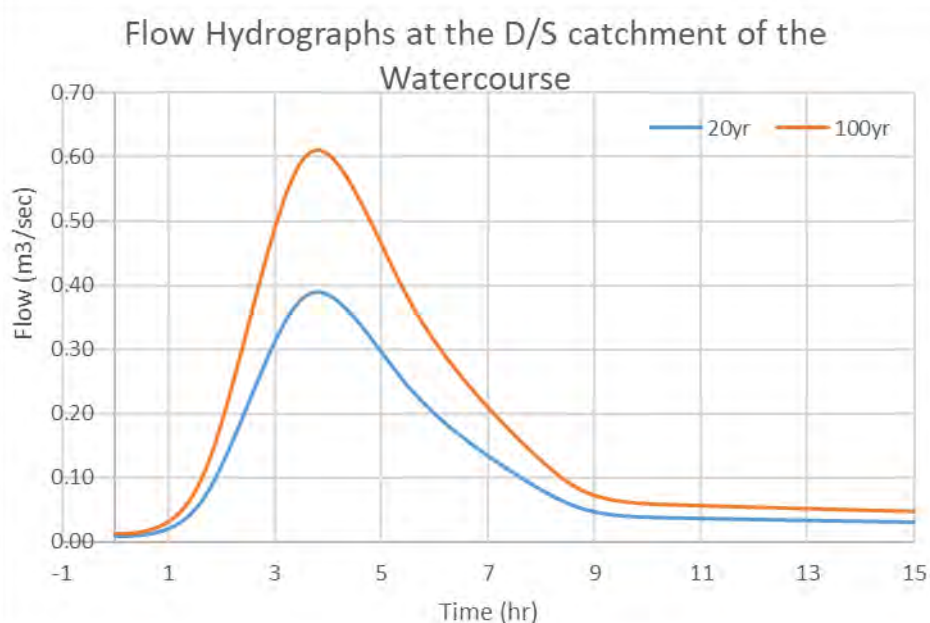
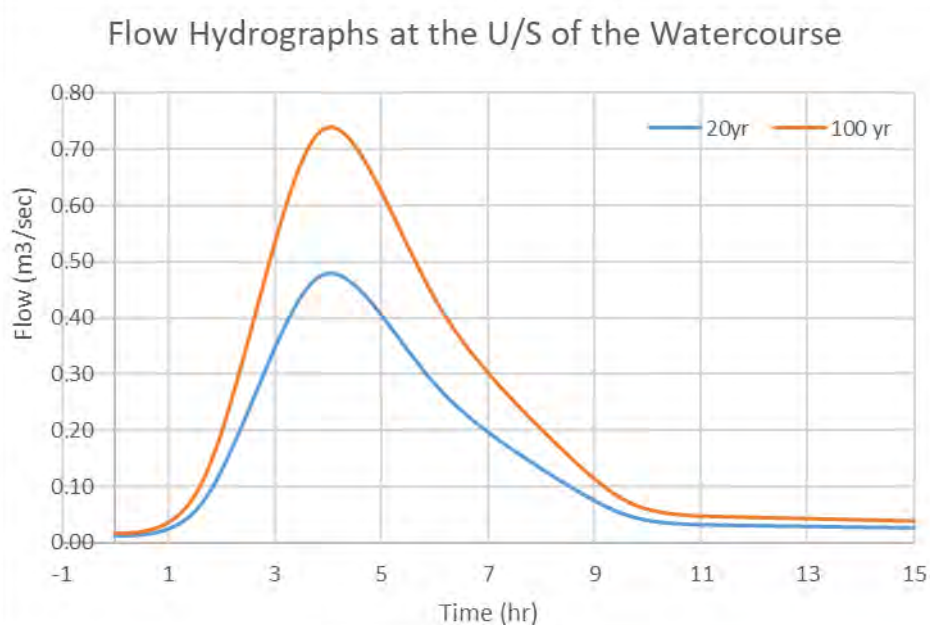
7.6 Uncertainty bounds

This table reports the flows derived from the uncertainty analysis detailed in Section 7.3. The 'true' value is more likely to be near the estimate reported in Section 7.5 than the bounds. However, it is possible that the 'true' value could still lie outside these bounds.

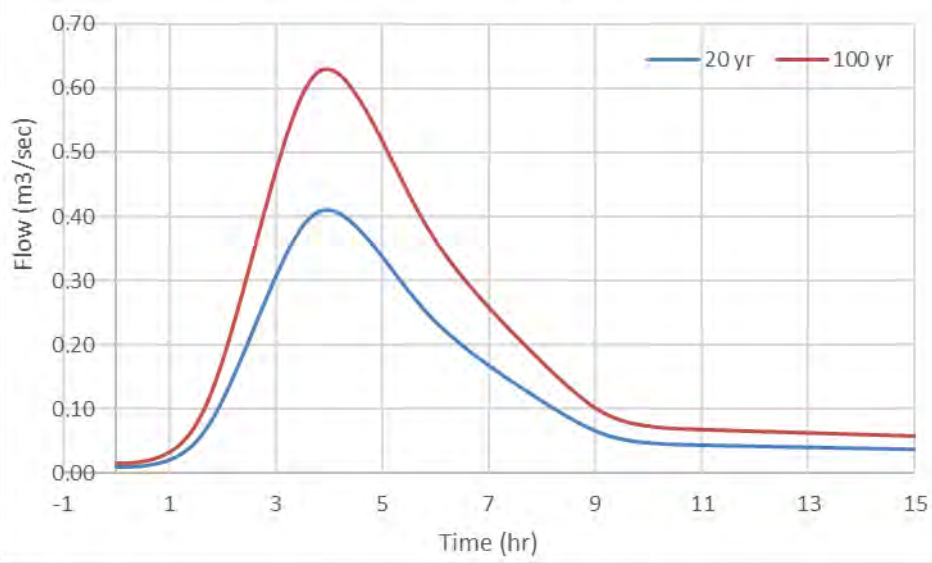
Complete this table with the flows from the uncertainty analysis. Some key design events have been added to the table, but these can be amended as required.

Site code	Flood peak (m³/s) or volumes (m³) for the following return periods (in years)							
	2		20		100		1,000	
	Flood peak (m³/s) or volumes (m³) for the following AEP (%) events							
	50		5		1		0.1	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
FEP1 (U/S)	0.11	0.44	0.24	0.98	0.36	1.51	0.66	2.75
FEP2 (D/S)	0.09	0.36	0.19	0.81	0.30	1.24	0.54	2.26
FEP3 (West)	0.09	0.37	0.20	0.83	0.31	1.28	0.56	2.32

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)



Flow Hydrographs at the U/S of the Drain



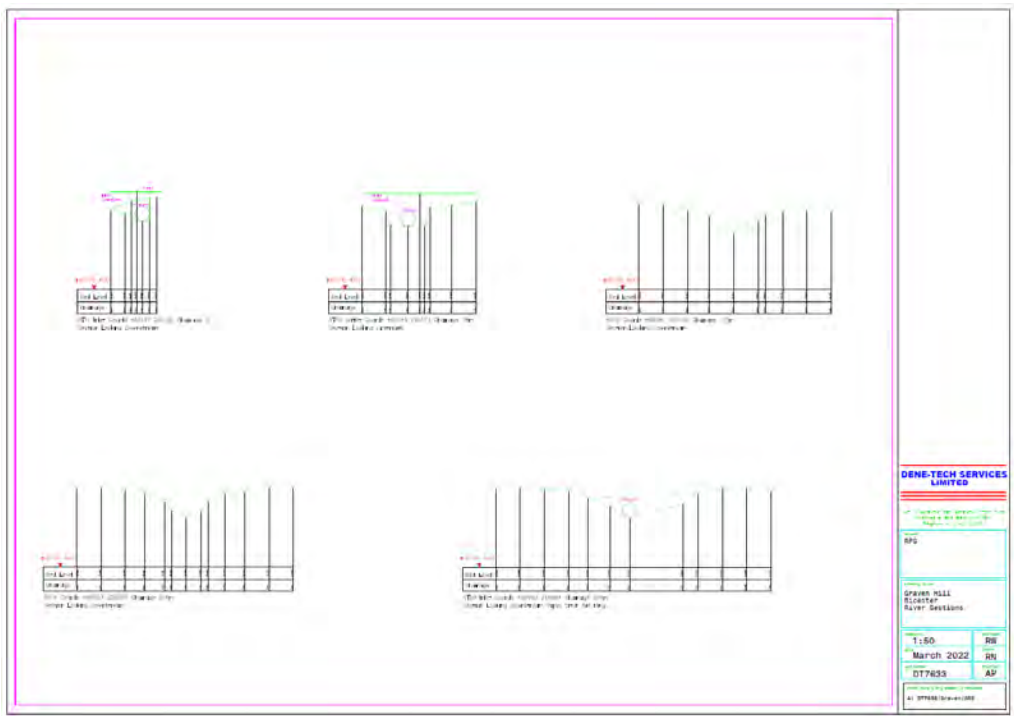
8 ANNEX

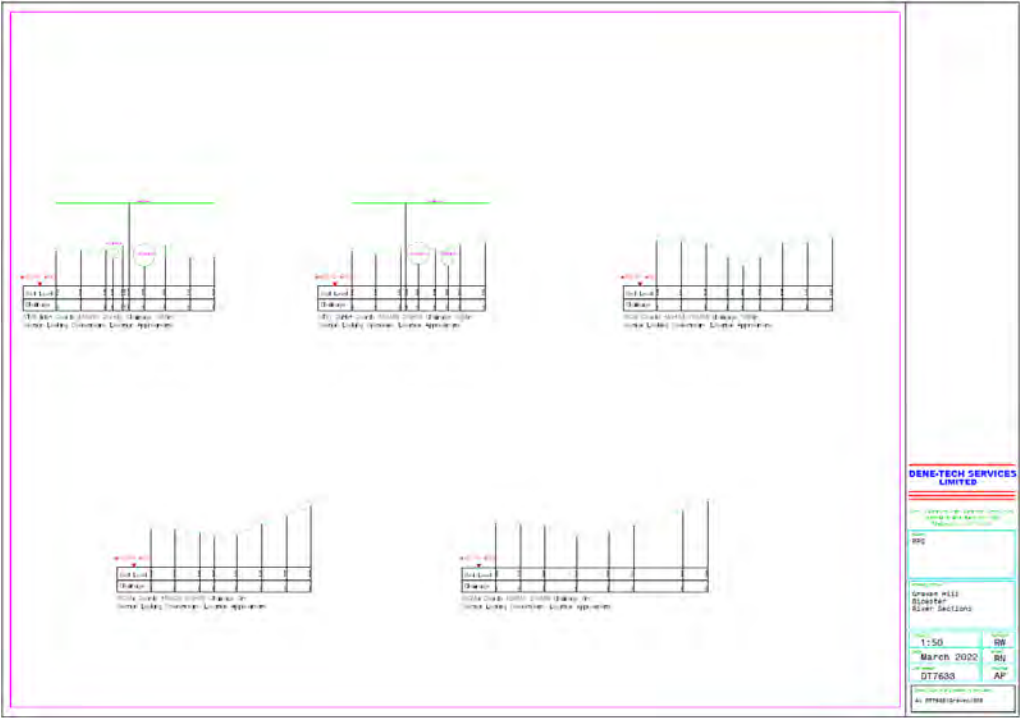
Pooling Group Composition (MOD Pooling)

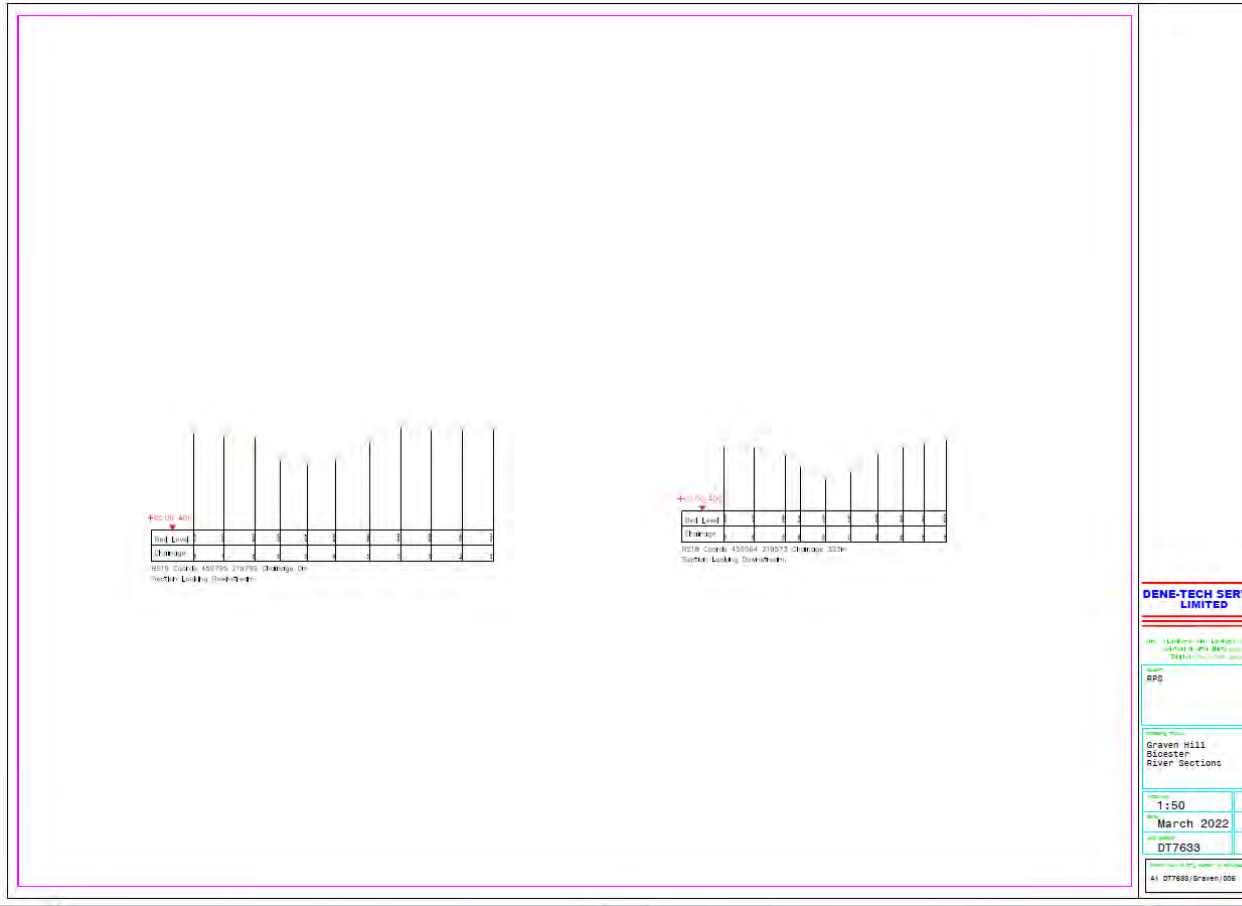
Site Number / Name	Distance	Initial Years of Data	QMED
76011 (Coal Burn @ Coalburn)	1.697	43	1.84
27073 (Brompton Beck @ Snainton Ings)	1.781	40	0.816
27051 (Crimple @ Burn Bridge)	1.968	48	4.544
26016 (Gypsy Race @ Kirby Grindalythe)	2.334	23	0.101
25019 (Leven @ Easby)	2.376	42	5.384
45816 (Haddeo @ Upton)	2.492	27	3.456
36010 (Bumpstead Brook @ Broad Green)	2.705	53	7.5
49005 (Bolingey Stream @ Bolingey Cocks Bridge)	2.721	10	5.972
27010 (Hodge Beck @ Bransdale Weir)	2.744	41	9.42
28033 (Dove @ Hollinsclough)	2.805	45	4.15
44008 (South Winterbourne @ Winterbourne Steepleton)	2.827	41	0.448
26014 (Water Forlornes @ Driffild)	2.862	22	0.431
41020 (Bevern Stream @ Clappers Bridge)	3.075	51	13.66
Total		544	

Appendix B Surveyed Section









DENE-TECH SER LIMITED

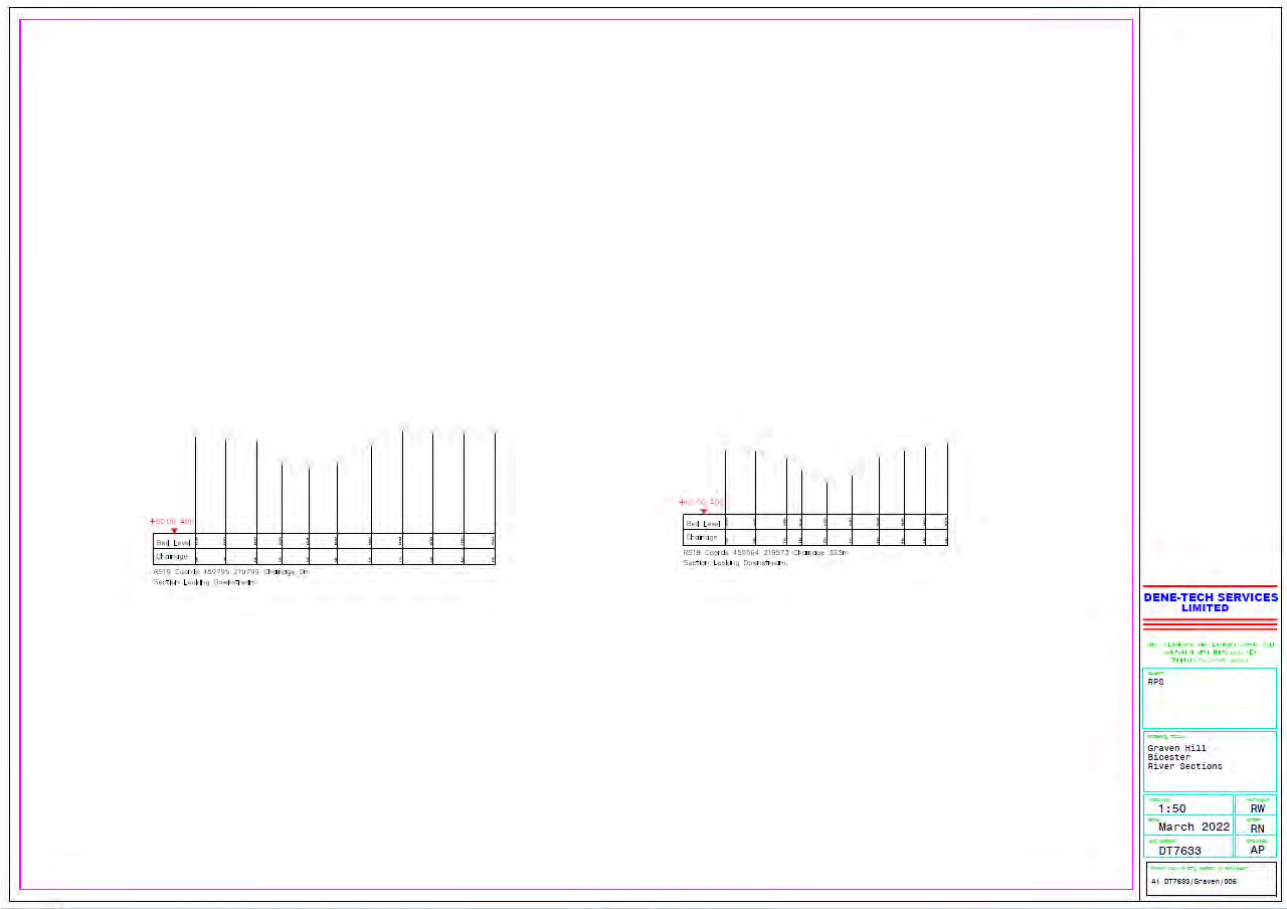
100, ALBERTA ST, LONDON, ONTARIO N6A 4A4
Tel: 519-837-1111 Fax: 519-837-1112

RPS

Graven Hill
Siloester
River sections

1:50
March 2022
DT7633

41 DT7633/Graven/008



Appendix C Photographs



Upstream Section of Drain



Section of Drain



Section upstream of twin culvert



Section 17 watercourse



Section Upstream railway culvert



Section Downstream railway culvert

Graven Hill, D1 Site, Bicester Outline Sustainable Drainage Systems (SuDS) Strategy

Prepared for

Graven Hill Purchaser Ltd

May 2022

Graven Hill, D1 Site, Bicester

Outline SuDS Strategy for Planning

1.0 Introduction

Outline planning permission was granted for a mixed-use development in August 2014 (ref: 11/01494/OUT) at the former Ministry of Defence-owned sites D1 and EL1 at Graven Hill, to the south of Bicester. The site is located on the southern side of Graven Hill and is identified for employment use in the consented outline application and proposals for development for B8 Storage or Distribution use are now being taken forward.

A new outline planning application is therefore being submitted in relation to the proposed development of the D1 and EL1 sites. Alan Baxter Ltd have been appointed by Graven Hill Purchaser Ltd to produce an outline Sustainable Drainage Systems (SuDS) strategy to support these proposals.

The outline SuDS strategy summarises the broad drainage arrangement on the existing site and sets out the key principles of the developing SuDS scheme. It has been informed by pre-application discussions with Oxfordshire County Council (OCC), who are the Lead Local Flood Authority (LLFA) for the area. See Appendix D for ABA's note recording this meeting.

2.0 Summary of Existing Site

The D1 and EL1 sites, OX26 6HF, cover an area of approximately 30.5 hectares on the southern side of Graven Hill (see Figures 01 and 02 in Appendix A for the site location). The site is bounded to the southwest by a railway embankment, to the west by woodland, to the north by Pioneer Road/Anniversary Avenue and the southeast by Wretchwick Farm.

The site was historically used by the Ministry of Defence (MOD) to store and distribute military equipment and contains five main warehouses, a number of smaller ancillary buildings, and a fire station. These buildings are linked by a number of private roads and railway lines. The existing buildings on site all date from 1941, apart from the fire station, which dates from the 1970's. Figure 03 in Appendix A shows the existing site plan.

2.1 Topography, Geology and Hydrology

Levels on the site vary from approximately 71m AOD along the northern boundary to 61.5m AOD in the south-eastern corner of the site, giving an average gradient of approximately 1:60. Although the site generally slopes gently, there are some local variations including the banks, cuttings and ditches relating to the existing railway lines. Graven Hill, which rises to approximately 115m AOD, is immediately to the north of the site. See Figure 04 for the existing site topography.

Geological maps and initial site investigations indicate that the site geology consists of made ground and topsoil over Oxford Clay. From nearby borehole logs, the bottom of the Oxford Clay strata appears to be approximately 20-30m below site ground level. Soakaway tests undertaken during the site investigation have confirmed that the underlying Oxford Clay has a very low permeability with no infiltration recorded at any of the test locations. See Appendix B for the site Ground Investigation report.

The topography and impermeable nature of the underlying soil means that in its natural condition, water falling on the site would likely have permeated through the topsoils and run south, following the contours of the hill, before eventually joining streams and ditches which drain into the River Ray (a tributary of the River Cherwell). There is a tributary to the River Ray which runs close to the south-eastern boundary of the site. This connects to the River Ray approximately 1 mile to the south of the site. See Figure 05 for the assumed existing site drainage.

Approximately 125,000 m² of building and roads have been constructed on the site since its development in the 1940's. These are understood to drain to the stream to the south of the site through a system of below ground pipes and ditches. It is not thought that any form of flow control or attenuation is incorporated into the existing site drainage.

Foul water drains via gravity to a Thames Water pumping station in the western part of the site. This pumps foul water through a rising main, which runs under the railway embankment south of the site and discharges to Bicester sewage treatment works, to the northwest of Graven Hill.

There are a number of sewers crossing the site, including a Thames Water foul sewer running along the site's eastern boundary, which is proposed to be partially diverted as part of the development of the site. All other live sewers and drains crossing the site are to be intercepted and diverted away from the site boundary by the current owner, the Graven Hill Village Development Company (GHVDC).

2.2 Theoretical Greenfield and Existing Brownfield Runoff Rates

The theoretical greenfield and existing runoff from site has been estimated to inform the developing SuDS strategy.

The theoretical greenfield runoff rates for the 1:1, 1:30, 1:100 and mean annual flood (Q_{BAR}) events were determined using the Flood Estimation Handbook (FEH) datasets on Microdrainage. See Table 1.

Storm Event	Greenfield Runoff Rate (l/s/ha)	Theoretical Site Greenfield Discharge Rates (l/s)
Q_1	2.8	85.4
Q_{BAR}	3.3	100.7
Q_{30}	7.6	231.8
Q_{100}	10.5	320.3

Table 1: Estimated Greenfield Runoff Rates

As noted in Section 2.1, the site was developed over the 20th Century and has an impermeable surface area of approximately 12.5 Ha. The discharge from these areas has been estimated based on constant rate rainfall intensities given by the Wallingford Procedure. The results are summarised in Table 2.

Storm Event	Rainfall Intensity (mm/h) 15 min Storm	Discharge Rate from Hardstanding Areas (l/s/ha)	Theoretical Discharge from Hardstanding Areas (l/s)
1:1	31.5	87.5	1093.8
1:30	77.3	214.7	2683.7
1:100	100.1	278.0	3475.0

Table 2: Estimated Discharge Rate from Hard Drained Areas

Total discharge from the site is therefore the combination of runoff generated from soft landscaped and impermeably surfaced areas, as summarised in Table 3.

The capacity of the existing site outflow pipe has also been assessed based on the available survey information. The pipe-full flow rate is approximately equal to the 1:1 year storm event, and it is therefore likely that discharge from the site is limited to this rate during more extreme events. Consequently, the positive impact of the proposed development on surface water runoff rates will be assessed against the pipe-full flow rate of 1140 l/s. See Appendix C for supporting calculations.

Storm Event	Discharge from Permeable Areas (l/s) (18 Ha Soft Areas)	Discharge from Impermeable Areas (l/s) (12.5 Ha Hard Area)	Discharge from Existing Site (l/s) (30.5 Ha Total Area)	Capacity of Existing Outflow Pipe (l/s) (675Ø pipe at 1:70 falls)
1:1	50.4	1093.8	1144.2	~1140
1:30	136.8	2683.7	2820.5	
1:100	189.0	3475.0	3664.0	

Table 3: Estimated Total Discharge Rate from Existing Site

3.0 Proposed Development

It is proposed to construct approximately 1.1 million sq. ft of internal floor space for B8 Storage or Distribution use, along with associated access roads, loading areas, infrastructure and tertiary buildings on the vacant brownfield site. The internal floorspace is proposed to be provided across nine separate units, as shown on the proposed site plan (Figure 06 in Appendix A).

The total site area is approximately 30.5 Ha. The proposed impermeable area of approximately 21.9 Ha comprises 10.4 Ha of roofed area and 11.5 Ha of impermeable paved area.

Due to the nature of the development, it has been agreed with the OCC during pre-application consultation that an Urban Creep allowance does not need to be included when considering the proposed impermeable areas, as discussed in Section 4.1.

4.0 Outline SuDS Strategy

4.1 Key Principles Agreed During Pre-Application Consultation

The design team met with OCC's Senior LLFA Engineer on 14/02/2022 to review the emerging proposals and agree the key principles of the strategy to be taken forward to outline planning.

The agreed principles are in part based on Waterman's 'Sustainable Drainage Design Code' ref. CIV15119 ES 001 Rev A01, which was included in the previously consented outline planning application, and have been revised to take account of the OCC's current requirements. The agreed principles are:

- Infiltration of surface water is not feasible. This has been verified by infiltration testing undertaken as part of the SI, which found the soil to be completely impermeable.
- Surface water discharged from the proposed site should be drained to the same location as existing. Sites D1 and EL1 should continue to drain southwards towards outfall 'SW4' which drains to a tributary of the River Ray.
- The discharge of surface water from the site should be limited to Q_{BAR} greenfield rate for all rainfall events up to the 1:100 + 40% climate change, unless this is shown to be unfeasible.
- In order to achieve these discharge rates during periods of heavy rainfall, on-site surface water attenuation will be required.
- Surface water attenuation should, wherever possible, be provided in the following SuDS features:
 - Swales and ditches
 - Filter drains and perforated pipes
 - Filter strips and rills
 - Open attenuation basins
- Where space is restricted such that the measures noted above are not practical, below-ground storage may be used to attenuate surface water runoff.
- Given the nature of the proposed development, an urban creep allowance does not need to be considered when determining the required volume of attenuation storage.

4.2 Proposed SuDS Strategy

The methods of discharging surface water runoff in Table 4 were considered during the development of this SuDS strategy.

Method of Discharge	Comments	Feasible
Infiltration	Site investigations have shown that the underlying soils are impermeable (see Appendix B). Concentrated methods of infiltration (e.g. soakaways) are therefore not feasible.	No
Open Watercourse	The existing site drains via the existing topography to an existing watercourse southeast of the site. It is therefore considered feasible that the proposed development can drain to the same location, as has been agreed with the LLFA during the pre-application process.	Yes
Surface Water Sewer	This method of discharge has not been considered, as it has been agreed with LLFA that the site should discharge as existing to an open watercourse.	N/A
Combined Sewer	This method of discharge has not been considered, as it has been agreed with LLFA that the site should discharge as existing to an open watercourse.	N/A

Table 4: Assessment of Surface Water Discharge Options

As noted in Section 4.1, the proposed development will continue to drain to the existing watercourses to the southeast of the site. In accordance with local planning requirements, the SuDS strategy will aim to limit the rate of discharge of surface water from the proposed hardstanding areas on site to as close as is practicable to the Q_{BAR} greenfield runoff rate for all rainfall events up to the 1:100 year (+40% climate change). Given a proposed site impermeable area of around 21.9 Ha, the target discharge rate for the impermeable areas will be 72.4 l/s.

Outline Microdrainage calculations indicate that in order to achieve this discharge rate for the 1:100 + 40% climate change rainfall event, a total of between around 16,000 and 22,500 m³ of attenuation storage could be required on the site (Appendix C).

Table 5 summarises the viability of different methods of attenuation that have been considered for the development.

Attenuation Type	Comments	Feasible
Rainwater Harvesting	Likely to be suitable for use in site irrigation.	Yes
Green Roofs	The type of building proposed in the development generally precludes the use of green roofs.	No
Permeable Paving & Porous Build-Ups	Due to known durability issues, permeable paving will be limited to low trafficked areas. Porous build-ups below impermeable paving may be used more widely where levels permit, with harder wearing impermeable surfacing. Any porous build-ups will be tanked (type 3) to prevent water softening the clay formation.	Yes
Below Ground Tanks & Oversized Pipes	The use of below ground attenuation to be limited to situations when storage cannot be provided in above ground basins.	Yes, but not preferred
Swales	To be used to convey flows between attenuation basins where possible.	Yes
Open Basins	Preferred method of attenuation. To provide the majority of attenuation storage on the site and to be designed to provide amenity benefits.	Yes

Table 5: Assessment of Surface Water Discharge Options

Figure 07 summarises the outline SuDS proposals for the site. The attenuation volumes shown are based on a high-level Microdrainage cascade model, which indicates that the total attenuation storage required is 19,970 m³. This model will be developed in greater detail at the next design stage. A train of SuDS features will be provided across the site. Permeable surfacing, small rain gardens and rainwater harvesting for irrigation will be provided where practicable throughout the development to act as source control.

Small basins, swales and areas of permeable paving/porous build-ups will act as local SuDS elements to each sub catchment. Where possible, the local swales and basins will be designed to provide amenity benefits as well as attenuation storage, and will be incorporated into the overall landscape design for the scheme. A residual uncertainty allowance (freeboard) will be provided to surface water storage feature, the details of which will be confirmed during the detailed design of the drainage network and site levels.

The outflow from each of these local SuDS features will be fitted with flow controls to restrict the outflows to the Q_{BAR} rate for the upstream catchment. Overflows will be provided to allow water that cannot be contained in each feature to drain to the next element of the train.

The final element of the SuDS train will be large landscaped basins in the south east corner of the site. The outline proposals allow for this to provide the majority of the site attenuation storage. A flow control on the outflow from this basin will restrict the discharge rate to Q_{BAR} for all rainfall events up to the 1:100 + 40% climate change event (72.4 l/s based on the outline masterplan).

The soft landscaped areas on the proposed site will continue to drain at greenfield rates with a Q_1 rate of 24.1 l/s and Q_{100} rate of 90.3 l/s (based on the approximately 8.6 Ha of soft landscaping in the proposed scheme).

As such, the overall proposed site discharge rate will be restricted to around 96.3 l/s for a 1:1 year rainfall event and 152.9 l/s for a 1:100 year rainfall event. As summarised in Table 6, this represents a reduction in discharge rate of 91% for the 1:1 year event and 87% for the 1:100 year event when compared to the existing conditions, contributing to a reduction of flood risk downstream of site.

Rainfall Event	Current Discharge (l/s)	Proposed Discharge (l/s)	Reduction
1:1	~1140	96.3	~91%
1:100	~1140	162.6	~86%

Table 6: Assessment of Discharge Reduction

4.3 Maintenance and Adoption of SuDS Features

A surface water drainage maintenance strategy will be developed to safeguard the long-term performance of the drainage infrastructure on site. It is assumed that this will be through establishing an estate management company, whose responsibilities would include the inspection and maintenance of the site's drainage infrastructure, along with the site roads, which are to remain private.

4.4 Phasing

The proposed development of the site will take place in several stages, and surface water drainage will be considered throughout. Firstly, the existing buildings, roads, railways and hardstanding will be demolished, with the demolition arisings to be cleaned, graded and stored on site for later reuse. Clearing the site will significantly reduce the area of hardstanding, which will in turn result in reduced surface water runoff rates during the demolition phase.

The site will then be graded to suit the proposed levels arrangement. This grading will include forming the various attenuation basins as well as the swales, ditches and pipes which will link the various landscaped attenuation basins. The drainage system will therefore be installed prior to the construction of any new impermeable surfaces. The site services and roads will then be constructed before the individual development plots are built out in stages, until the completed scheme is fully constructed.

4.5 Exceedance

Although the surface water drainage infrastructure will be designed to contain rainwater for storms up to the 1:100 + 40% climate change event, there is a residual risk that surface water runoff could overtop the system and result in overland exceedance flows in a more extreme event. This could be caused by exceptionally high rainfall levels or unexpected flows from upstream catchments.

The exceedance strategy for the proposed development aims to limit the risk of flooding to the buildings on the site in the event of the drainage infrastructure being overwhelmed. In an exceedance event, runoff will follow the site topography and flow to the south east and the proposed site outfall. Flows will be directed to the various basins, and away from the building entrances to reduce the risk to people and property. Figure 08 sets out the outline exceedance strategy for the site, which will be further developed at detailed design stage to confirm the on-site routes.

4.6 Effect of Flood Events Downstream of Site on the Drainage System

4.6.1 Drainage System Invert Level

It is proposed that the attenuated runoff from the site will discharge immediately upstream of the culverted section of the Ray tributary which passes under the railway embankment.

Initial modelling from the project's flood risk consultant (RPS Group) suggests that the water level in the channel upstream of the culvert may rise above the top of bank level during extreme events (refer to RPS' Flood Risk Assessment for more details). To reduce the risk of the site discharge from being locked during flood events, the system invert level has been set at the channel's top of bank level, as advised by RPS. This level is 61.72m AOD, i.e. approximately level with the soffit of the existing culvert.

4.6.2 Potential for Site Discharge to be Blocked & Effect on Attenuation Volumes

1D modelling suggests that the water level in the channel may rise above 61.72m AOD for up to 6 hours during the most extreme events. Flooding at this level would effect the ability of the site to discharge, and would require the SuDS scheme to provide additional storage to account for the time the outfall is locked. Initial calculations show approximately 1,600m³ of additional attenuation may be required.

Where additional storage is required, it could be provided by increasing the depth and extent of the attenuation basins, or by installing porous build-ups more widely across the site. See Figure 09 for areas where further storage could be provided. This comprises approximately 6,700 m² of basin and 13,700 m² of porous build-ups, and are therefore sufficient to provide the additional attenuation that may be necessary.

However, it has been noted that the 1D modelling does not accurately reflect the behaviour of the flood level once it rises above the bank full level, and that the real flood level will be significantly lower than the level they have modelled. Additional 2D modelling is required to accurately determine the height and extent of flooding over time, and to confirm whether flooding downstream of site will require the SuDS strategy to provide additional attenuation. This modelling will be undertaken by the flood risk consultant at the next design stage.

5.0 Outline Foul Drainage Strategy

A new foul drainage system will be constructed to convey the site's foul runoff under gravity to the existing Thames Water pumping station, from which it will be pumped to Bicester sewage treatment works. A Thames Water foul sewer crosses adjacent to the site's eastern boundary, and it is proposed to divert this sewer to fit the layout of the proposed development. Additionally, a short run of Thames Water sewer which is being made redundant by the works will be abandoned.

All other private live sewers and drains crossing the site are currently being intercepted and diverted away from the site boundary by the Graven Hill Village Development Company (GHVDC).

Based on a previously submitted Impact Assessment undertaken by Thames Water (Appendix D), it is understood that no off-site capacity upgrades will be required to accommodate the proposed development.

6.0 Summary

It is proposed to develop the D1 and EL1 sites at Graven Hill, Bicester for B8 Storage or Distribution use. This will comprise several warehouse units and associated infrastructure and landscaping. A surface water drainage strategy has been developed for the proposed re-development of the site, based on the principles agreed with LLFA during pre-application consultation.

The development will limit the rate surface water discharge to Q_{BAR} for rainfall events up to the 1:100 year plus 40% climate change. This will significantly reduce surface water runoff from the site during extreme events, reducing the risk of flooding downstream.

Open attenuation basins will provide the majority of surface water storage on the site, and a number of source control features such as rainwater harvesting, swales, permeable paving and porous build-ups will provide additional storage as well as water quality benefits. The open basins will be designed to provide amenity and biodiversity benefits, which will be considered in more detail post-planning.

Prepared by David Bowles and Rory McColl
Reviewed by Olivier Fernandez
Issued April 2022

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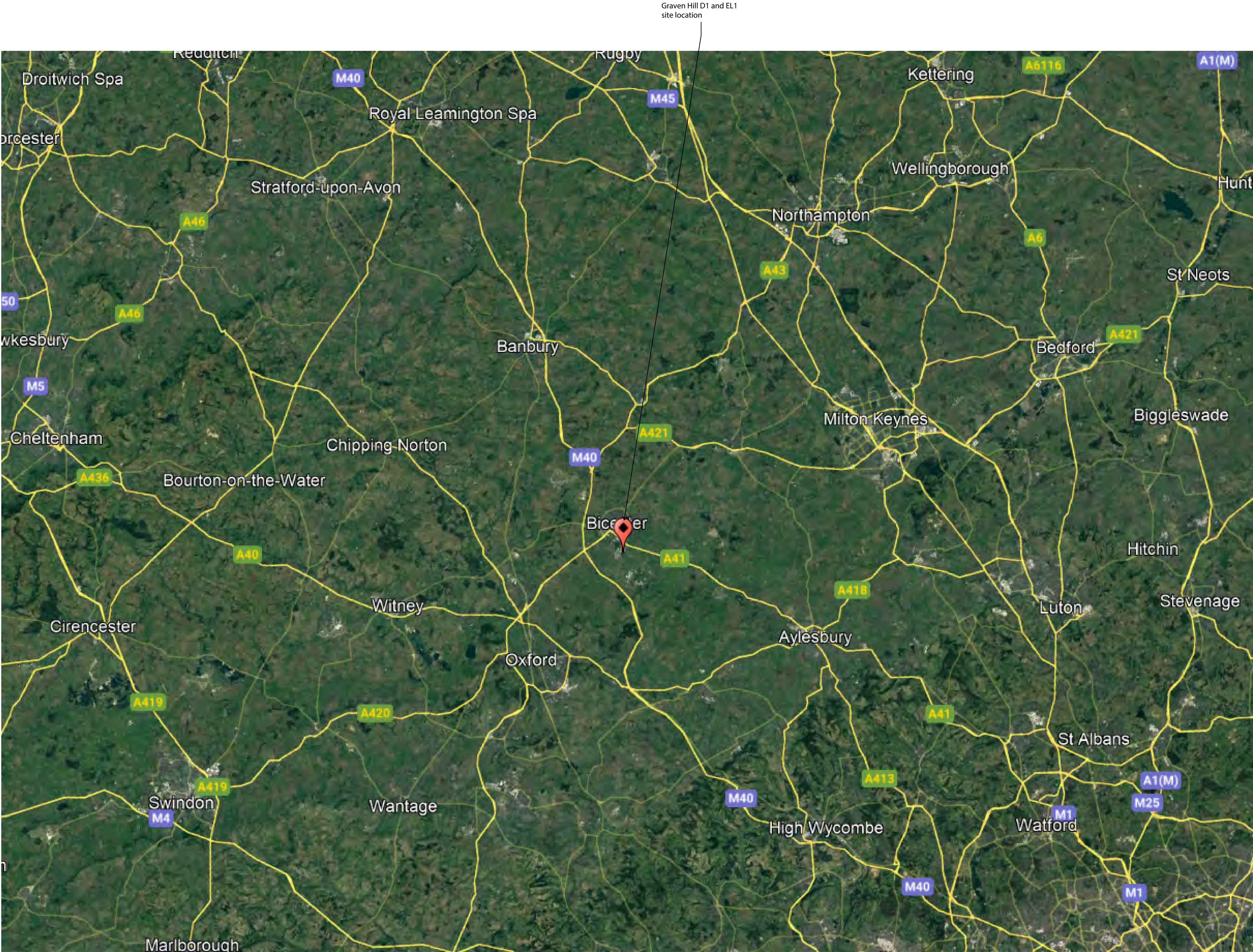
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Appendix A

Figures



- notes
1. This drawing is to be read in conjunction with all relevant Architect's and Engineer's drawings and the specification.

A	17.05.22	ISSUED FOR PLANNING.	RM
-	21.04.22	ISSUED FOR INFORMATION.	-

Job
**GRAVEN HILL SITE D1,
BICESTER**

Title
**FIGURE 01 -
SITE LOCATION PLAN**

drawn	checked
RM	-
date	scale (original - A1)
APR '22	NTS

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