JBA consulting

Flood Risk Assessment

Deal Ground, Norwich

Final (S3-P05)

June 2023

Prepared for:

Serruys Property Company Ltd

www.jbaconsulting.com

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This report describes work commissioned by Serruys Property Company Limited by an instruction dated 22 August 2022. The Client's representative for the contract was Akis Chrisovelides of Serruys Property Company Limited . Gavin Hodson, Stuart Harwood and Peter Barber of JBA Consulting carried out this work.

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- Serruys Property Company Limited
- Stolon Studio
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- Environment Agency

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Abbreviations

BGS..........................British Geological Survey
CC............................Climate Change
CSO ....Combined Sewer Overflow
DEFRA......................Department for Environment, Food & Rural Affairs
EA ....Environment Agency
FMfP.........................Flood Map for Planning
FRA..........................Flood Risk Assessment
FZ.............................Flood Zone
IH124........................Institute of Hydrology Report 124
JBA...........................Jeremy Benn Associates Ltd
LiDAR.......................Light Detection and Ranging
mAOD ....metres Above Ordnance Datum
NGR ....National Grid Reference
NPPF........................National Planning Policy Framework
OS............................Ordnance Survey
PPG..........................Planning Practice Guidance
RRMfD ....Rainfall Runoff Method for Development
SAAR ....Standard Average Annual Rainfall
SFRA........................Strategic Flood Risk Assessment
SuDS........................Sustainable Drainage Systems

Definitions

1. Functional Floodplain: The land where water has to flow or be stored in times of flood.
2. Net zero: The balance between the amount of greenhouse gas produced and the amount removed from the atmosphere.

Return period and AEP conversion.

Years	%AEP	Years	%AEP	Years	%AEP
2	50	30	3.3	200	0.5
5	20	50	2	500	0.2
10	10	75	1.33	1,000	0.1
20	5	100	1		

1 Introduction

1.1 Overview

This Flood Risk Assessment (FRA) has been developed to support the discharge of Planning Conditions and Reserved Matters for the site known as Deal Ground and May Gurney in East Norwich (planning application references: 12/00875/O for Norwich City Council and 2011/0152/O for South Norfolk Council).

This document has been prepared in accordance with latest planning policy, the National Planning Policy Framework (NPPF) and associated Planning Practice Guidance (PPG) and uses site-specific hydraulic modelling and hydrological estimation to assess flood risk at the site.

The site was granted outline planning permission for mixed-use development in 2013. The application was supported by an FRA prepared by Total Flood Solutions Limited and DBR Associates Limited (November 2010). This FRA built on previous work undertaken by JBA in 2008 in terms of hydraulic modelling of the site and wider Norwich area. This (2023) assessment builds upon the previously approved FRA and the associated design principles and assesses the impact of updated development proposals, considering the policy and guidance published since the original outline application.

1.2 Site location and description

The site is located to the east of Norwich adjacent to the confluence of the River Wensum and River Yare. The site lies within 1.5 km of the City Centre and is 1km from Norwich Railway Station. The site is located within two local authority districts (Figure 1-1) Norwich City Council and, South Norfolk Council. The Broads Authority is located immediately downstream of the site.

Table 1-1: Site Description

	Description
Size	12.13ha
North	The River Wensum boarders the northern perimeter of the site. Over the river lies a proposed development site known as the 'Utilities Site' which forms part of the East Norwich Strategic Regeneration Area.
South	The site borders on to the public highway known as Bracondale, which provides access over the River Yare from Norwich City to the village of Trowse Newton
East	To the east the site is bordered by the River Yare and County Wildlife Site (primarily fenland). Further is Whitingham Country Park which consists of two large water bodies.

	Description
West	A coated roadstone processing plant is located along the western boundary of the site. An underpass provides possible, future connectivity to the Carrow Works site.
Current land use	The site is currently a mixture of green and brownfield land consisting of demolished warehouses and former construction company headquarters.
Land use history	Previous land uses include timber yard/sawmills, factory printworks, bottle factory and historical mining and infilling. Most recently any buildings within the Deal Ground element of the site have been demolished and the May Gurney component consists of dilapidated buildings.
Access arrangements	Both parts of the site are accessed off Bracondale. May Gurney through the existing highway junction and the remainder of the site is accessed via an access track off Bracondale which travels along the side of the processing plant to the Carrow Yacht Club situated to the north east of the site.

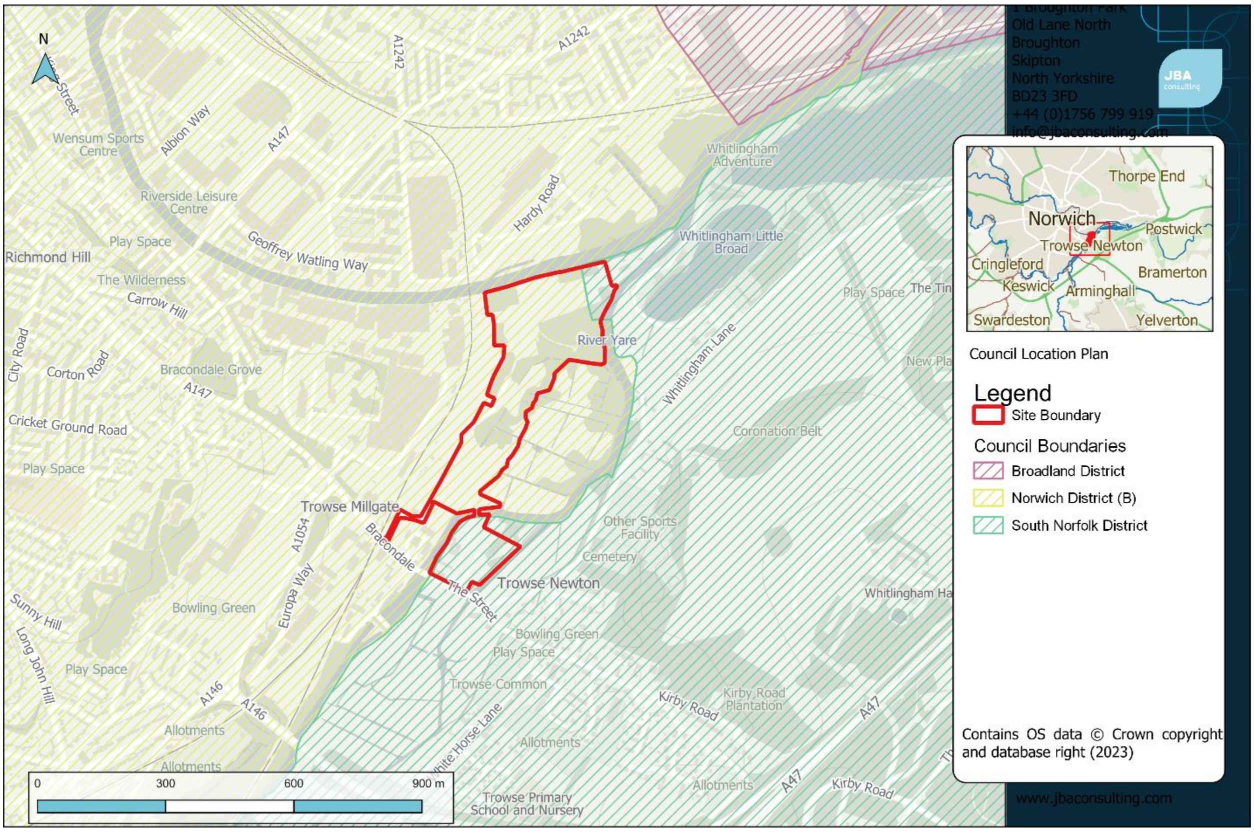

Figure 1-1: Location and administrative boundary plan

1.3 Proposed development

1.3.1 2013 Proposed development

The 2013 proposed development consisted of 317 houses and 365 apartments with shops, restaurant and bars with an access road and associated car parking. The 2013 Application set out the following concepts:

"A landscape led development, in which the conventional boundaries between dwellings and nature are blurred forming a transitional urban area as a soft feathered edge to the City which aims to locate development in the areas of least flood risk and to create a visual buffer to the railway line, extend the marsh between development to create a multi-functional landscape that can provide flood storage, ecological enhancement and semi-public space create a series of new neighborhoods each with its own unique identity and a place where people live and play next door to nature."

A drawing for reference is provided in Appendix A.

1.3.2 2023 Proposed development

The proposed development comprises of three distinct areas. The names of these areas will be used moving forward in this report to aid with clarity of description (Table 1-2).

Detailed plans of the proposed development are provided in Appendix A.

Table 1-2: Proposed development - Description

Area	Description
Overall (Lifespan)	The site is to consist of a mixture of residential and commercial development and therefore it is assumed a lifespan of at least 100-years.
Wensum Edge	Characterised by taller buildings, public spaces and distinct river frontage. The Wensum Edge is the focal point of the development containing a public square complete with commercial units for dining and shopping.
The Views	A village edge, with a mix of dwellings arranged in mews streets and close type streets. The building line is interspersed by nature corridors reducing the visual prominence
Yare Edge	A village character with low buildings in close knit arrangements. A mix of terraces, semi-detached and detached homes providing shared gardens to create a more spacious arrangement.

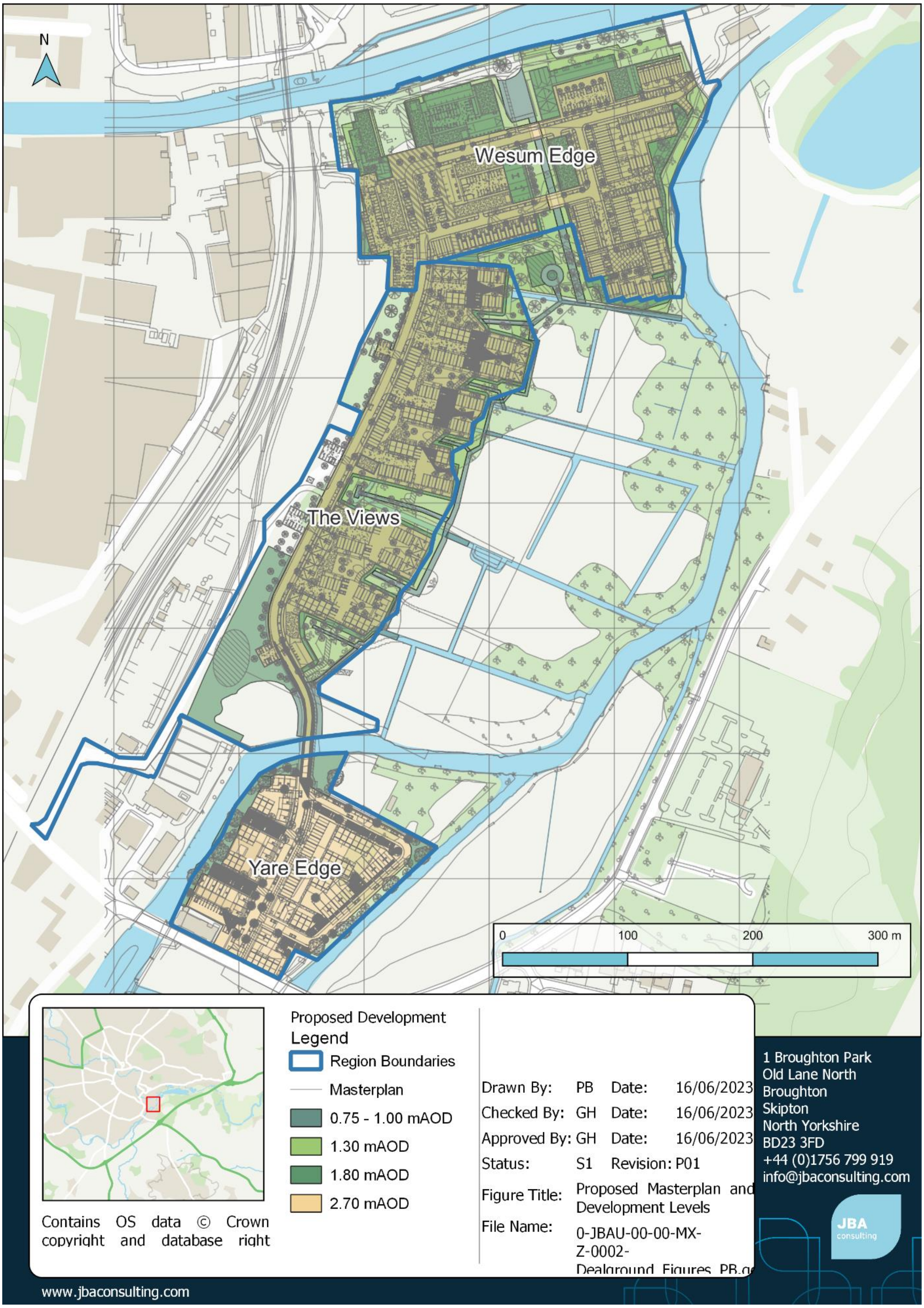

Figure 1-2: 2023 Masterplan

1.4 Flood risk management design principles

As noted above, the site benefits from outline planning permission (2013) for a mixed-use development comprising up to 670 dwellings, commercial uses and associated infrastructure. The application was supported by an FRA prepared by Total Flood Solutions Limited and DBR Associates Limited (November 2010). JBA were involved as Flood Risk advisors on the site, since 2008. The flood risk management design principles set out in the 2010 document included:

1. Maintaining and making space for flood flow pathways (i.e. between the River Yare and River Wensum);
2. Application of the sequential approach to site master planning;
3. Ground raising within Flood Zones 2, 3a and 3b to provide development platforms above the design flood level;
4. Provision of level-for-level floodplain storage compensation to mitigate the impacts of ground raising within the floodplain;
5. Raised floor levels, including a minimum freeboard of 300mm above the design flood level;
6. Elevated building floor slabs (i.e. allowing floodwater to enter the void beneath);
7. Flood resilient construction;
8. Provision of safe access/egress, dry vehicular access and dry refuge within buildings;
9. Car-parking areas elevated above the design flood level, including the use of geo-cellular systems that enable floodwater to pass beneath the finished car-park surface;
10. Vehicles moved off site should an extreme (0.1% probability) flood event be forecast;
11. Implementation of a flood warning and evacuation plan;
12. Incorporation of SuDS to manage the quantity and quality of surface water run-off arising from the development (post-development rate of run-off reduced by 30% compared to the pre-development rate and storage provided using below ground tanks with pumped outflows to the River Yare and River Wensum).

This (2023) assessment builds upon these established flood risk management design principles and, where practicable, sets out an improved design concept.

1.5 Planning conditions - Flood risk

Five conditions relating to flood risk and surface water drainage accompanied the outline consent for the site in 2013. This document aims to provide an evidence base to discharge the conditions set out in the 2013 outline planning permission. Specifically, conditions 2, 10, 30, 31, 32 and 33 for Norwich City Council and conditions 3, 7, 23, 24 and 25 for South Norfolk Council (full wording is provided in Appendix B). In summary, the conditions are linked to the following:

- Flood risk related to development phasing and associated hydraulic structures such as bridges and culverts
- Off-site impacts and mitigation strategy
- Management of surface water flows
- Finished floor levels and flood resilient design.
- Sustainable drainage systems

2 Planning policy and strategic context

2.1 National Policy

2.1.1 National Planning Policy Framework

The NPPF, as revised 20th July 2021, sets out national planning policy with regards to development and flood risk. The accompanying PPG ‘Flood Risk and Coastal Change’ (discussed below) provides local planning authorities with guidance on implementation of the planning policy as set out in the NPPF.

The NPPF (Paragraphs 161-163) advocates use of the risk-based, sequential approach (which recognises that risk is a function of probability and consequence), in which new development is preferentially steered towards areas at the lowest probability of flooding. It also requires that new development should be planned to avoid increased vulnerability to the range of impacts arising from climate change. In respect of flood risk, paragraph 159 states that:

“Inappropriate development in areas at risk of flooding should be avoided by directing development away from areas at highest risk (whether existing or future). Where development is necessary in such areas, the development should be made safe for its lifetime without increasing flood risk elsewhere”.

The overall approach of the NPPF to flood risk is summarised in paragraph 167 of the document:

When determining any planning applications, local planning authorities should ensure that flood risk is not increased elsewhere. Where appropriate, applications should be supported by a site-specific flood-risk assessment. Development should only be allowed in areas at risk of flooding where, in the light of this assessment (and the sequential and exception tests, as applicable) it can be demonstrated that:

within the site, the most vulnerable development is located in areas of lowest flood risk, unless there are overriding reasons to prefer a different location;

the development is appropriately flood resistant and resilient such that, in the event of a flood, it could be quickly brought back into use without significant refurbishment;

it incorporates sustainable drainage systems, unless there is clear evidence that this would be inappropriate;

any residual risk can be safely managed; and

safe access and escape routes are included where appropriate, as part of an agreed emergency plan

2.1.2 Planning Practice Guidance

The PPG (Ministry of Housing, Communities and Local Government, 25th August 2022) defines the Flood Zones that provide the basis for spatial planning. The Flood Zones are defined as follows (PPG Table 1 Paragraph: 078 Reference ID: 7-078-20220825):

- Flood Zone 1: Low probability of flooding - less than 0.1% (1 in 1,000) annual probability of river or sea flooding in any year;
- Flood Zone 2: Medium probability of flooding - between 1% and 0.1% (1 in 100 and 1 in 1,000) annual probability of river flooding and between 0.5% and 0.1% (1 in 200 and 1 in 1,000) annual probability of sea flooding in any year;
- Flood Zone 3a: High probability of flooding - 1% (1 in 100) or greater annual probability of river flooding or 0.5% (1 in 200) or greater annual probability of sea flooding in any year; and
- Flood Zone 3b: The functional floodplain - where water from rivers or the sea has to flow or be stored in times of flood. The functional floodplain will normally comprise land having a 3.3% or greater annual probability of flooding, with any existing flood risk management infrastructure operating effectively; or land that is designed to flood (such as a flood attenuation scheme), even if it would only flood in more extreme events (such as 0.1% annual probability of flooding).

It should be noted that Flood Zones 1, 2 and 3a definitions ignore the presence of flood defences.

The 'Flood Risk and Coastal Change' PPG advocates the use of SuDS to reduce the overall level of flood risk. SuDS can reduce the causes and impacts of flooding, remove pollutants from urban run-off at source and combine water management with green space providing benefits for amenity, recreation and wildlife.

The NPPF (Paragraphs 153 and 154) and the 'Flood Risk and Coastal Change' PPG require that the spatial planning process should consider the possible impacts of climate change and contingency allowances are provided to enable impacts to be considered over the lifetime of the development.

2.1.3 Requirements for a Flood Risk Assessment

The requirements for an FRA are provided in the NPPF and associated PPG. The NPPF outlines that a site-specific FRA should be submitted as part of a planning application for all developments larger than 1 hectare in Flood Zone 1 or any sized development within Flood Zones 2 and 3 on the EA's Flood Map for Planning (FMfP). In this instance, the site lies within Flood Zone 1, 2 and 3 and as such, requires an FRA.

Paragraph 159 of the NPPF states that: "Inappropriate development in areas at risk of flooding should be avoided by directing development away from areas at highest risk (whether existing or future). Where development is necessary in such areas, the development should be made safe for its lifetime without increasing flood risk elsewhere".

FRAs should describe and assess all sources of flood risk to, and from, the development and demonstrate how they will be managed, including consideration of the potential impacts of climate change (CC).

2.1.4 Sequential and exception tests

Paragraph 161 of the NPPF requires that the sequential approach is applied to steer new development to areas with the lowest risk of flooding.

Policy R9 of the Norwich Local Plan (adopted December 2014) identifies Deal Ground as a strategic regeneration site in east Norwich and allocates the site for a residential-led, mixed use development.

Paragraph 166 of the NPPF states: 'Where planning applications come forward on sites allocated in the development plan through the sequential test, applicants need not apply the sequential test again.'

The Local Planning Authority has identified the site as suitable for development, the site selection process was informed by an evidence base comprising a Strategic Flood Risk Assessment and Outline planning permission was granted in 2013. It is not therefore necessary to apply the Sequential Test.

2.2 Local Policy

2.2.1 Joint Core Strategy (JCS) for Broadland, Norwich and South Norfolk

The JCS was prepared by Broadland, Norwich and South Norfolk Councils working with Norfolk County Council as the Greater Norwich Development Partnership. The Strategy was adopted in March 2011 and subsequent amendments adopted in January 2014.

The JCS comprises a 'high level' strategy and provides the framework for the development of each council's Development Plan. By identifying broad locations for growth and defining strategic policies, the Strategy sets out the long-term vision and objectives for the area.

Relevant area-wide policies include:

Policy 1 - addressing climate change and protecting environmental assets

Requires that development (i) is located to minimise flood risk, mitigating any such risk through design and implementing sustainable drainage, and (ii) minimises water use and protects groundwater sources.

Policy 2 - promoting good design

Requires that development is designed to avoid harmful impacts on key environmental assets and, in particular SACs, SPAs and Ramsar sites.

Policy 3 - energy and water

Requires that sufficient water infrastructure is in place to meet the demands of new development and that water quality is protected or improved. This includes improvements at the Whitlingham wastewater treatment works.

2.2.2 Norwich Local Plan

The development plan for Norwich comprises the Site Allocations Plan and the Development Management Policies Plan. The Site Allocations Plan sets out the spatial planning framework for Norwich to 2026. Policy R9 identifies 'The Deal Ground, Trowse', as an allocation for a major residential-led, mixed use development as part of the regeneration of the eastern fringe of Norwich. Policy R9 requires that development will:

be planned as an exemplar development providing for flood resilience including addressing identified risks from fluvial and surface water flooding, providing for sustainable drainage

The Development Management Policies Plan sets out local standards and criteria against which planning applications for the development and use of land and buildings will be assessed. The policies relevant to this FRA are summarised as follows:

Policy DM1 - achieving and delivering sustainable development

Sets out the development principles for Norwich and requires that development proposals combat the effects of climate change.

Policy DM5 - planning effectively for flood resilience

This policy requires that all sources of flooding are considered and that development proposals are supported by an FRA prepared in accordance with the NPPF. It also requires that Sustainable Drainage measures (SuDS) are used to manage surface water run-off arising from development and, where possible and practicable, reduce flood risk within the surrounding area.

Policy DM6 - protecting and enhancing the natural environment

Requires that development proposals take all reasonable opportunities to avoid harm to and protect and enhance the natural environment, taking particular account of the need to avoid harm to the adjoining Broads Authority Area.

Policy DM11 - protecting against environmental hazards

This policy requires that proposals falling within designated groundwater source protection zones incorporate mitigation measures to mitigate the risk of pollution of the water source.

2.2.3 South Norfolk Local Plan

The Local Plan comprises the Site Specific Allocations and Policies Document and Development Management Policies Document. Guided by the Joint Core Strategy, it designates areas of land to deliver housing, employment, recreation, open spaces and community uses. Together with the other documents that make up the Development Plan it is used to assess planning applications and guide development proposals. The documents were formally adopted on 26 October 2015 and cover the period up to 2026.

The Site Specific Allocations and Policies Document identifies the former May Gurney site as a 'committed site' (reference 2011/0152). The Development Management Policies Document is used 'to help determine how the Council carries out its development management responsibilities to promote sustainable development and how it will determine all planning applications'. The policies are framed around three 'dimensions' (economic, social and environmental) and those relevant to this FRA are summarised as follows:

Policy DM 1.3 - the sustainable location of new development

Requires that new development is located so that it contributes to sustainable development and is located on allocated sites or within the development boundaries of settlements.

Policy DM 4.2 - sustainable drainage and water management

Requires that SuDS are incorporated within development proposals, that they contribute to amenity and biodiversity and that measures are included to manage water quality.

Policy DM 4.4 - natural environmental assets - designated and locally important open space

Requires that development contributes to the improvement of natural environmental assets, including opportunities for establishing biodiversity enhancement areas and multi-functional green infrastructure networks.

2.2.4 Greater Norwich Local Plan (GNLP)

Norwich City Council is working with Broadland District Council and South Norfolk Council to develop a joint strategic plan (the GNLP) for the period to 2038. The GNLP identifies the strategy for growth, the sites to deliver growth and will be used to assess planning applications. When adopted, the GNLP will replace the local plans in each of the three districts.

A pre-submission draft plan was published in February/March 2021 and includes the following:

Policy 2 (sustainable communities), which requires that:

flood risk should be minimised, including avoiding inappropriate development in areas at significant risk of flooding, reducing the causes and impacts of flooding, supporting a catchment approach to water management and using sustainable drainage.

development must protect water quality, both surface and groundwater.

Policy 7 (strategy for areas of growth) identifies the East Norwich Strategic Regeneration Area (ENSRA), which includes Deal Ground and May Gurney, as a key area of future growth and requires that it includes:

flood resilient design which addresses identified risks from river and surface water flooding

As part of the development of the GNLP, a draft Supplementary Planning Document (May 2022) has been prepared to provide planning and design guidance for the ENSRA and provide a framework for the preparation and assessment of future planning applications. This identifies measures to manage flood risk, including raising ground levels above the design flood level and providing floodplain storage compensation to mitigate the impacts of ground raising in the floodplain (this being the design approach set out in the FRA (2010) prepared in support of the outline planning application).

2.3 Flood Risk Evidence Base Studies

2.3.1 Greater Norwich Area Strategic Flood Risk Assessment (SFRA) - Level 1 (November 2017)

The Level 1 SFRA was prepared to support decision-making on local plan site allocations and support the determination of planning applications across the Broadland District, Norwich City and South Norfolk Council areas.

The study was based upon a combination of Environment Agency flood maps (tidal, fluvial, reservoir and surface water), data derived from hydraulic models, the Areas Susceptible to Groundwater Flooding dataset and historic flood data.

The SFRA flood mapping indicates that the County Wildlife Site is located almost entirely within Flood Zone 3 (High Probability). However, that part of Deal Ground identified for development (i.e. outside the CWS) falls largely within Flood Zone 1 (Low Probability) and Flood Zone 2 (Medium Probability), with limited areas within the northern area of Deal Ground adjacent to the River Wensum located in Flood Zone 3.

The former May Gurney site is shown to be unaffected by Flood Zone 3 and comprises areas within Flood Zones 1 and 2.

2.3.2 Greater Norwich Level 2 Strategic Flood Risk Assessment (SFRA) (February 2021)

The Level 2 SFRA was undertaken to support application of the NPPF Exception Test, considered 26 proposed development sites and included flood risk data published following completion of the Level 1 study.

A detailed summary table is presented for each site (including the Deal Ground and May Gurney site - site reference GNLP0360), setting out the nature of risk associated with all sources of flooding, the potential implications of climate change and the opportunities for SuDS measures to manage surface water run-off. A copy of the summary table is included within Appendix C of this FRA and indicates that 38% of the site lies within Flood Zone 1, 62% lies within Flood Zone 2 and 44% lies within Flood Zone 3 (noting that the figure quoted for Flood Zone 2 includes the area within Flood Zone 3).

In terms of surface water flood risk, the summary table indicates that only very limited and localised areas (comprising 4% of the site) are affected by flooding. The study refers to the Areas Susceptible to Groundwater Flooding dataset and notes that:

The majority of the site has a >75% susceptibility to groundwater flood emergence from superficial deposits; and

The southern part of the site has a >50% to <75% susceptibility to groundwater flood emergence from superficial deposits

The SFRA notes that Environment Agency records show the site to have been affected by flooding in 1912.

The SFRA concludes that development of the Deal Ground and May Gurney site is likely to be feasible, subject to, inter alia '…integrated flood resilient and sustainable drainage design…with habitable floor levels above the fluvial design flood event taking into account climate change', consideration of safe access and egress during flood conditions and a flood warning and evacuation plan being prepared.

2.3.3 Greater Norwich Water Cycle Study (March 2021)

The study reviews planned future growth within the context of water supply capacity, wastewater treatment capacity, water quality, flood risk, surface water drainage and aquatic ecology and identifies the water services infrastructure required to support growth.

In respect of flood risk, the study refers to Environment Agency flood mapping at https://flood-map-for-planning.service.gov.uk/ and https://check-long-term-flood-risk.service.gov.uk/. For the Deal Ground and May Gurney site (site reference

GNLP0360), the study notes that 37% of the site lies within Flood Zone 1, 20% within Flood Zone 2 and 43% within Flood Zone 3 and that 4% of the site is at a low risk of surface water flooding.

In terms of surface water management, the study recommends that SuDS are implemented as part of new development to reduce run-off rates to as close to greenfield rates as possible.

2.4 Climate change

This FRA will consider an allowance for climate change to help provide resilience to flooding and minimise the vulnerability of the development now and into the future. All climate change values used in this FRA have been taken from the EA Guidance titled Flood Risk Assessments: Climate Change Allowances (February 2016 updated May 2022) at www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances.

2.4.1 Climate change - Tidal

The tidal climate change allowances for the Anglian Region are provided in Table 2-1. Although the full effect of sea level rise will not be felt at the site due to its inland location, sea level rise will still impact future flood risk in Norwich. Therefore, an assessment of tidal flood risk in isolation and coupled with fluvial flood risk has been undertaken as part of this study.

Table 2-1: Climate Change - Tidal Allowances

Allowance	2000 to 2035 (mm)	2036 to 2065 (mm)	2066 to 2095 (mm)	2096 to 2125 (mm)	Cumulative rise 2000 to 2125 (metres)
Higher central	5.8 (203)	8.7 (261)	11.6 (348)	13 (390)	**1.20**
Upper end	7 (245)	11.3 (339)	15.8 (474)	18.1 (543)	1.60

2.4.2 Climate change - Fluvial

Table 2-2 indicates the recommended peak river flow uplifts for climate change for the Broadland Rivers Management Catchment. In accordance with current EA guidance on considering climate change in FRAs, the central allowance (11%) should be used for proposed developments classed as More Vulnerable in Flood Zone 3a.

In is worth noting that these values differ to those used in the Greater Norwich SFRA. This difference has arisen because the EA climate change guidance for Flood Risk Assessments was revised following completion of the SFRA. For this assessment the most up to date values have been used.

Table 2-2: Climate Change - Fluvial allowances

Allowance category	Total potential change anticipated for '2020s'	Total potential change anticipated for '2050s'	Total potential change anticipated for '2080s'
Central	8%	3%	**11%**
Higher	14%	10%	20%
Upper	27%	27%	44%

2.4.3 Climate change - Rainfall

Norwich lies within the Broadland Rivers Management Catchment and the rainfall allowances for the region are shown in Table 2-5. The rainfall allowances, unlike the fluvial allowances, are split into the 3.3% AEP and 1.0% AEP events. The 1% AEP rainfall allowance shows a reduction in the climate change allowance between the 2050s and 2070s epoch, which is caused by rounding in the calculation of the allowances. Despite the lower 2070s allowance, the conservative 45% will be used, as confirmed by the LLFA.

Table 2-3: Climate change - Rainfall Allowances

Epoch	Central	Upper End
3.3%AEP		
2050s	20%	40%
2070s	20%	40%
1%AEP		
2050s	20%	**45%**
2070s	20%	40%

3 Baseline environmental conditions

3.1 Current land use

The site consists of the following current land uses (Figure 3-1):

- To the north along the River Wensum a series of former warehouses/factory buildings which have now been demolished and the concrete flooring broken up.
- In the centre of the site this area consists of grass and woodland. In this area it forms the edge of the County Wildlife Site (CWS).
- To the south of the River Yare this part of the site is considered fully brownfield and is made up of the former May Gurney headquarters. The majority of this part of the site is covered by impermeable surfaces and served by a drainage system of pipes discharging directly to the river.
- An access track runs through the Deal Ground site providing access to a yacht club located at the confluence of the River Wensum and Yare.

3.2 Topography

The following topographic information is available for the site (Table 3-1)

Table 3-1: Topographic Data Sources

Data Type	Description / Source
LiDAR	National LiDAR programme 1m resolution[1]
Topographic Survey	Survey Solutions - July 2022 - 42887IPLS-01-11.dwg

The site is relatively low lying with average elevations of between 1.84mAOD and 2.20mAOD at Deal Ground and May Gurney respectively. Highest elevations are located along the western boundary of The Views and across through the Wensum Edge. Along the most northern boundary adjacent to the River Wensum, elevations are generally 1.10-1.70mAOD. The lowest elevations in the vicinity of the site are in the CWS lying at approximately 0.51mAOD (Figure 3-2).

The LiDAR data shows good correlation with the site-specific survey. A comparison plot is provided in Appendix D.

1 DEFRA Data Services - https://environment.data.gov.uk/DefraDataDownload/?Mode=survey

Figure 3-1: Current land use (Google Maps)

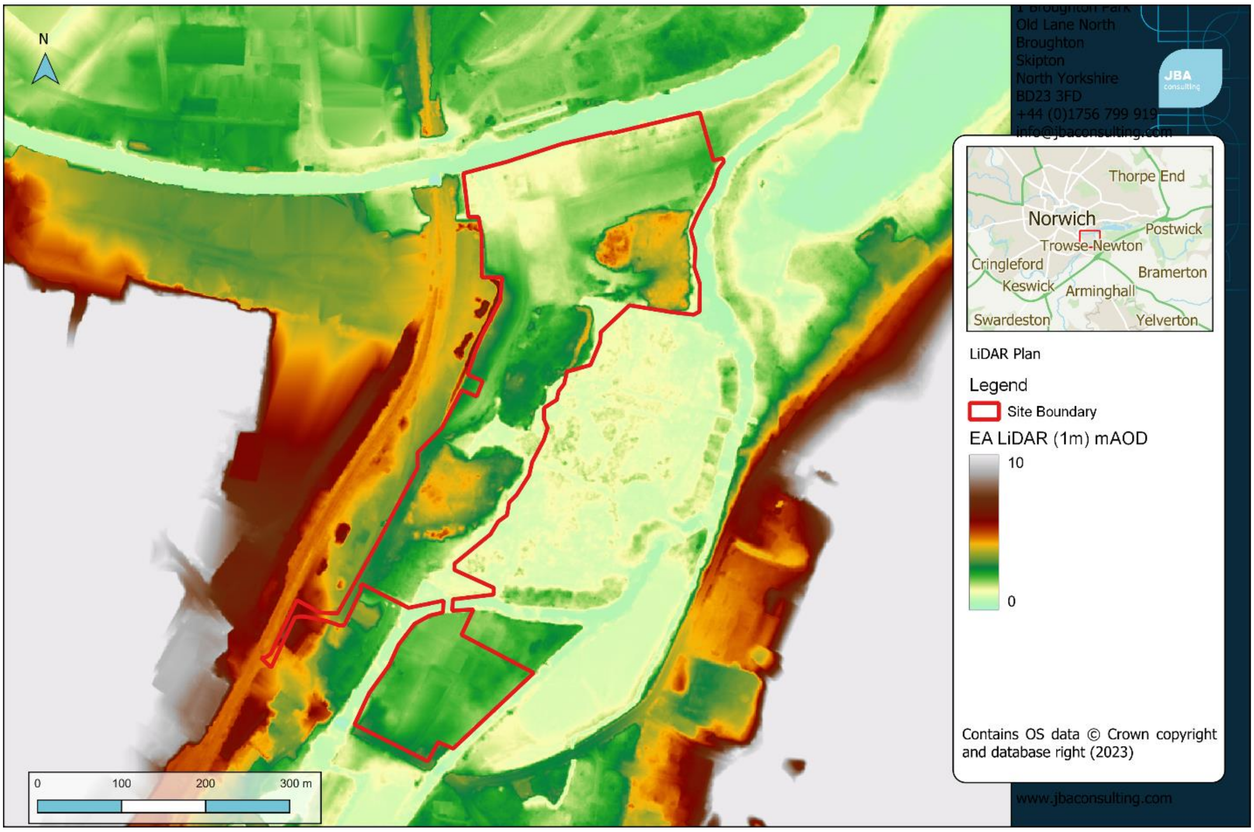

Figure 3-2: Topography (LIDAR 1m Resolution)

3.3 Waterbodies

3.3.1 Wider context

Overall, the Wensum is a low gradient, groundwater dominated river, which has a natural channel with extensive low lying floodplain areas. All surrounding watercourses are shown in Figure 3-3. A network of artificial drainage channels run parallel to the river draining the floodplain and discharging into the river at various locations to allow the land to be operated for farming. A series of mills and water control structures affect water levels upstream and within Norwich.

The underlying geology of the catchment is predominantly chalk. The superficial geology is mainly formed by Till Diamicton, with glacial sand and gravel, and sand and clay from the Crag formation concentrated in the area of Norwich and at the confluence with the River Tas. The distribution of the superficial deposits makes the upper part of the catchment more permeable than downstream areas.

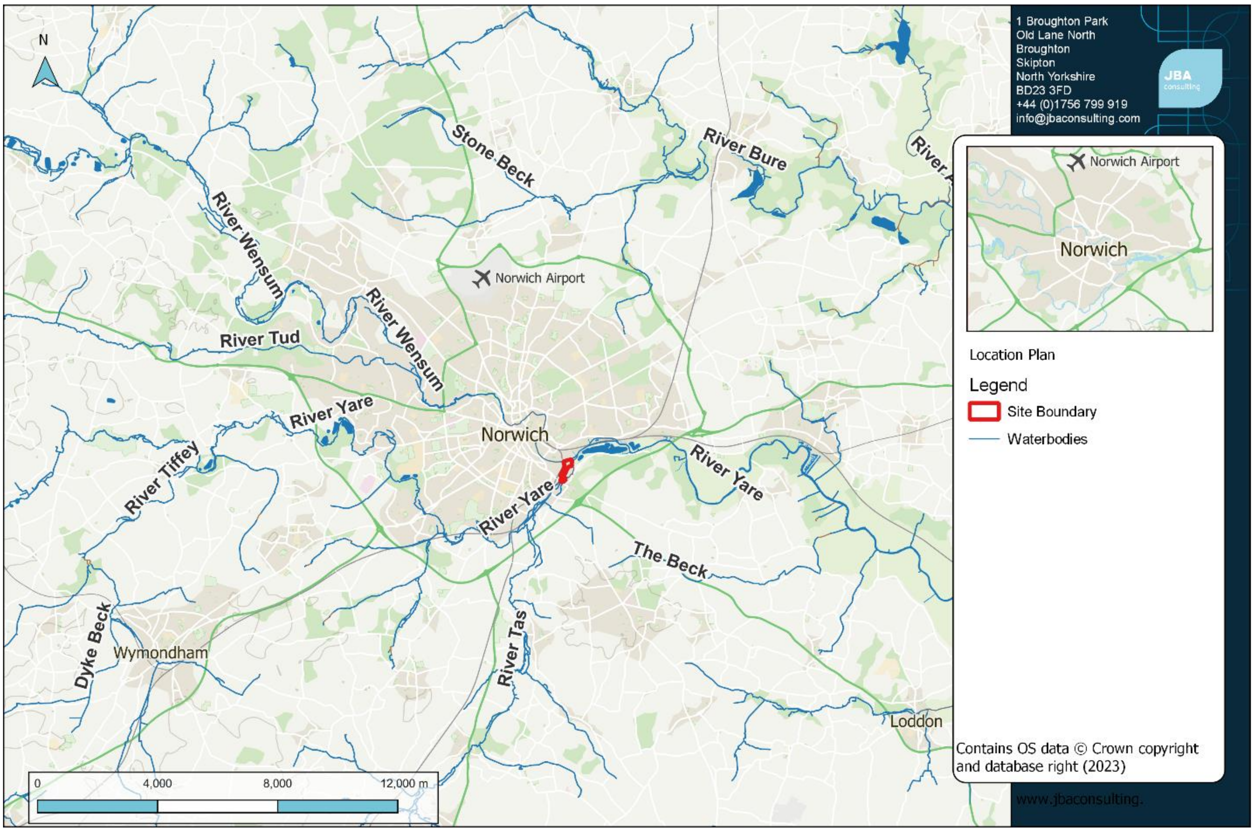

Figure 3-3: Water bodies (Regional)

3.3.2 Local

The site is bounded to the north by the River Wensum and to the South / East by the River Yare. A series of minor ditches exist with the CWS adjacent to the site. To the East of the site lies Whitingham Broads two large waterbodies.

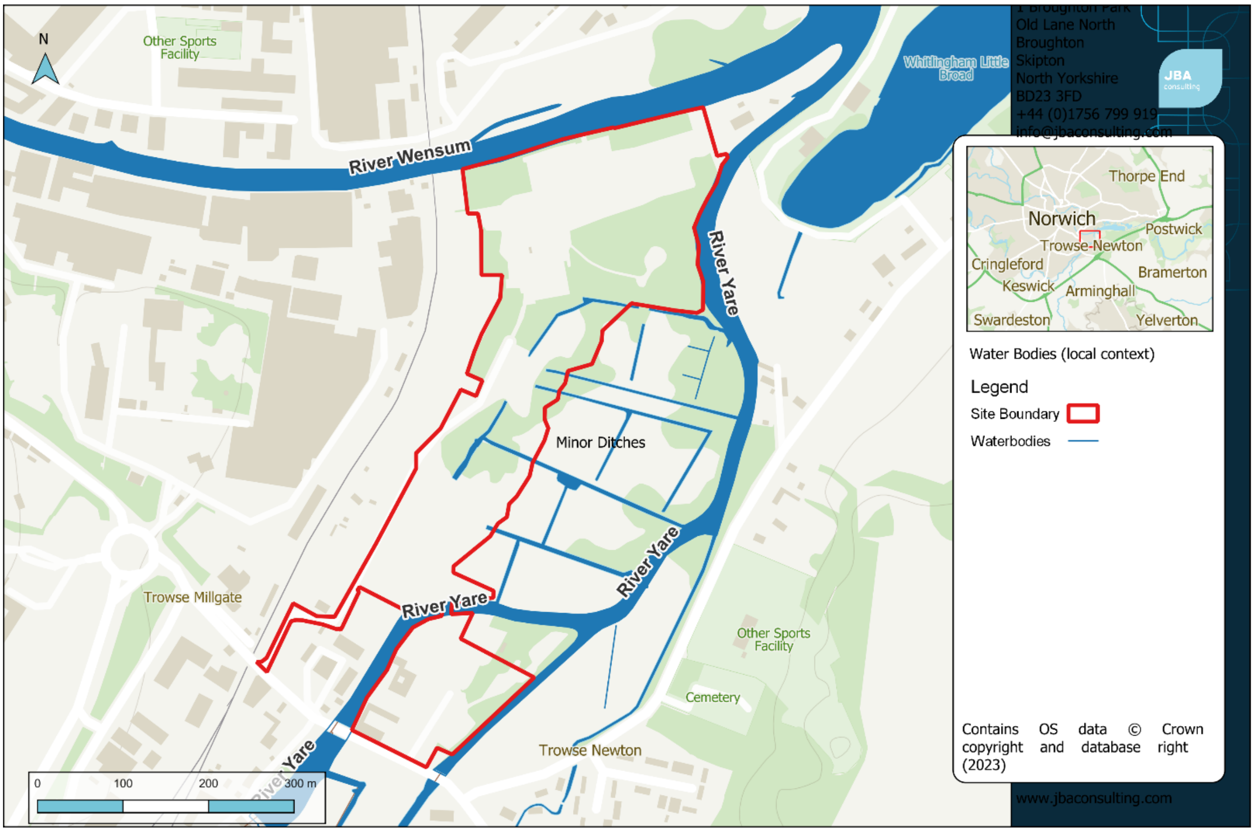

Figure 3-4: Water bodies (local)

3.4 Coastal

Although Norwich is located some 30km inland from the coast, tidal influences are still seen within Norwich. The range of fluctuation in Norwich (Carrow Bridge immediately upstream of the site on the River Wensum) is approximately 600mm due to the tidal influences. When the Mean High Water Springs occurs on the coast (Great Yarmouth) the tide level is in the region of 1.3-1.4mAOD on the coast and this equates to a level of 0.8-0.9mAOD at Norwich.

3.5 Geology and hydrogeology

The British Geological Survey (BGS)[2] Geology of Britain viewer shows that the site's bedrock derives from various types of chalk from the cretaceous period formed some 72.1 - 93.9million years ago. The types of chalk include; Lewes Nodular Chalk, Seaford Chalk, Newhaven Chalk, Culver Chalk and Portsdown Chalk Formations. The viewer also indicates superficial alluvial deposits of clay, silt, sand and gravel formed between 11,000 years ago and the present day (quaternary period). The chalk is classed as a Principal Aquifer and alluvium deposits considered a Secondary A aquifer.

2 https://mapapps.bgs.ac.uk/geologyofbritain/home.html

Information from Soilscapes[3] shows soils in the area are loamy, sandy and contain a high peat content. The soils have a high groundwater with a high-water table leading to typically wet soil conditions.

3.6 Designations

The site lies on the edge of the Broads National park. In addition, there are a number of potentially water sensitive sites in the vicinity of the site. These include Local Nature Reserves, SSSIs and heritage assets such the Bottle Kiln located on site (Figure 3-5).

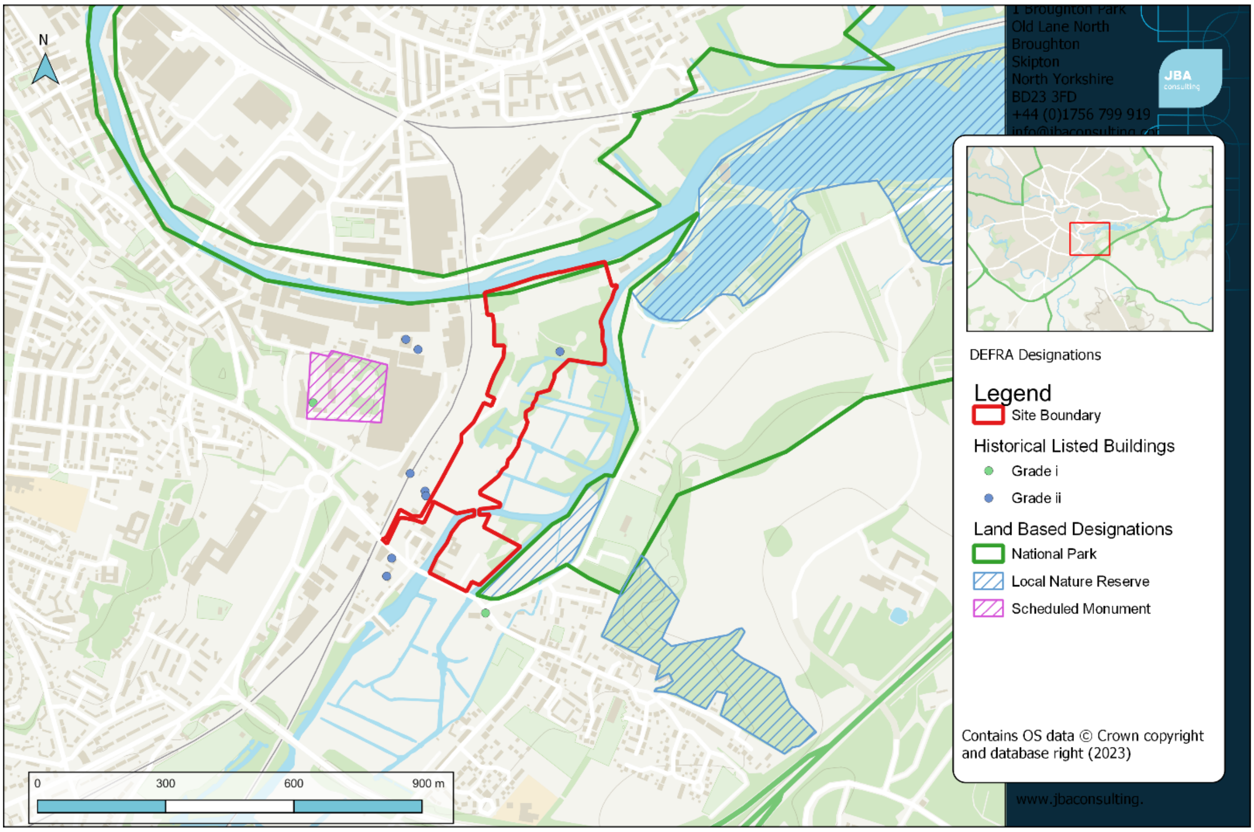

Figure 3-5: Natural England Designations (MAGICmap)

3.6.1 Habitats & Species

The following priority habitats are found at the site:

- Lowland Fens (England)
- Deciduous Woodland (England)

Full ecological and arboricultural assessments have been carried out for the site and should be referred to for further information.

3 http://www.landis.org.uk/soilscapes/

4 Consultation and Data Request

4.1 Overview

The following organisations were consulted as part of the FRA process:

- Environment Agency
- Norfolk County Council as Lead Local Flood Authority and Highways Authority
- Internal Drainage Board - Norfolk Rivers Internal Drainage Board

4.2 Environment Agency

A meeting was held on the 12 January 2023 to discuss the latest development proposals and the 2013 application within the context of current flood policy and guidance. Hydraulic modelling requirements were also discussed. The meeting was attended by the following members of the EA:

- Ed Abigail
- Sarah Palmer

At the time of writing, no formal response has been provided by the EA regarding the EIA scoping request of September 2022 (scoping opinions: 22/01225/EIA2 Norwich City Council and 2022/1847 South Norfolk Council).

4.3 Local lead Flood Authority

Norfolk County Council acting as LLFA were consulted as part of the FRA process. The following responses were received from the LLFA and full documentation is provided in Appendix E.

- EIA Scoping opinion (October 2022)
- Updated EIA Scoping opinion (March 2023)
- Response to Design Code (March 2023)

In addition, a meeting was held between the design team and the LLFA on the 11 April 2023 and the accompanying meeting minutes are provided in Appendix E.

5 Preliminary Assessment - Baseline

5.1 Overview

This section provides an overview of baseline flood risk data from all sources including flood history information. This section defines the criteria for detailed analysis undertaken later in the report.

5.2 Flood history

The following flood history information has been collated from various sources (Table 5-1). Based on latest estimation techniques, the flood of 1912 has an estimated rainfall design event more than 1000-years[4]. Table 5-1 provides a summary of the largest flood events experienced in Norwich and the Norfolk area.

Table 5-1: Flood History information[5]

Date	Event description
August 1912	186mm of rainfall in 29 hours. At Hellesdon Mill, located at the Tud Wensum confluence, flood levels reached the soffit of Hellesdon Bridge Road (5.27mAOD). A maximum level between 4.67mAOD (New Mills) and 2.35mAOD at Carrow lifting bridge were recorded in Norwich. Local news reported that about 15,000 people lost property in the disaster and 42 bridges were destroyed. The districts of Heigham and Coslan in the west of the city were the most affected by the flood.
October 1993	This was a combined fluvial/ tidal event which caused flooding all over the North Norfolk area. Flooding was noted along the Wensum and Wendling Beck at several properties between Fakenham and Costessey. Locations affected by the flooding include: Great Ryburgh , Lyng Lenwade, Hellesdon, Wendling
January and February 2007	Combined surface water and fluvial flooding. Flooding at a mobile phone mast near Fakenham Road was reported.
June 2007	Surface water event. Flooding was reported at Fakenham and in the surrounding areas of Colkirk, Stibbard and Kettlestone.

4 Calculated using FEH Web Service rainfall event rarity estimator using FEH22 rainfall data.

5 Jacobs (2017) Hydraulic Modelling Report

Date	Event description
May and July 2014	A series of rainfall events resulting in flooding to 80 properties within the Norwich urban area, of which two severe events occurred on the 27th of May and the 20th of July 2014, causing the most impact to people, property and infrastructure. These events are most likely attributable to surface water flooding.
December 2020	Largest flow on the River Yare since recording began. However, there was limited flooding experienced.

5.3 Fluvial, surface water, coastal and reservoir flood risk

5.3.1 Environment Agency Flood Map for Planning

The EA FMfP shows the site is located in Flood Zones 1, 2 and 3. Flood Zones are based on the output form the EA's hydraulic model for Norwich which was last updated by CH2M (now Jacobs) in 2017 (Figure 5-1).

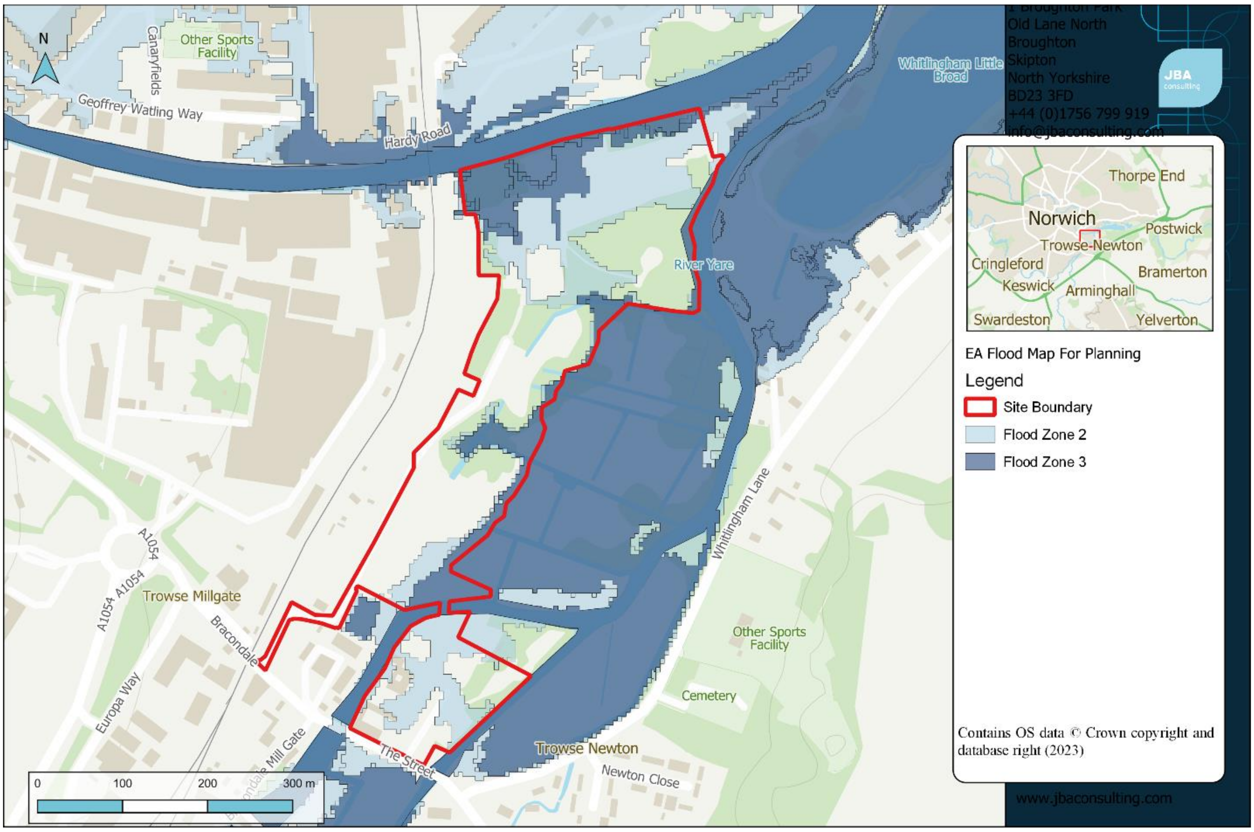

Figure 5-1: EA Flood Map for Planning

5.3.2 Flood defences

The EA AIMS (Asset Information Management System) Database was inspected for the presence of flood defences in the vicinity of the site. The database confirmed there are no formal defences that protect the site from fluvial / tidal flooding.

5.3.3 Environment Agency Flood Map for Surface Water

The EA's Risk of flooding from Surface Water map (RoFSW) is shown in Figure 5-2. The mapping shows that most of the Deal Ground and the former May Gurney sites are at 'Very Low' risk of surface water flooding. The map identifies a very limited number of isolated and very localised areas at medium and low risk of surface water flooding. Due to the surrounding topography being relatively flat, there is little opportunity for surface runoff to enter and/or flow through the site.

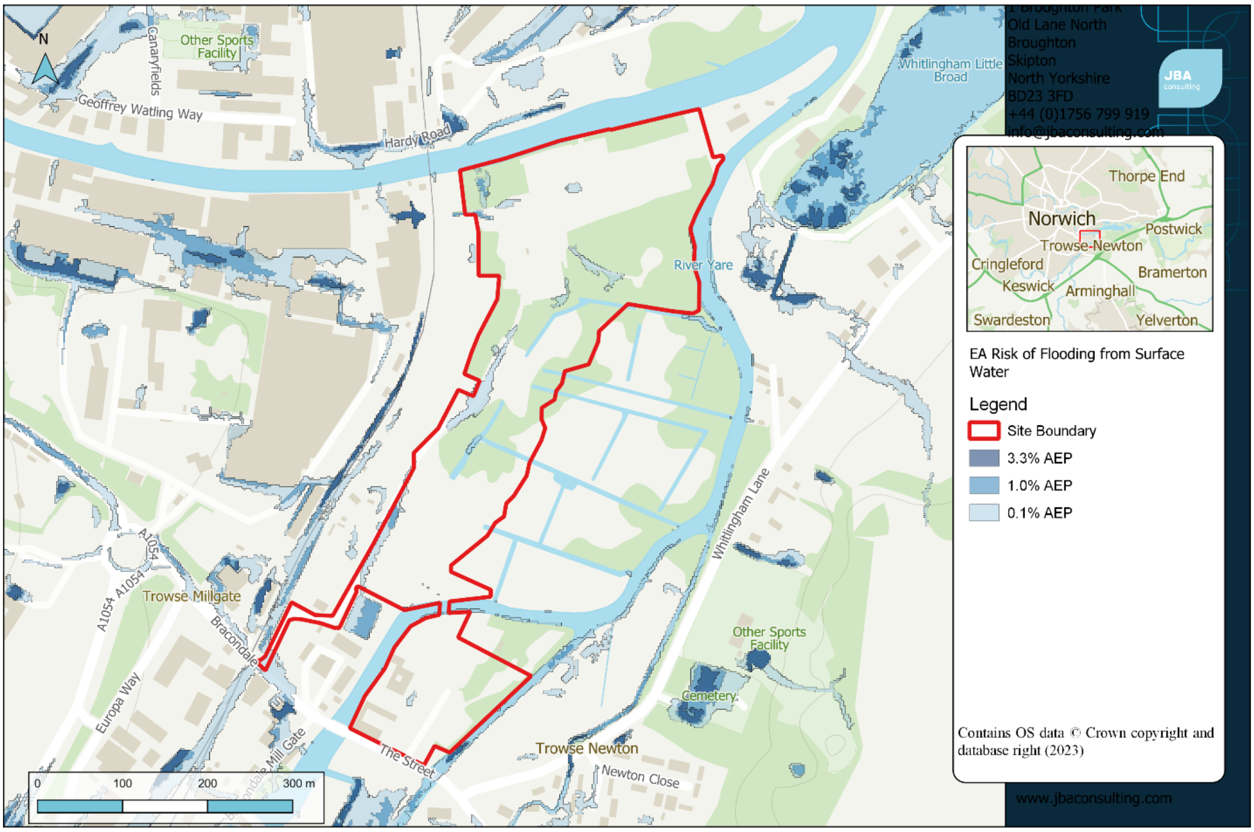

Figure 5-2: EA Risk of Flooding from Surface Water

5.3.4 Environment Agency Reservoir Inundation Map

According to EA records the nearest reservoir is located approximately 16km to the north-west of Deal Ground. The EA's inundation map (Figure 5-3) shows that, when river levels are normal, neither Deal Ground nor the former May Gurney site are affected by reservoir flooding. The mapping shows that under conditions when there is also flooding from rivers, the entirety of the former May Gurney site may be affected by reservoir flooding. Whilst much of the Deal Ground site is also affected by reservoir flooding when there is also flooding from rivers, a corridor along the western edge adjacent to the railway is shown to be unaffected.

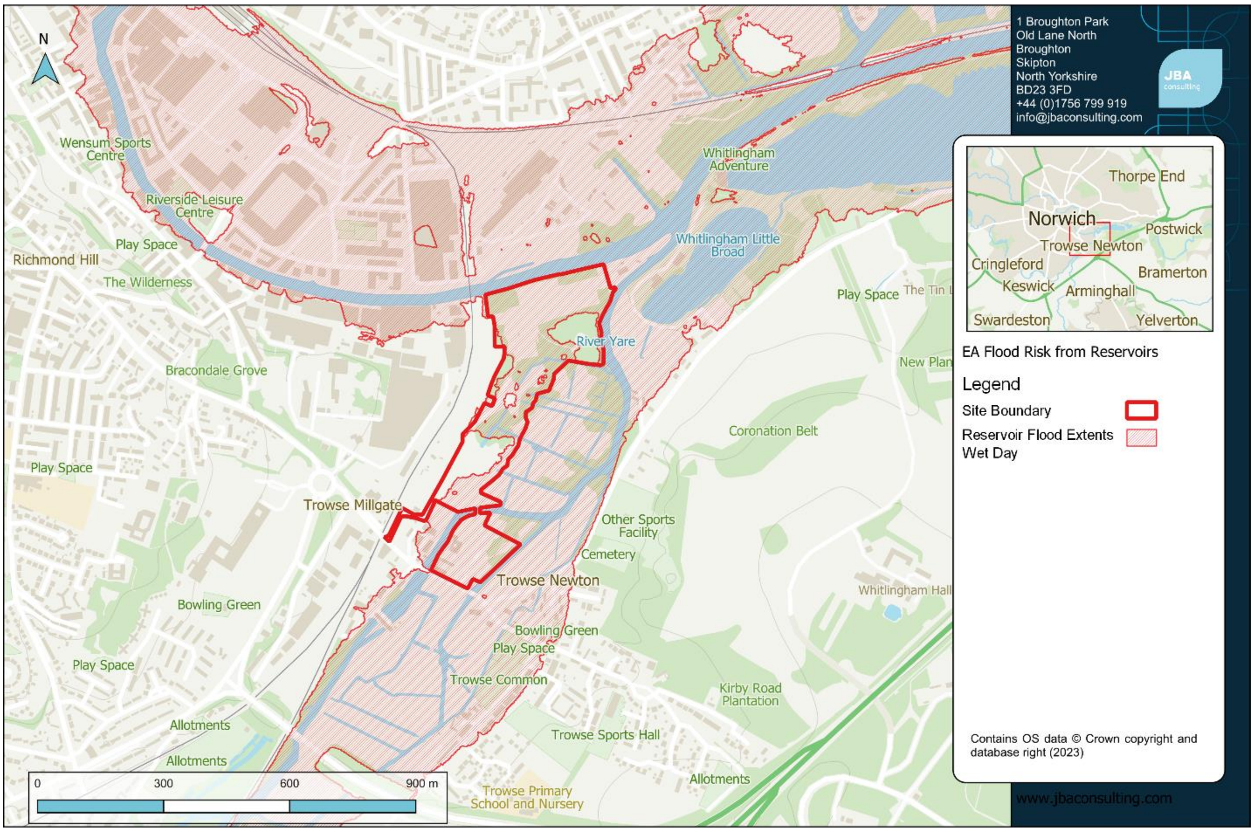

Figure 5-3: EA Risk of Flooding from reservoirs

5.3.5 Groundwater

The EA's Groundwater Vulnerability Map shows the site to be located within a 'high risk' area where solution features may be present. The site is located in Groundwater Source Protection Zone 1.

Following ground investigations and groundwater monitoring in 2021, groundwater was recorded at depths of approximately 1m below the ground surface.

The Greater Norwich Level 2 Strategic Flood Risk Assessment (February 2021) refers to the Areas Susceptible to Groundwater Flooding dataset and notes that (i) the majority of the site has a >75% susceptibility to groundwater flood emergence from superficial deposits and (ii) the southern part of the site has a >50%-<75% susceptibility to groundwater flood emergence from superficial deposits.

Further information can be found in the ground investigation report found in Appendix F.

6 Detailed Assessment - Baseline

6.1 Overview

As set out above, the site was granted outline planning permission for mixed-use development in 2013. The application was supported by an FRA prepared by Total Flood Solutions Limited and DBR Associates Limited (November 2010). For this site specific FRA, in support of discharge of conditions, the flood extents presented in the 2010 FRA have been updated based upon analysis using the latest hydraulic models.

6.2 Definition and Guidance changes

Since the approval of the outline consent there have been the following changes to flood risk definitions and guidance which have been applied to update understanding of baseline flood risk:

1. Flood Zone 3b - In 2013 Flood Zone 3b was delineated using the 5%AEP flood extent. This has subsequently been updated to the 3.3%AEP flood extent.
2. Climate change - There have been several changes to how climate change is assessed. Latest values as stated in chapter 2 have been applied to output presented in this FRA.

6.3 Hydraulic modelling

6.3.1 Overview

A site-specific model was created using the EA's Norwich Hydraulic Model (CH2M, 2017) and the Broadland Environmental Services Limited model (BESL) (Jacobs, 2019). The two models were truncated and merged to best represent the flood mechanisms at the site with the data available. A full description of the model and associated updates is included in the accompanying hydraulic model build and justification document in Appendix G.

6.3.2 Site specific model updates

A full review of the hydraulic model supplied by the EA was conducted as part of the project. The review identified several sources of uncertainty within the modelling analysis. The sources of uncertainty and measures taken to resolve them are included in Table 6-1.

Table 6-1: Model Update Summary

Model Attribute	Review comment	Model update (2023)
Model Instability	Model instability was identified in the upper reaches of the Wensum model.	The reach affected is located a significant distance from the site and the model could therefore be truncated to improve the overall stability of the model.
LiDAR	The LiDAR in the Wensum model is dated 2009/2011 and therefore needed to be updated to represent changes to the ground level.	The model LiDAR was updated to National Plan 2021 1m LiDAR. This dataset is more recent and is of a higher resolution.
Model schematisation	Several aspects of the model schematisation were noted to be incorrect. There were several areas where the 1D-2D connections were not located on the bank top. Some bridge decks had been included in both the 1D and 2D domains.	The 1D-2D connections were updated to match bank tops according to the 2021 LiDAR and the 1D cross-section data. Bridge decks were modified and represented in the 1D domain only.
Roughness	There is widespread use of 0.03 roughness across the 2D domain which did not accurately represent the variety of land uses within the catchment.	The material layer now has 20 unique land use categories. The data is from OS Master Map mapping.
Missing Flow routes	There is no flow route connection between the Whitlingham Little and the Great Broads	Whitlingham Broads now represented in the 2D domain and therefore intrinsically connected.
Boundary Conditions	Downstream boundary was located close to the site.	Downstream boundary now moved 19km downstream of site. BESL model used as an extension.

6.3.3 Climate change allowances

The climate change allowances for the fluvial and tidal inflows are defined in Table 2-2 and Table 2-1. Where fluvial climate change has been applied to the model, all fluvial inflows have been increased by 11% (Central 2080s). Further details of the model inflows are included in Appendix G. The tidal influences have been derived from the Jacobs BESL model. Sea level rise was applied along the open coast and the model run to derive levels further inland to allow for future sea level rise.

6.3.4 Updated approach - Downstream boundary

Initial model runs highlighted the influence of the downstream boundary on flood levels at the site. The downstream boundary is for the model used in this study is calculated using the BESL model. To avoid ambiguity in relation to the downstream boundary the model was extended 19km downstream at Reedham. Updated levels were extracted from the BESL model and applied to the study model. Further information is provided in Appendix G.

6.3.5 Joint probability

Previous studies stated that the equal probability of the same magnitude events on the Wensum and Yare is likely to be conservative. This assumption has been retained for this study.

6.4 Flood Extents

6.4.1 Flood Extents - Present Day

The baseline flood extents for the 3.3%, 1% and 0.1% AEP are shown in Figure 6-1. The results show that parts of the Deal Ground experience flooding during a 3.3% and 1%AEP events. May Gurney site experiences the onset of flooding in the 0.1%AEP event. The lower lying areas of the County Wildlife Site (CWS) are completely inundated in the 50%AEP event. The present-day baseline also shows flow routes that connect the Wensum Edge to the CWS flow route behind an area of raised ground along the western boundary during the 1%AEP as well as 0.1% AEP events.

6.4.2 Flood Extents - Climate change

The baseline climate change flood extents are shown in Figure 6-2. This gives a representation of future flood extent (2100s) for present day site conditions. The area of the site that is most impacted by climate change is the Wensum Edge where the extent of the 3.3% CC event and the 1%AEP + CC11% are increased (Figure 6-2).

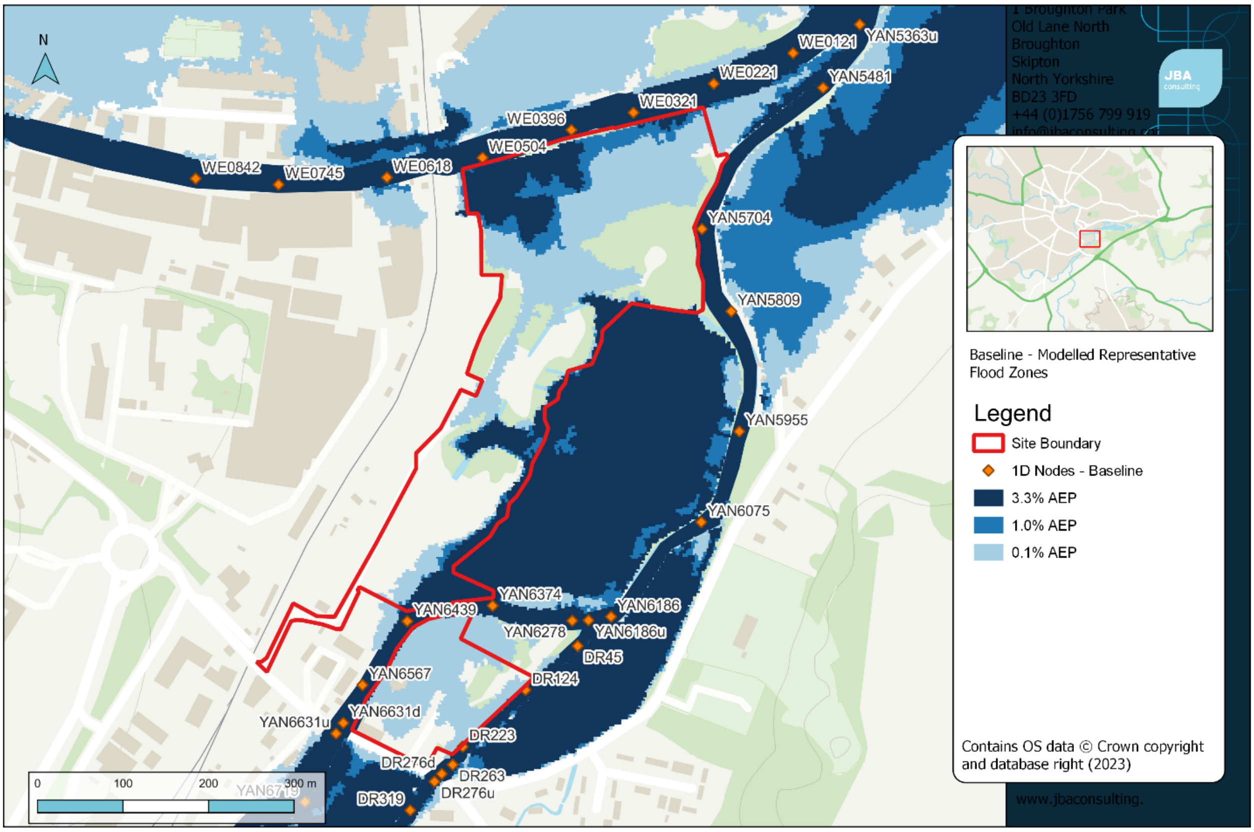

Figure 6-1: Baseline flood extents - Present Day

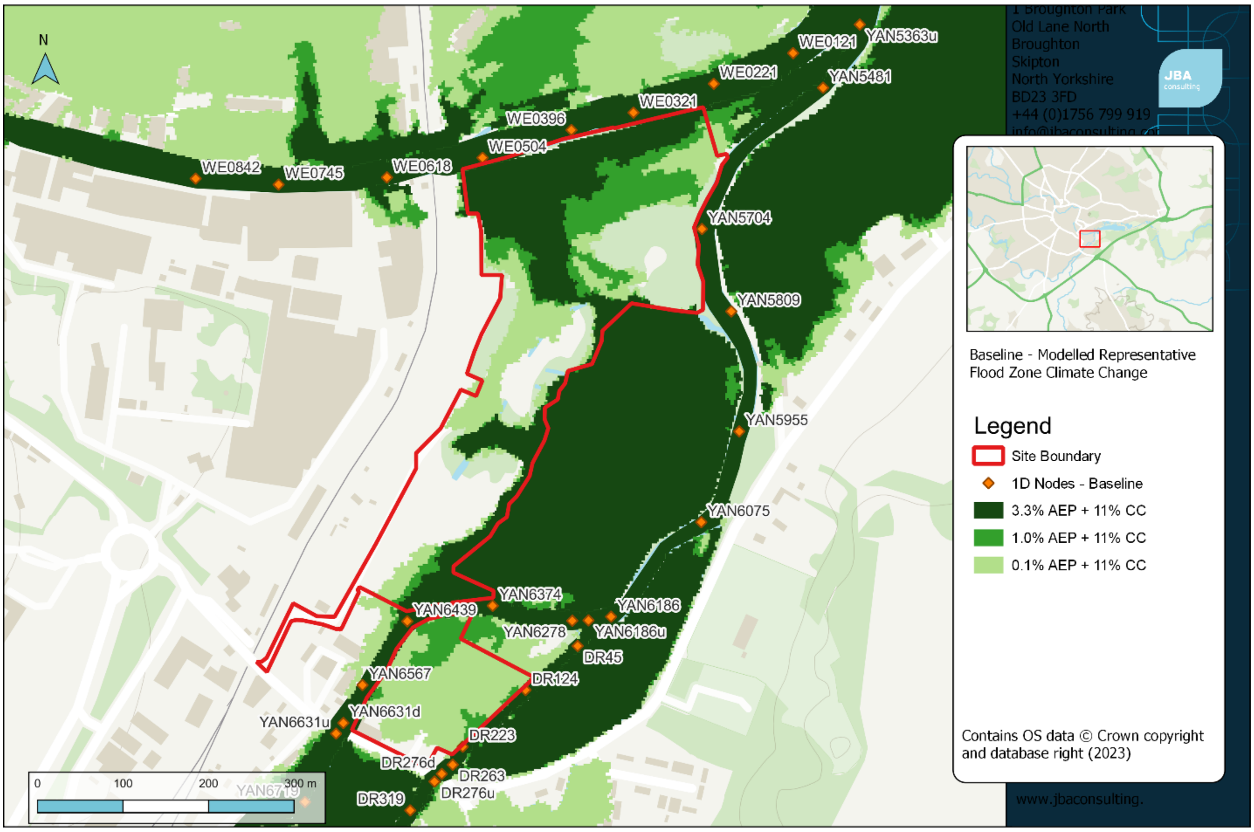

Figure 6-2: Baseline flood extents - Climate Change

6.4.3 Flood Levels

The modelled flood levels are shown in Table 6-3 and Table 6-4 for the present day and climate change events accordingly. A model node plan is shown in Figure 6-1. The average ground elevations within the site vary from 0.51 - 6.85mAOD with lowest elevations found in in the CWS and along the edge of the River Wensum.

The climate change events show an expected increase compared to present-day flood levels with the difference ranging from 0.22m - 0.34m in all events. The difference is greatest along the edge of the River Wensum.

Table 6-2: Maximum Flood Levels (Present Day) (mAOD)

Node	3.3%AEP	1%AEP	0.1%AEP
YAN6567	1.69	1.85	2.30
YAN6439	1.60	1.80	2.26
YAN6186u	1.60	1.78	2.25
YAN5955	1.55	1.74	2.24
YAN5704	1.52	1.68	2.21
YAN5363u	1.44	1.62	2.19
WE0504	1.46	1.65	2.24
WE0221	1.46	1.63	2.19

Table 6-3: Maximum Flood Levels (Climate change) (mAOD)

Node	3.3%AEP CC	1%AEP CC	0.1%AEP CC
YAN6567	1.87	2.06	2.51
YAN6439	1.85	2.03	2.48
YAN6186u	1.84	2.02	2.48
YAN5955	1.82	2.00	2.48
YAN5704	1.79	1.98	2.47
YAN5363u	1.77	1.96	2.43
WE0504	1.78	1.99	2.47
WE0221	1.77	1.96	2.44

Table 6-4: Level increase (m) due to climate change

Node	3.3%AEP / CC	1%AEP / CC	0.1%AEP / CC
YAN6567	0.18	0.21	0.21
YAN6439	0.25	0.22	0.22
YAN6186u	0.24	0.24	0.22
YAN5955	0.27	0.26	0.25
YAN5704	0.27	0.30	0.26
YAN5363u	0.33	0.34	0.24
WE0504	0.32	0.34	0.23
WE0221	0.31	0.34	0.24

6.5 Flood Depths

The flood depths for the 3.3%AEP and 1%AEP climate change events are shown in Figure 6-3 - 6-6 and depth statistics are provided in Table 6-5 and Table 6-6.

The main area of interest regarding depth is within the Wensum Edge, as overland flows are experienced within this area of the site. Elsewhere, depth statistics are skewed by low lying levels with the CWS and river channels.

The tables show that there are large discrepancies between the average and maximum flood depths, this is attributed to local depressions in the floodplain.

Table 6-5: Baseline - Flood Depth Statistics

	Average Depth (m)		Maximum depth (m)	
	3.3%AEP	1%AEP	3.3%AEP	1%AEP
Wensum Edge	0.15	0.27	0.66	0.87

Table 6-6: Baseline - Flood Depth Statistics - Climate Change

	Average Depth (m)		Maximum depth (m)	
	3.3%AEP	1%AEP	3.3%AEP	1%AEP
Wensum Edge	0.32	0.39	0.97	1.15

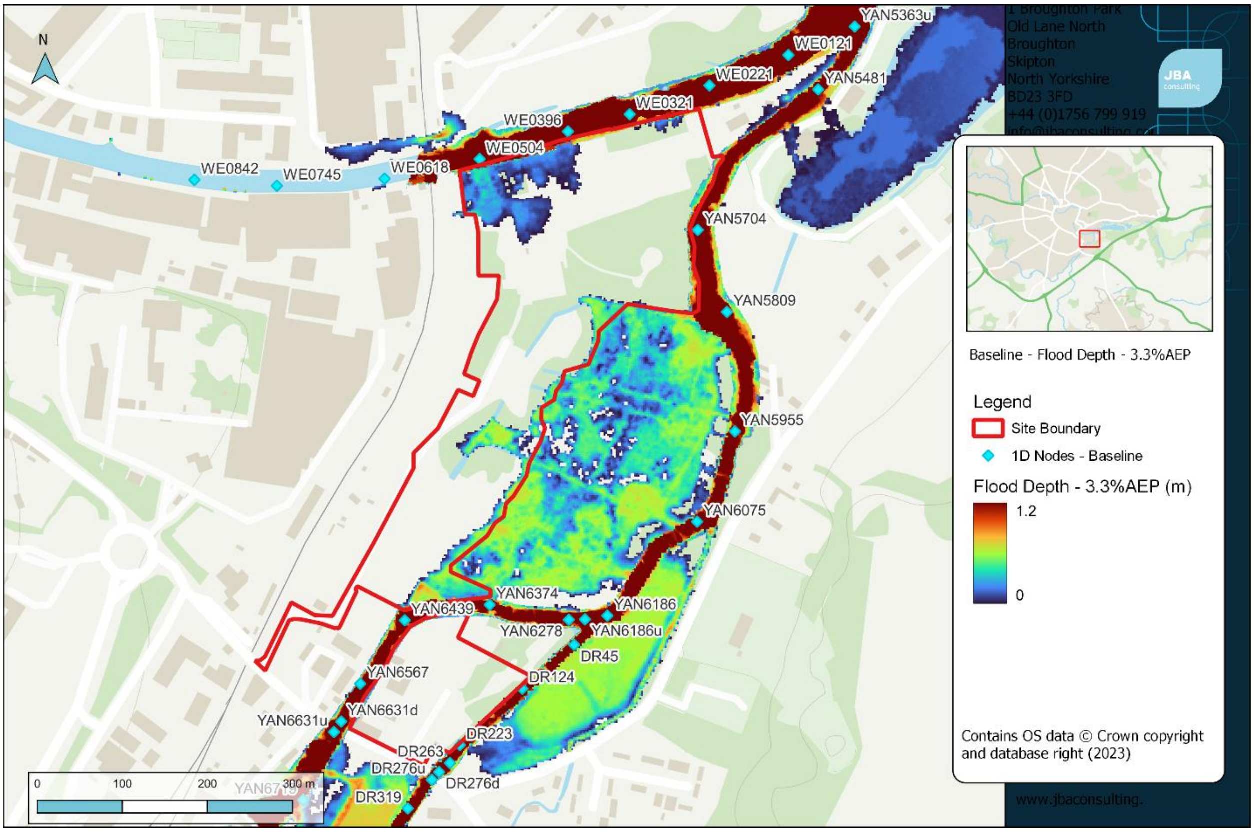

Figure 6-3: Flood Depths - 3.3% AEP

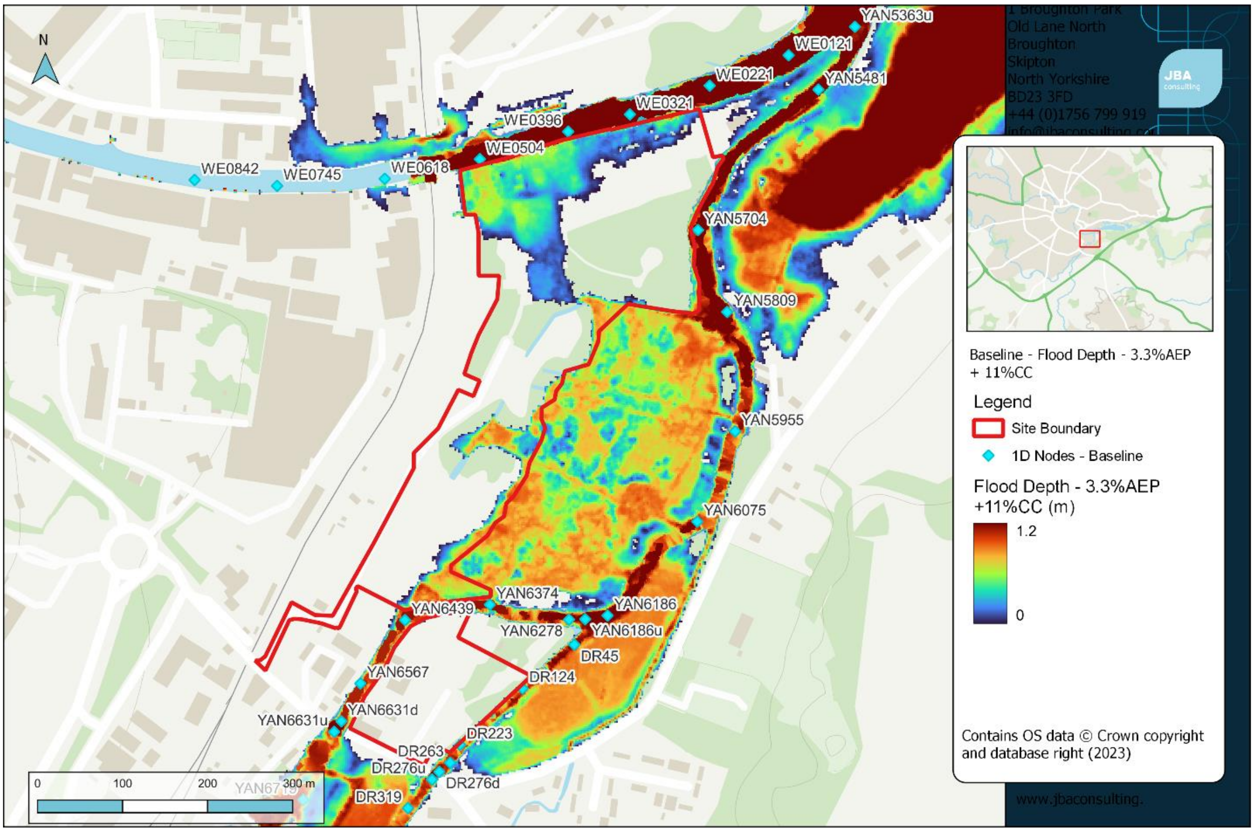

Figure 6-4: Flood Depths - 3.3% AEP + CC11%

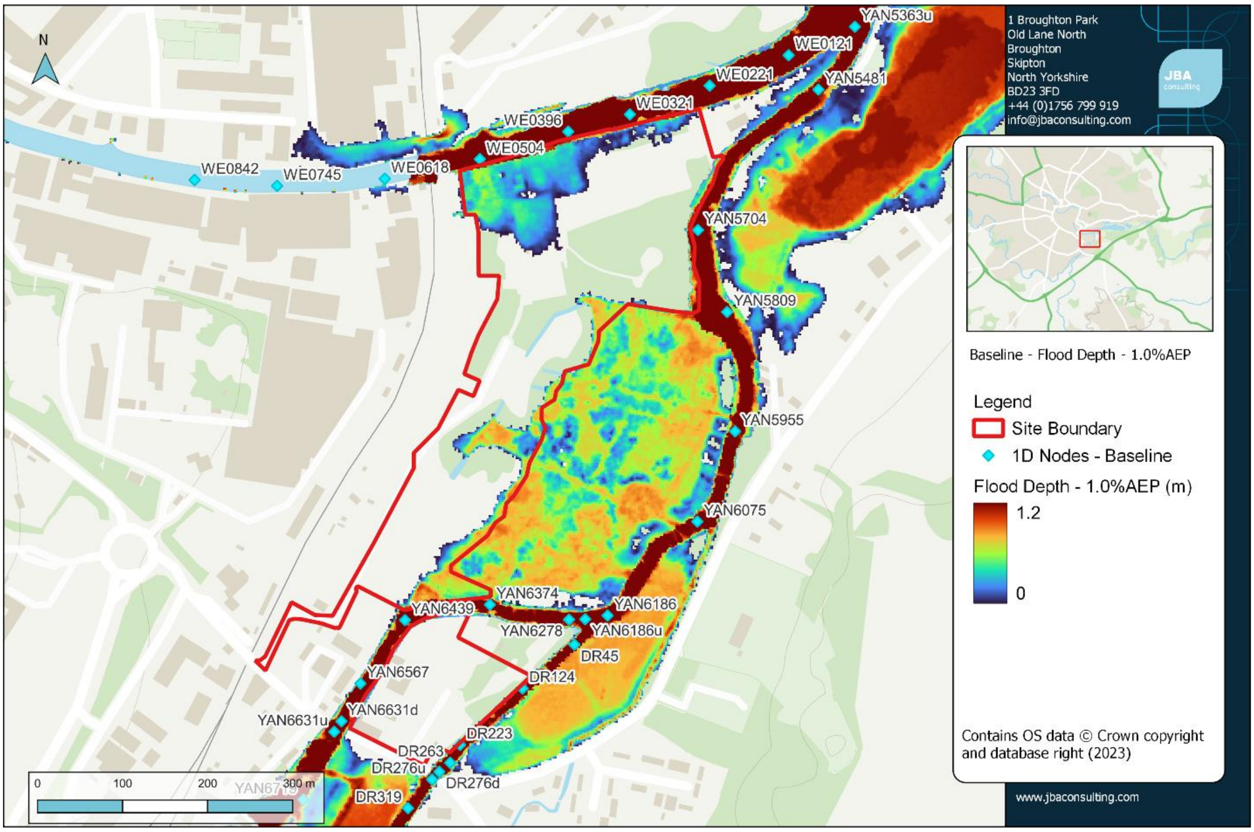

Figure 6-5: Flood Depths - 1% AEP

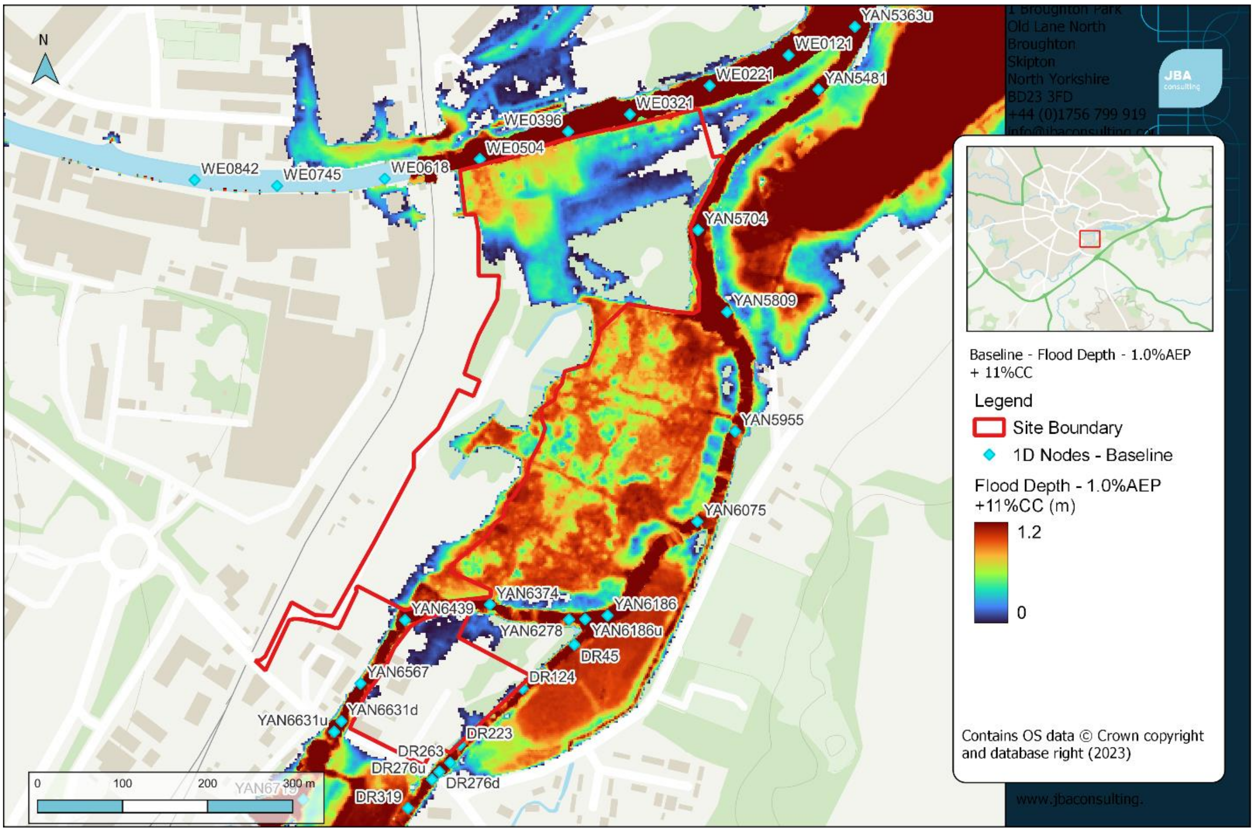

Figure 6-6: Flood Depths - 1% AEP + CC11%

6.6 Extreme Tidal scenario

An extreme tidal event was simulated in order to assess the impact to the site. The 0.5% AEP CC (2100s) tidal levels were applied to the BESL model.

The peak level at the node closest to the site, YA15000d was 1.619mAOD. The water level has been represented as a contour in Figure 6-7. This level is considerably less than the peak fluvial levels.

Analysis from previous Jacobs 2017 study studies suggests it is unlikely that fluvial and tidal events will occur at the same time.

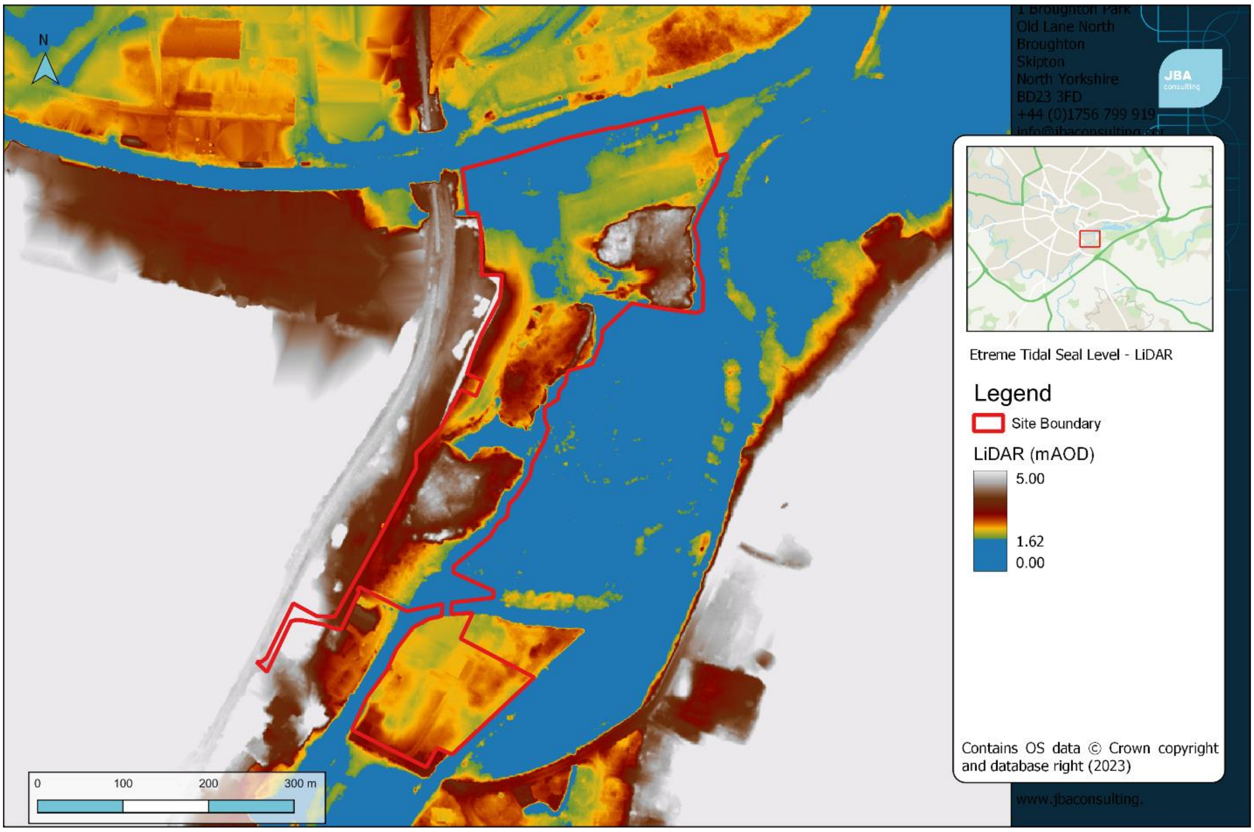

Figure 6-7: Extreme Tidal Sea Level LiDAR Contour

7 Impact Assessment - Site levels and Hydraulic Structures

7.1 Overview

The masterplan has been further developed for the Reserved Matters submission to carefully respond to the updated flood risk constraint present at the site. The following principles were carried through into the masterplan which were approved in the outline application:

- Access and egress not to be impeded by flood water and all access and estate roads are elevated above the 0.1%AEP + CC11% flood level;
- All finished floor levels (FFL) of property to be sited above the 1% AEP +CC11% flood level and allowing for freeboard, which are also above the 0.1%AEP + CC11% flood level;
- All parking to be located above the 1%AEP + CC11% flood level;
- All bridges and culverts have been designed to latest guidance incorporating for freeboard and potential for flow impediment;
- No net loss of floodplain storage due to the proposed development through the provision of compensatory storage;
- No development within the updated footprint of the 3.3%AEP event based on the compensatory storage configuration.

Through the implementation of these principles and application of latest flood risk data this combines to make a suitable flood risk management strategy to reduce flood risk to the proposed development for its intended life span.

7.2 2013 Masterplan review (flooding)

In the 2013 masterplan the minimum finished floor levels were set at 2.4mAOD or higher. The 2013 flood risk management approach included:

1. Land raising and lowering to provide a compensatory storage scheme.
2. Both residential and commercial areas were to be constructed with voids to allow flooding underneath the structure. This was mainly focused along the Wensum frontage and the area in the vicinity of the bottle kiln.
3. Flood resilient construction for all properties with an FFL below the 0.1%AEP_CC flood level (at the time of assessment to be 3.1mAOD) were to be designed to tolerate flood water.
4. An overland flow route between the Wensum and Yare floodplain.
5. Bridges were to be designed to not impede flow.

7.3 Site configuration

7.3.1 Overview

The updated masterplan follows the general principles within the consented scheme with some amendments to meet present day requirements. Additional sensitivity testing has been undertaken to provide further context to the impact of the proposed scheme (i.e. land raising across the whole site without the provision of compensatory storage).

7.3.2 Site levels

Site levels have been based on the latest masterplan. Predominantly the developable area will be elevated above the 1%AEP + CC11% flood level. This applies for Yare Edge and The Views. Within the Wensum Edge ground levels are more variable in order to:

1. Maintain the flow route between the River Wensum and River Yare.
2. Provide sufficient compensation for areas located in within the 3.3%AEP+CC11% extent.

Measures for appropriate design within the Wensum Edge are explored further in Section 7.3.5. Development ground levels used in the model were determined from the water levels calculated in Section 6. The model was therefore configured as shown in Figure 7-1.

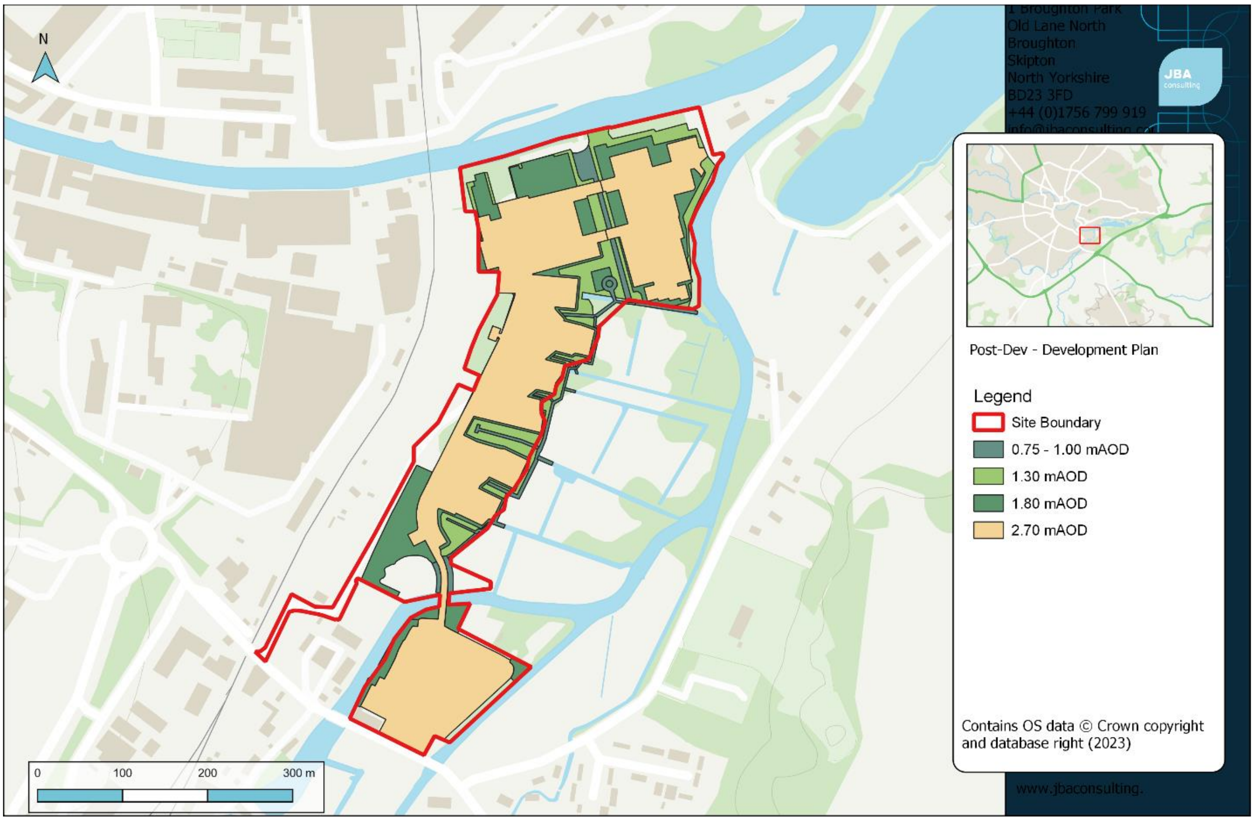

Figure 7-1: Proposed development levels

A volumetric analysis was undertaken to assess any gains/losses due to the development footprint (Table 7-1). The analysis shows there is a post development storage surplus at each measured interval and an overall net increase of over 7,500m^3.

Table 7-1: Compensatory Storage - Volumetric Analysis

Existing			Post Development			
Elevation (mAOD)	Cumlative Volume (m^3)	Volume per band (m^3)	Elevation (mAOD)	Cumlative Volume (m^3)	Volume per band (m^3)	Surplus / Deficit (m^3)
0.95	718	-	0.95	619	-	
1.05	2,740	2,022	1.05	2,663	2,045	23
1.15	6,665	3,925	1.15	7,097	4,433	508
1.25	11,842	5,177	1.25	12,994	5,897	720
1.35	18,027	6,186	1.35	20,038	7,045	859
1.45	25,399	7,371	1.45	28,281	8,242	871
1.55	33,579	8,180	1.55	36,986	8,705	525
1.65	42,446	8,867	1.65	46,771	9,786	919
1.75	52,674	10,229	1.75	57,557	10,786	557
1.85	62,865	10,191	1.85	68,454	10,897	706
1.95	72,715	9,850	1.95	79,351	10,897	1,047
2.05	82,565	9,850	2.05	90,102	10,752	902

Note: Calculations in Table 7-1 assume a ground level beneath blocks 2 and 3 of the development are at a level of approximately 1.65mAOD.

7.3.3 Yare Crossing

The proposed bridge consists of a larger opening spanning the river channel and box culverts incorporated to maintain floodplain conveyance. Details of the bridge and culvert implementation in the model are shown in Figure 7-2, Figure 7-3 and Appendix G. The soffit height of the bridges and culverts were designed to be 600mm above the 1%AEP+CC11% flood level.

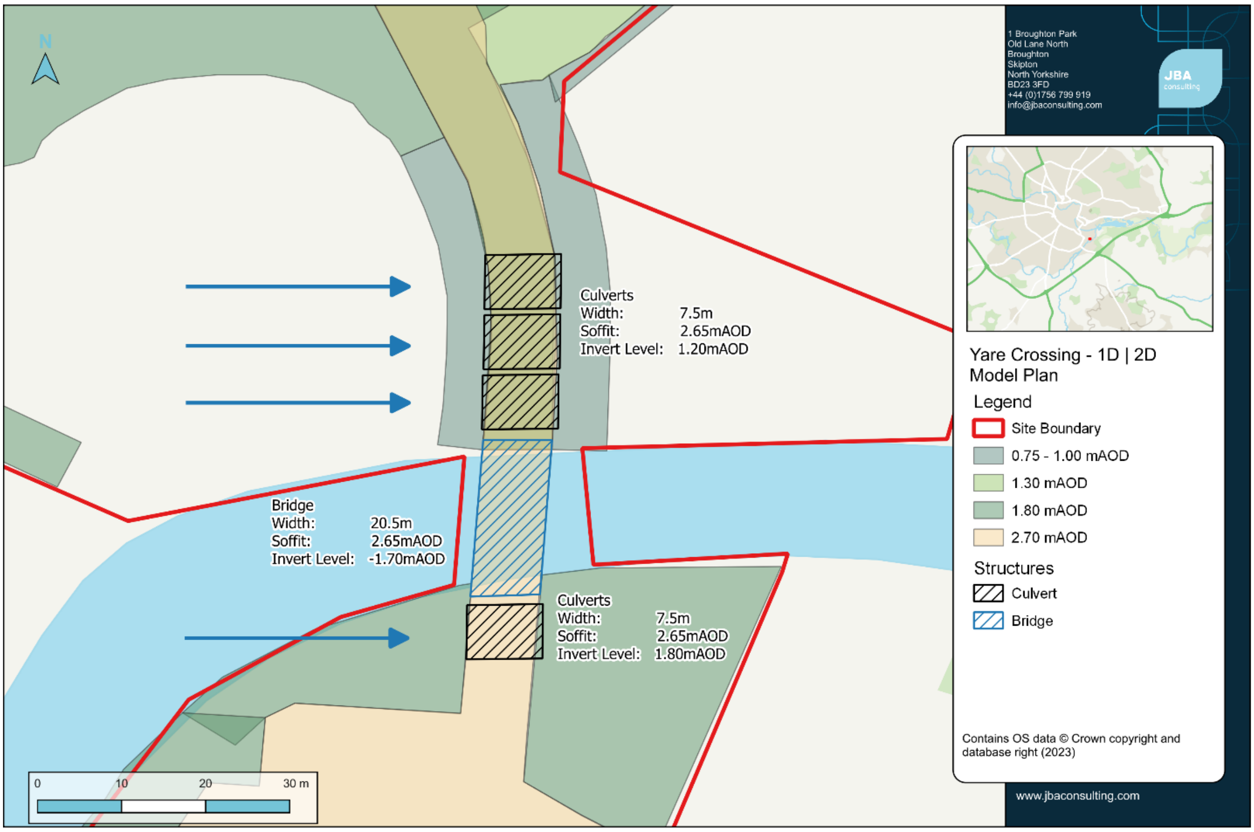

Figure 7-2: Yare Crossing - Model arrangement

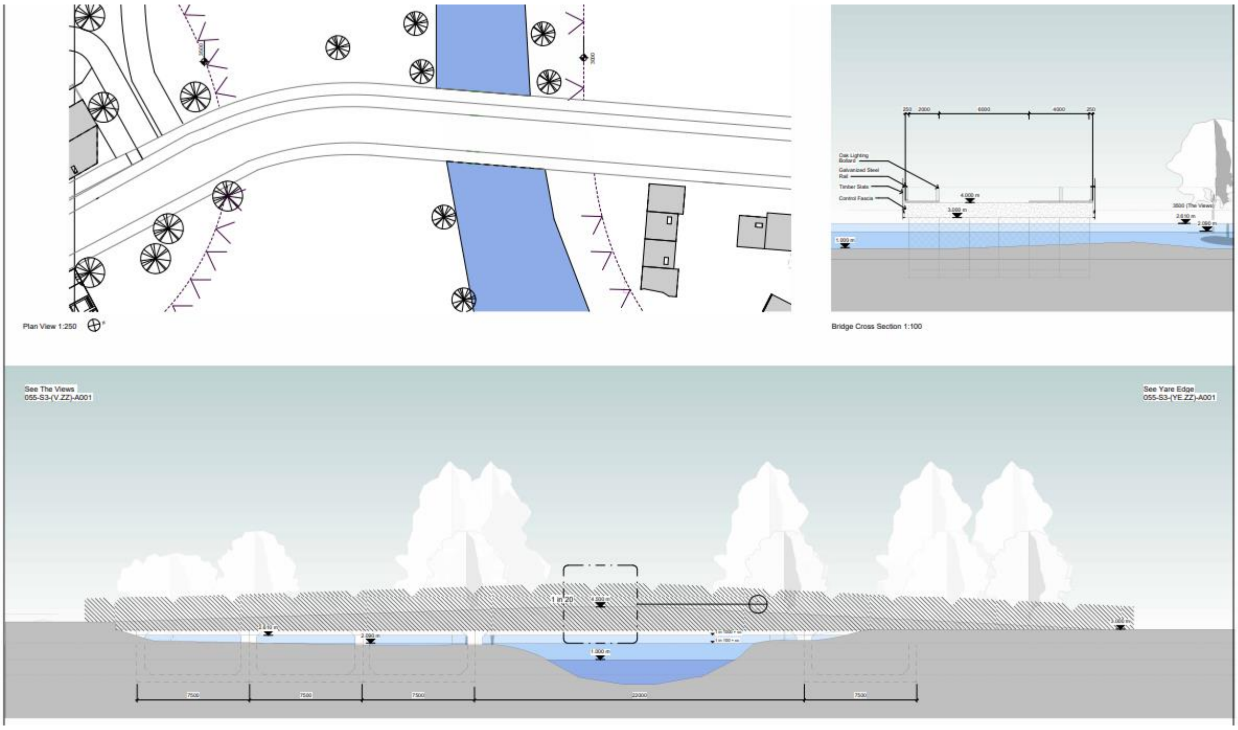

Figure 7-3: Yare Crossing - Proposed Bridge Design

7.3.4 Wensum Crossing

Eventually, a bridge across the Wensum will link the Wensum Edge development to the north bank of the River Wensum. The design for the Wensum bridge has not yet been finalised. Therefore, it has not been represented in the hydraulic modelling. The impact of the bridge is predicted to be negligible due to its height above the river and the proposed use of thin supports that intrude into the channel.

7.3.5 Wensum loop

Baseline modelling showed a flow route present during extreme events connecting the River Yare and River Wensum. To preserve this flow route and provide sufficient compensatory storage, a wet zone has been incorporated through the Wensum Edge to connect to the CWS / River Yare. The location of this flow route was established in the 2013 masterplan. The wet zone will be crossed at two locations by the Wensum Loop highway and culverts will be provided under each section of the carriageway. Figure 7-4 shows the location of the two culverts and initial dimensions.

Figure 7-4: Wensum Loop - Flow route / culvert arrangement

7.4 Impact assessment

7.4.1 Compensatory Storage

A quantitative analysis was undertaken to assess peak flood levels pre and post-development (i.e. following ground raising and the implementation of floodplain storage compensation) to test the impact of the scheme in flood risk terms.

Development levels (Figure 7-1) were applied within the model to assess the impact on water levels. The in-channel water levels are compared in Table 7-2 and Table 7-3 and floodplain water levels are compared in Figure 7-6 and Figure 7-8.

The levels outlined in Table 7-2 show that the proposed development lowers the water level in a 3.3%AEP event. In the 1.0% and 3.3% AEP +CC events there is a negligible increase in channel water levels due to the addition of the development, with the largest increase of 0.008m at model node YAN5704.

However, given that the compensatory scheme design shows a net increase in storage (Table 7-1), the increase in water level can be attributed to model 'tolerance' due to ground level changes. In the 0.1%AEP + CC11% event there is a decrease in 1D water levels caused by the post-development scenario. However, the floodplain water level comparison shows there is little to no change in floodplain water levels. Therefore, it is considered there is no detrimental impacts to offsite receptors. The post-development depth, velocity and hazard grids are shown in Figure 7-5 and Figure 7-7.

Table 7-2: Modelled Water Level Comparison - Present Day

Node	3.3% AEP			1.0% AEP		
	Baseline (mAOD)	Post Dev (mAOD)	Difference (m)	Baseline (mAOD)	Post Dev (mAOD)	Difference (m)
YAN6567	1.69	1.62	-0.072	1.85	1.84	-0.003
YAN6439	1.60	1.59	-0.006	1.80	1.81	0.005
YAN6186u	1.60	1.57	-0.029	1.78	1.79	0.004
YAN5955	1.55	1.52	-0.035	1.74	1.75	0.006
YAN5704	1.52	1.48	-0.042	1.68	1.69	0.008
YAN5363u	1.44	1.41	-0.031	1.62	1.62	0.002
WE0504	1.46	1.43	-0.032	1.65	1.65	0.001
WE0221	1.46	1.41	-0.046	1.63	1.63	0.001

Table 7-3: Modelled Water Level Comparison - Climate Change

Node	3.3% AEP + 11% CC			1.0% AEP + 11% CC		
	Baseline (mAOD)	Post Dev (mAOD)	Difference (m)	Baseline (mAOD)	Post Dev (mAOD)	Difference (m)
YAN6567	1.87	1.88	0.004	2.06	2.06	-0.001
YAN6439	1.85	1.86	0.007	2.03	2.03	0.003
YAN6186u	1.84	1.85	0.006	2.02	2.02	-0.001
YAN5955	1.82	1.83	0.007	2.00	2.00	0.000
YAN5704	1.79	1.80	0.008	1.98	1.98	0.001
YAN5363u	1.77	1.77	0.004	1.96	1.96	0.000
WE0504	1.78	1.79	0.004	1.99	1.99	-0.001
WE0221	1.77	1.77	0.004	1.96	1.96	0.000

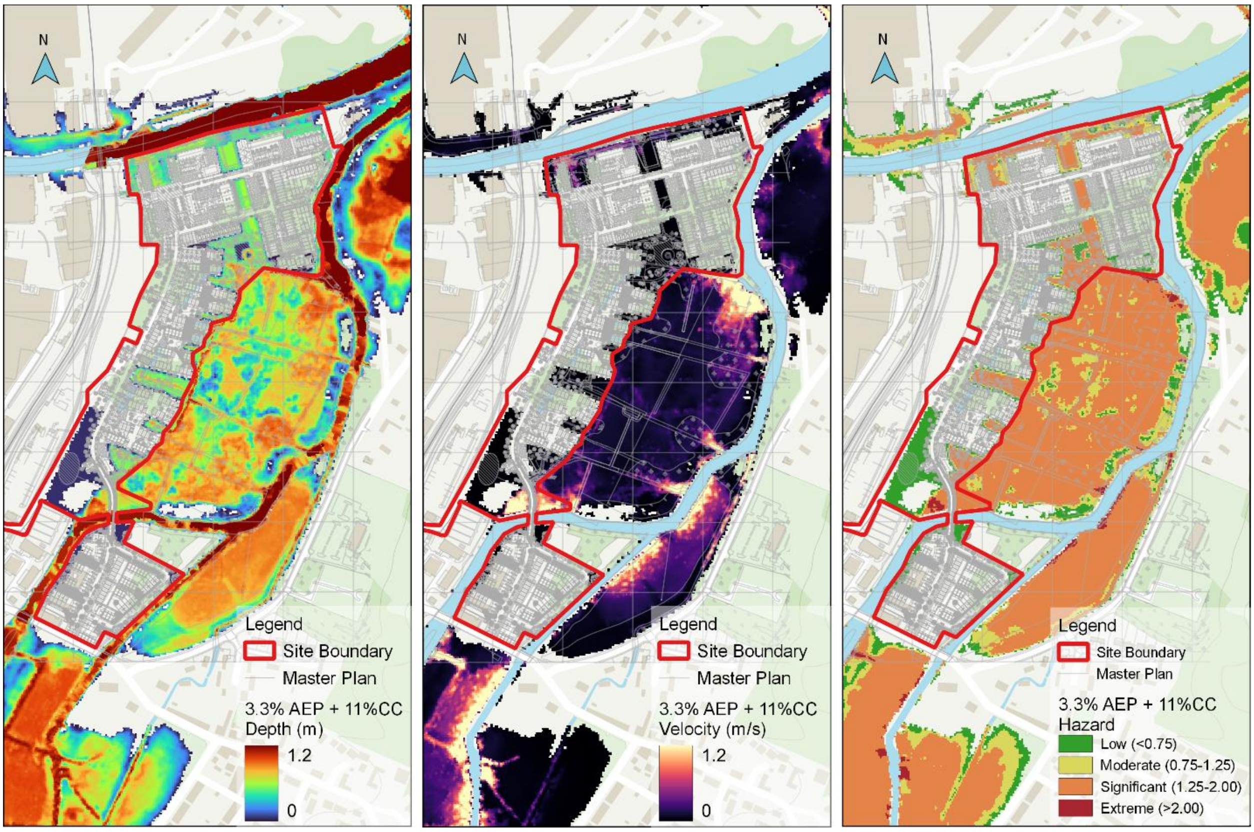

Figure 7-5: Depth, Velocity and Hazard - Post Development- 3.3% AEP + CC11%

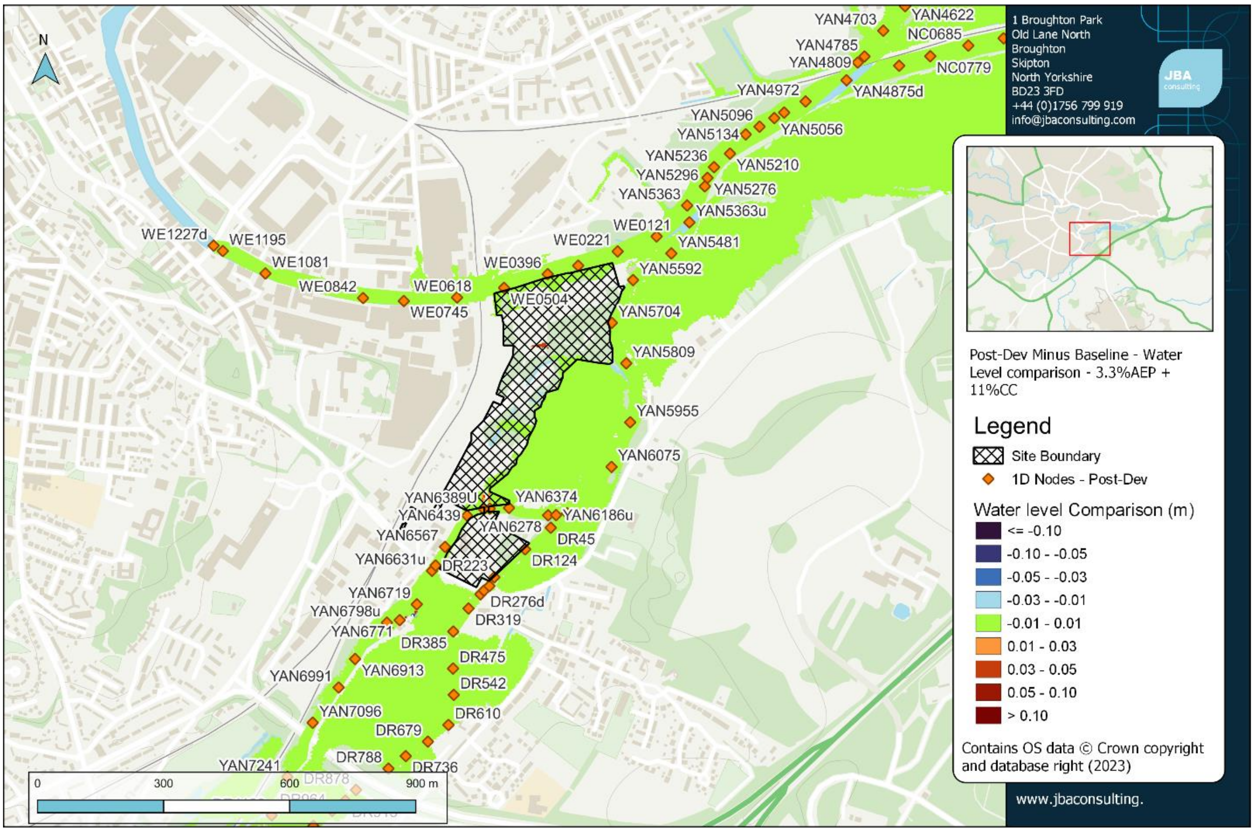

Figure 7-6: Level comparison - Post Development - 3.3% AEP + CC11%

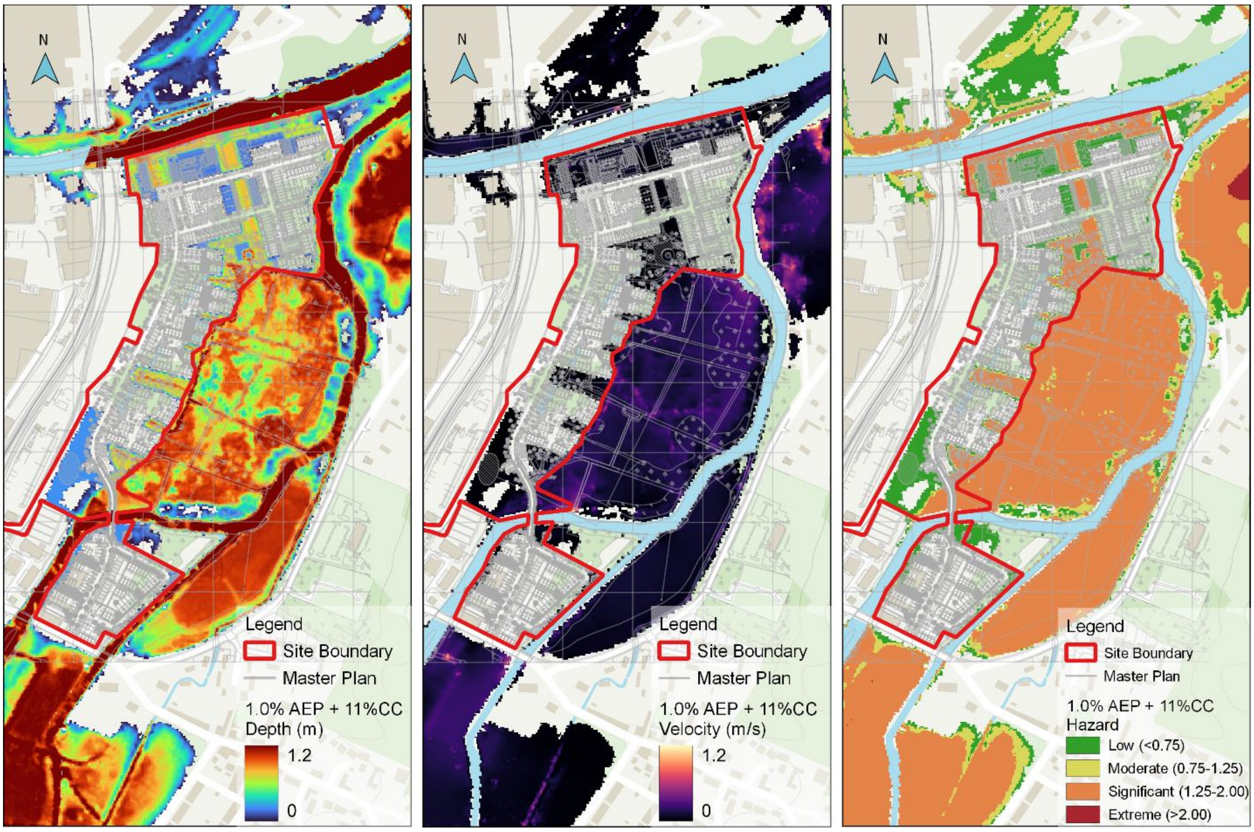

Figure 7-7: Depth, Velocity and Hazard - Post Development -1%AEP + CC11%

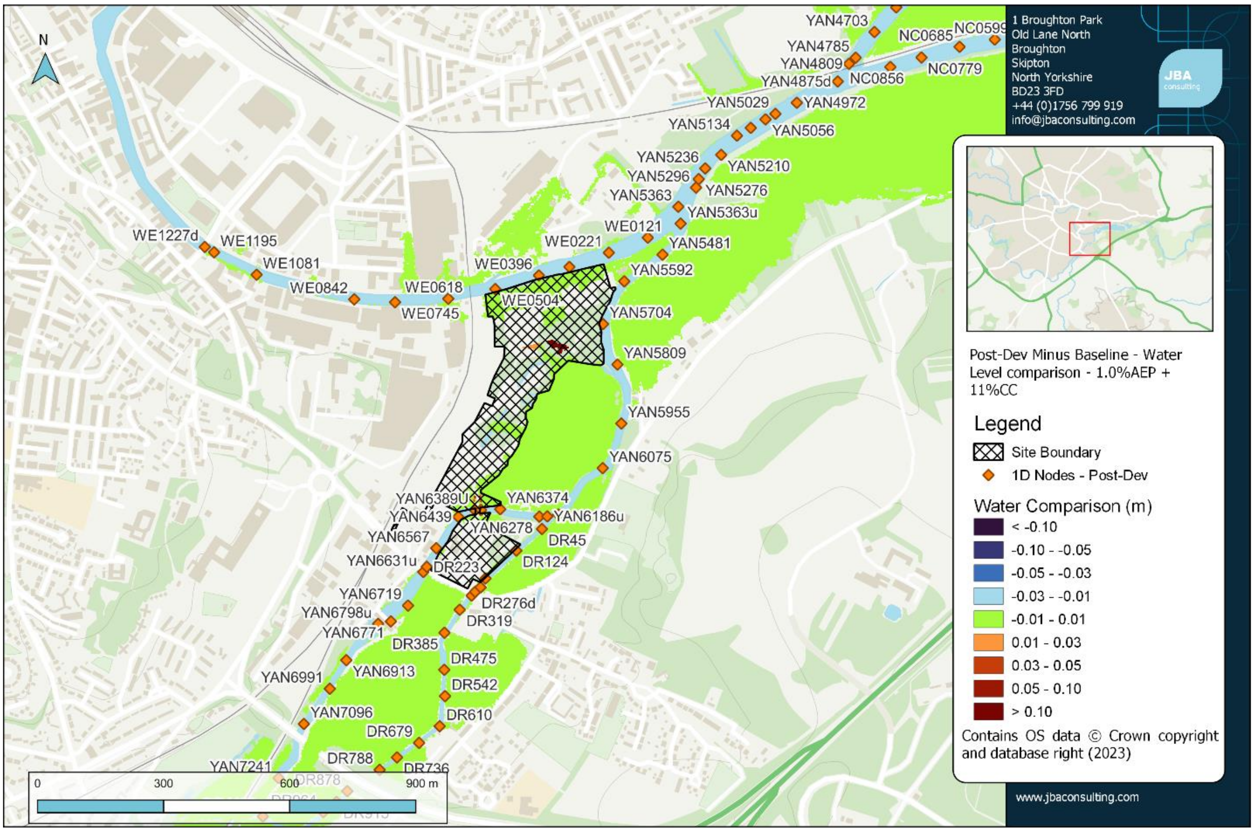

Figure 7-8: Level comparison - Post Development - 1.0%AEP + CC11%

7.4.2 River Yare crossing

The River Yare crossing was implemented in the model as set out in Section 7.3.3. It is located at model node YAN6389. This node is not included in the baseline model. The model demonstrates that there is minimal impact on flood levels with a maximum increase of 3mm upstream of the bridge during the 1%AEP+CC event. This is to be expected due to the losses associated with structures within a hydraulic model and falls within the accepted tolerance range of hydraulic modelling.

Table 7-4: Flood Level Comparison - Yare Crossing (1%AEP + CC)

Node	Baseline	Post Development	Difference (m)
YAN6331d	2.09	2.09	0.002
YAN6567	2.06	2.06	0.002
YAN6439	2.03	2.03	0.003
YAN6374	2.03	2.03	0.001
YAN6278	2.03	2.03	-0.001

7.4.3 River Wensum crossing

The bridge soffit needs to provide 600mm freeboard above the 1.0%AEP + CC11% water level. The 1.0%AEP + CC11% water level at node WE0504 is 1.99mAOD, see Table 7-5. Therefore, the bridge soffit will be a minimum height of 2.59mAOD.

Table 7-5: Wensum Crossing - In channel water levels (mAOD) - 1%AEP+CC11%

Node	Baseline	Post Development (mAOD)	Difference (m)
WE0618	1.99	1.99	0.000
WE0504	1.99	1.99	-0.001
WE0396	1.98	1.98	-0.001
WE0321	1.97	1.97	0.000
WE0221	1.96	1.96	0.000

7.4.4 Wensum Loop flow path

Culverts and channels were created in and around the Wensum Loop, as detailed in Section 7.3.5, to preserve the flow route in this region. Table 7-6 shows the water levels in this area are unchanged. Figure 7-9 shows the velocity vectors at the proposed Wensum Loop . All values near the Wensum Loop (B and C) show little variation, this confirms that the baseline flow route is preserved.

Table 7-6: Wensum Loop Point Analysis (1%AEP + CC11%)

Data Extraction Point	Baseline - Water Level (mAOD)	Post-Development - Water Level (mAOD)
Point A	2.00	2.00
Point B	1.98	1.99
Point C	1.98	1.98

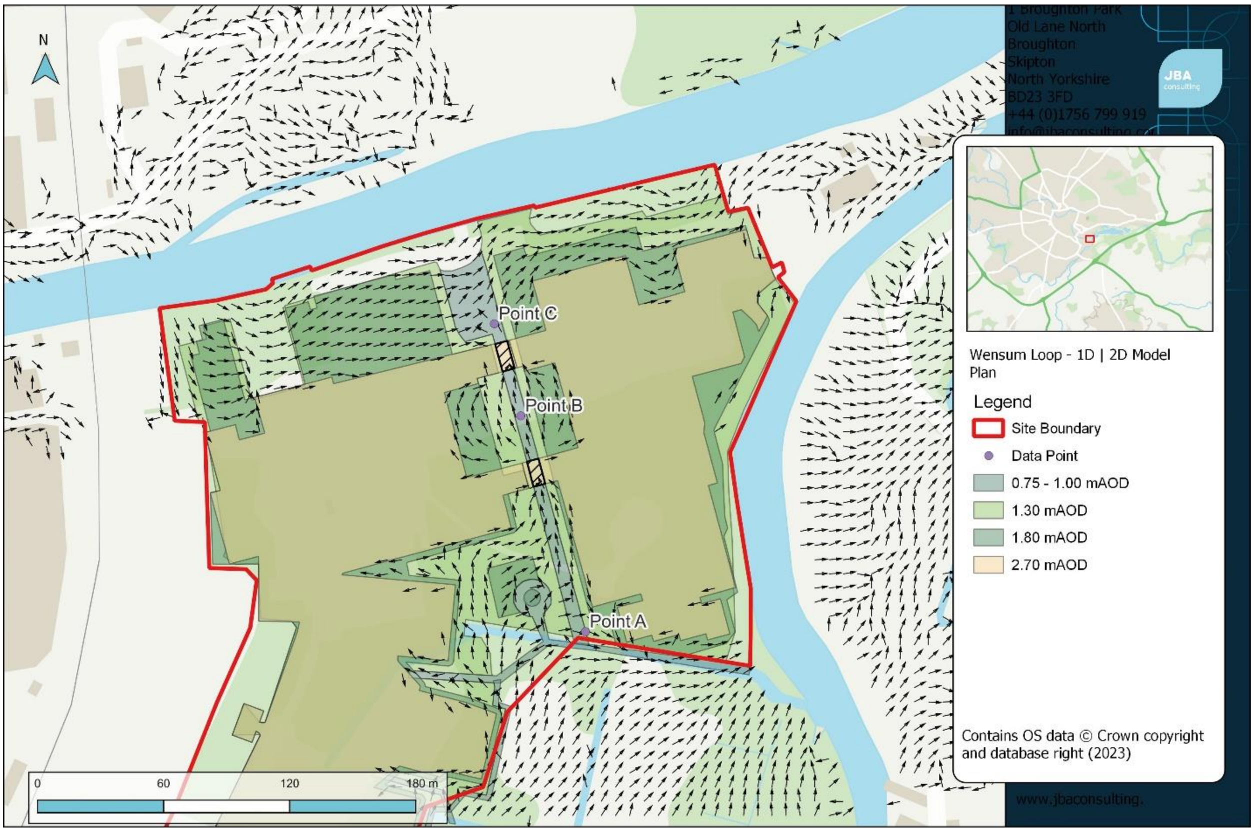

Figure 7-9: Wensum Loop - Flow Direction Vectors

7.4.5 Model sensitivity

To understand the sensitivity of the model to change, a scenario was developed where all land within the site boundary was raised above the 1%AEP+CC11% flood level, with no floodplain storage compensation provided.

In-channel flood levels were compared (Table 7-7) which show the largest increase of 15mm occurred at model node YAN6439.

The negligible increases are due to the large amount of floodplain storage available in the immediate vicinity. Therefore, only minor increases are found due to all the land within the site boundary being raised without any compensatory storage scheme.

Table 7-7: Development Sensitivity (1%AEP + CC11%)

Node	1%AEP + CC		
	Baseline (mAOD)	Raised Site (mAOD)	Difference (m)
YAN6567	2.06	2.07	0.010
YAN6439	2.03	2.04	0.015
YAN6186u	2.02	2.02	-0.002
YAN5955	2.00	2.01	0.002
YAN5704	1.98	1.98	0.001
YAN5363u	1.96	1.96	0.000
WE0504	1.99	1.99	-0.002
WE0221	1.96	1.97	0.000

7.4.6 Summary

The modelling analysis shows that the impact of the proposals upon flood levels is negligible and changes in water levels reported by the model generally fall within the accepted range of modelling tolerance. On this basis, the proposed scheme is considered to be 'nil detriment' in flood risk terms.

8 Development design and flood resilience

8.1 Overview

This section sets out the design principles/parameters to be adopted to make the development and users/occupants safe from flooding.

8.2 Finished Floor Levels

Property thresholds will be set no lower than the 1%AEP + CC11% flood level plus 300mm (2.30-2.35mAOD). In most cases this will be higher due to maintaining existing levels where possible within the site. Figure 8-1 shows indicative FFLs across the whole development. A range is provided at this point as the vertical alignment of the development is to be confirmed.

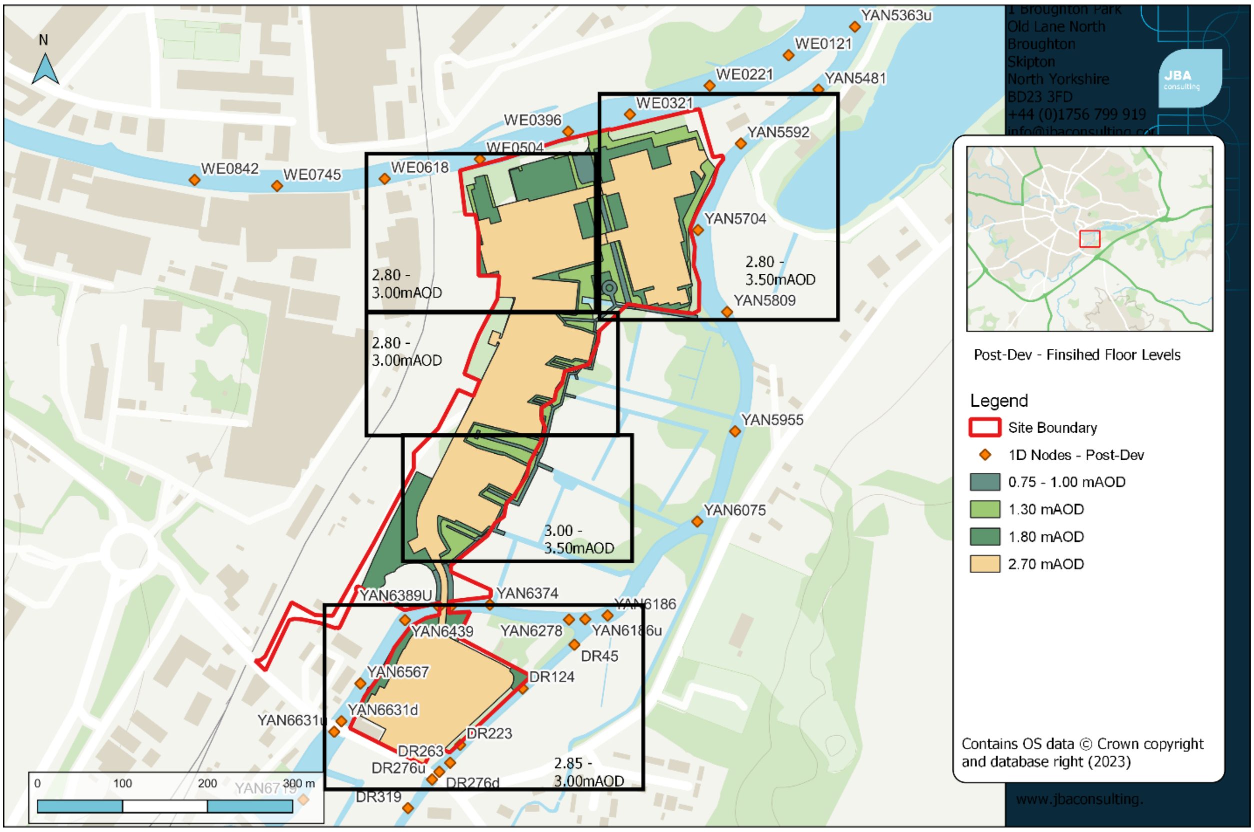

Figure 8-1: Proposed Finished Floor Levels

8.3 Voids

To provide the required FFLs and sufficient floodplain compensatory storage, voids will be provided under blocks 1, 2, 3/4, 6 and 7. This is in line with the previously agreed principles for the consented scheme, which utilised the voids under both larger blocks and smaller residential dwellings. However, the updated masterplan does not include any voids under smaller residential dwellings and so partially addresses the updated requirement that voids should not normally be relied upon for compensatory storage. Therefore, it is considered to comprise an improved design.

Voids will be designed to allow flood flow to freely enter and drain from the space beneath each block. It is envisaged that louvred panels will be used to enclose the void space and to prevent the void being used for storage of residential or commercial property, plant equipment and any future construction that may compromise flood storage.

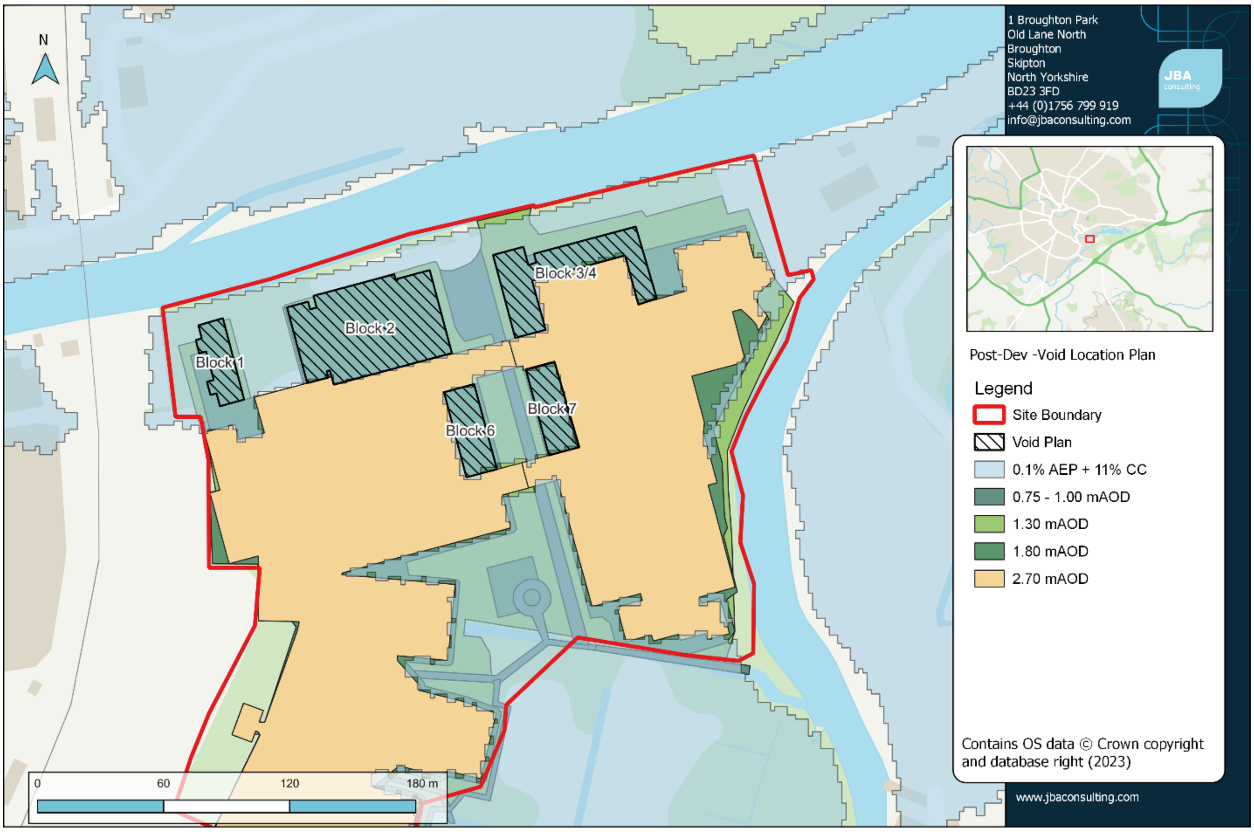

Figure 8-2: Void arrangement plan

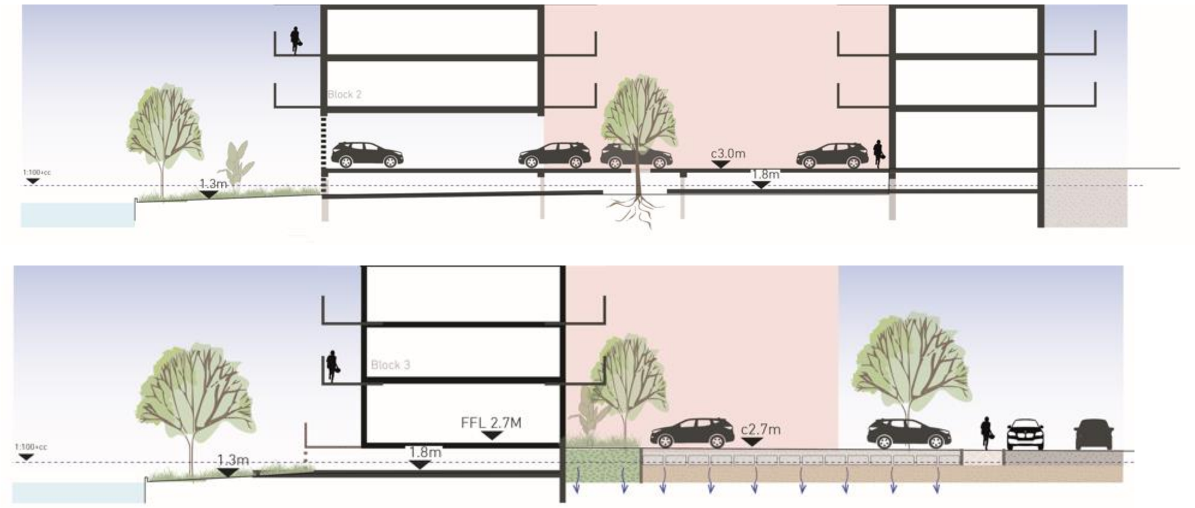

Figure 8-3: Example Void Sections (Top = Block 2 - and Bottom = Block 3)

8.4 Access and Egress

All access roads are elevated above the 0.1%AEP +CC flood level (2.66mAOD or higher). The Wensum loop provides two access routes to the eastern area of the Wensum Edge. Figure 8-4 shows that in a 0.1% AEP + CC event, all access roads are unaffected by flooding. The development will therefore benefit from dry and flood-free access/egress.

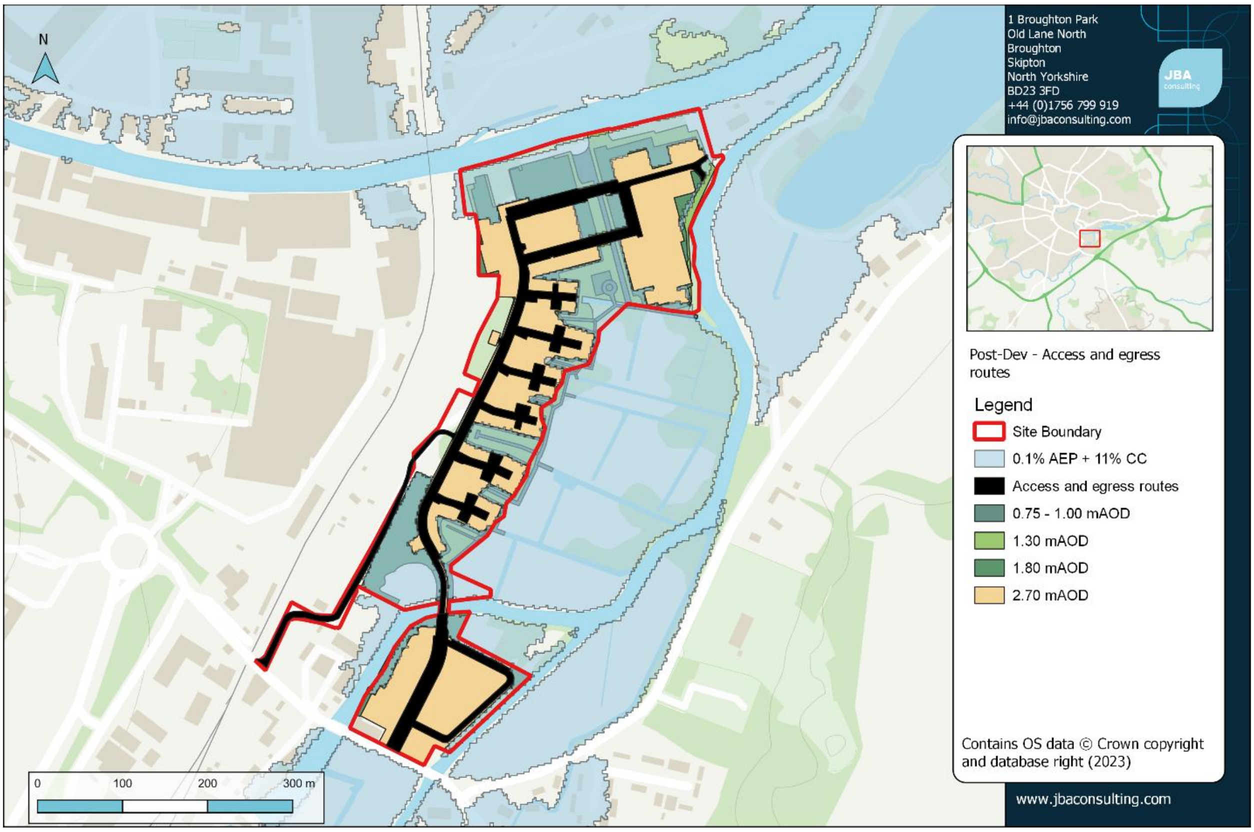

Figure 8-4: Access and egress routes

9 Surface water management plan

9.1 Overview

The following chapter outlines the surface water management strategy for the proposed development. The strategy has been proposed considering latest surface water management techniques, policy and guidance. All aspects of the strategy are housed within this chapter including:

- Review of the 2013 drainage strategy approved as part of the outline application.
- SuDS appraisal and constraint identification for the whole site.
- SuDS Arrangements including run-off rates and storage volumes for:
    - Adoptable Roads
    - Wensum Edge
    - The Views
    - Yare Edge
- Treatment / Water Quality and future maintenance of all proposed options.

9.2 Planning Conditions

Condition 33 for Norwich City Council and condition 26 for South Norfolk Council sets out the requirements for surface water management for the proposed development. The condition sets out the scheme should be based on sustainable drainage principles and contain the following:

a. details of the proposed location, dimensions and design of each element of the surface water scheme,
b. Calculations of existing runoff rates for the 1, 30 and 100-year and a range of durations.
c. Restriction of surface water runoff into rivers to no greater than the existing runoff rates to ensure there is no increase in offsite flood risk.
d. Calculations to demonstrate the proposed attenuation storage features are sized to contain peak duration 1:100 rainfall event plus CC.
e. Details of the location and volumes of surface water exceedance flows in extreme rainfall event.
f. Details of who is responsible for the adoption and maintenance of each aspect of the proposed surface water drainage system.

9.3 2013 Application - Review

The approved outline scheme was reviewed as part of this surface water management plan. The 2013 scheme was set out as follows:

9.3.1 Disposal

The 2013 application did not consider infiltration a viable mechanism of disposal due to the underlying geology (alluvium). The alluvium consists of clay, silt sands and gravels. Also, the 2013 FRA notes there is a high susceptibility to the risk of ground water flooding or high-water table based on the underlying geological conditions particularly in flood conditions. The FRA concluded discharge to a local watercourse was the most appropriate for the site.

9.3.2 Discharge rates

3. Deal ground (The Views and Wensum Edge)
    a. Assumed total of area is 16.79ha and based on site survey includes 2.85ha of tarmac and concrete hardstanding (this included the site of the former works which have now been demolished). Although no positive drainage system was identified the FRA concluded that surface water runoff would shed off these areas directly into the River Wensum.
    b. Greenfield runoff rates were calculated using IH124 and a 30% reduction was applied to predevelopment run off rates. But a 30% uplift was applied to represent climate change. Meaning run off rates remained unchanged.
    c. EA requirement stipulated a further reduction in predevelopment run off rates of 10%.
4. May Gurney (Yare Edge)
    a. Assumed total site area 2.45ha with existing impermeable area of 1.56ha. Proposed developed area has impermeable area of 1.28ha. A comprehensive drainage system discharging to the river was identified.
    b. The FRA stated as the developable area is less than the existing impermeable area then storage is not required. However, a reduction by 30% was applied to account for climate change.

9.3.3 Storage

A series of storage tanks were proposed (28 in total) distributed across the site. The proposal was to utilise 2x2m box culvert units to create the sufficient volume required. All further details were deemed subject to detailed design.

9.3.4 Flow control

It was proposed that storage tanks would be drained using pumps. It was envisaged that a multi pump system would be provided in each tank. It was also proposed that where possible a gravity outfall would be provided but was subject to detail design.

The total discharge of the pumps was stated as 520l/s and 1,020l/sec for the 2-year and 100-year storm events.

9.3.5 Review conclusion

The previous application outlined a workable solution for the site. However, there are several elements that are not in line with current guidance and policy. To meet the current requirements of the LLFA the surface water drainage system would need to utilise SuDS and restrict discharge rates to or as close as possible to greenfield runoff. The potential to meet current requirements and improve upon the consented scheme has been assessed in the following section.

9.4 Design standards / requirements

9.4.1 NCC Highways drainage standards

NCC design standards[6] are set out as follows:

- Minimum diameter of 225mm pipe drains will be provided.
- There will be a free-flowing outfall at 10% AEP (1:10)
- There should be no flooding above ground at the 3.33% (1:30) plus climate change rainfall event (unless in a drainage system designed to convey water (e.g. a swale))
- Flooding at the 1% AEP plus 40% climate change rainfall event be kept within the development boundary and / or within the Highway boundary if works are only within the Highway boundary. Any area of flooding should be kept to areas designed or expected to accommodate it. It may not be appropriate to hold water within the carriageway *(40% value superseded by LLFA and 45% and has been assessed instead).*

6 https://www.norfolk.gov.uk/rubbish-recycling-and-planning/planning-applications/highway-guidance-for-development/drainage#:~:text=Minimum%20diameter%20of%20225mm%20pipe,convey%20water%20(eg%20a%20swale)

9.5 Conceptual strategy - SuDS Appraisal

9.5.1 Overview

Based on the review of the 2013 scheme and in line with Condition 33 (NCC) and Condition 26 (SNC) of the following design principles have been set for the proposed development:

1. System to drain via gravity only to remove the reliance on pumping.
2. Storage where possible to be sited above the 1%AEP + CC11% flood level to provide a free discharge.
3. Drainage outfalls will be sited at or above 10%AEP flood level.
4. Reduced discharge rates towards or as close to greenfield runoff rates.
5. Separate systems to be provided for adoptable highway and private residential / commercial areas.
6. Blending the natural environment with the urban landscape to provide amenity, education, and ecological benefit.

9.6 Surface water disposal

The following runoff disposal hierarchy has been assessed (Table 9-1) and following review it has been deemed that discharge to surface water body is most appropriate for the proposed development.

Table 9-1: Surface water disposal

Disposal method	Description	Outcome
Into the ground	Based on the hydrogeology assessment ground waters may become elevated (within 1m of the surface).	Insufficient freeboard (<1.2m) between the base of infiltration system and ground water levels.
To a surface water body	**The site is bounded by the River Wensum and River Yare provided a discharge location immediately adjacent the site.**	**Preferred option due to proximity of watercourse and with additional environmental enhancements to the county wildlife site through re wetting.**
To a surface water sewer, highway drain or another drainage system	No sewer located near the site that could be used.	Deemed not feasible without complex pumping arrangement.

Disposal method	Description	Outcome
To combined sewer	No sewer located near the site that could be used.	Deemed not feasible without complex pumping arrangement.

9.7 Run-Off Rates and existing land cover

Runoff rates have been calculated for the whole site. Alternative approaches have been undertaken to demonstrate the suitability for use in this SuDS strategy (Table 9-2). ReFH2 is now considered to be the method of choice for calculating greenfield runoff for developments and therefore been used in all calculations in this SuDS Strategy. This method utilises most recent rainfall information (FEH). Further information regarding runoff calculations is provided in Appendix H.

Table 9-2: Runoff Rates

Disposal method	Greenfield Runoff Rates (l/s/ha) (QBAR)	Existing conditions (l/s/ha) (QBAR)
Norfolk guidance	2	n/a
ICP SUDS (MicroDrainage)	2.5	n/a
ReFH2	**2.6**	**15**

9.8 SuDS Arrangement - Adoptable Highway

9.8.1 Overview

The development is to be served by a spine road off Bracondale and heads north over the River Yare and continues towards the River Wensum. A loop road is provided within the Wensum Edge area of the proposed site. The spine road is also required to provide access to over the River Wensum to the potential future development site known as the 'Utilities Site'.

The spine road and Wensum loop are to be considered for highway adoption therefore a separate drainage system will be provided to facilitate effective surface water management.

Figure 9-1: Adopted highway - SuDS Examples

9.8.2 Drainage arrangement

Drainage for the adoptable highway is to be split into two zones:

- **HIGHWAY-001** - Spine Road south of the River Yare (Yare Edge) including on street parking footpaths and cycle paths.
- **HIGHWAY-002** - Spine Road north of the River Yare and the Wensum loop including on street parking footpaths and cycle paths.

The layout of the scheme is described in Table 9-3. Indicative highway levels are presented and proposed drainage arrangement in Appendix H. Levels are preliminary only subject to change. Drainage calculations and arrangements will be updated on completion of the vertical alignment of the public highway.

Table 9-3: Adoptable highway - Drainage arrangement

Area	Imp area (**ha**)	Discharge Rate (l/s)	Required Volume (m3)	Description
HIGHWAY-001 (Yare Edge)	0.47	1.22	545	Area to be served by linear engineered swales before discharging into a wetland / pond located immediately downstream of the proposed Yare Bridge.

Area	Imp area (ha)	Discharge Rate (l/s)	Required Volume (m3)	Description
HIGHWAY-002 (Wensum Loop and Spine Road)	0.98	2.56	1275	**Spine Road** - To be served by a linear swale / pond system which will discharge into the marsh within the Views. Flows to be restricted by a hydrobrake. **Wensum Loop** - To be served by a high-level drainage system (Beany block, Max-e Channel or equivalent). The system will convey flows towards main spine road and discharge into the Swale / Pond system. In addition, planted zones / tree pits will be provided between parallel parking spaces

9.9 SuDS Arrangement - Wensum Edge

9.9.1 Overview

The Wensum Edge is split into six separate drainage zones with certain zones having the ability to be connected to reduce the number of discharge locations. The SuDS arrangement utilises features within development design such as providing green roofs on flat roofs and locating storage under private roads and parking areas. Within these areas street scene SuDS will be integrated providing a more natural environment to the urban landscape.

Examples of urban SuDS are shown in Figure 9-1 which depict aspects of the overall strategy for the Wensum Edge.

Figure 9-1: Wensum Edge - SuDS Examples

9.9.2 General arrangement

A summary of the SUDS arrangement for The Wensum Edge is summarised in Table 9-4. Further details and drawings are provided in Appendix H.

All permeable paving elements are to be Type C (no infiltration) due to the underlying ground conditions and calculations have been based on an aggregate void ratio of 30% and an operating depth of 1m unless specified.

Table 9-4: Wensum Edge - Drainage Arrangement

Area	Imp area (ha)	Discharge Rate (l/s)	Required Volume (m3)	Description
WEN-001-ABC	0.85	2.21	929	**Storage** - Green Roof and permeable paving (use of attenuation creates could be considered if sufficient treatment provided). All three Zones to be connected via pipes under adopted highway. Section 50 agreement required. **Discharge location** - Combined with WEN-002 and WEN-003 and discharge into rain garden / public wetland located between Block 1 and 2
WEN-001-D	0.0853	1	118	**Storage** - Green roof and street scene swale **Discharge location** - Discharge into Wensum Flow path or potential to link to WEN-005
WEN-001-E	0.70	1.81	684	**Storage** - Green Roofs and permeable paving (use of attenuation creates could be considered if sufficient treatment provided). **Discharge location** - Discharge into the River Yare adjacent to the site boundary
WEN-001-F	0.56	1.46	540	**Storage -** Green Roofs and permeable paving (use of attenuation creates could be considered if sufficient treatment provided). **Discharge location** - Discharge into the landscaped area adjacent to the CWS

9.10 SuDS Arrangement - The Views

9.10.1 Overview

The Views is separated into three separate drainage zones. Each zone is to operate under the same principles. Underground storage will be provided in the private highway of each of the development fingers. The fingers will drain into a green open SuDS features within the communal gardens before discharging into the marsh. Therefore, in the area most ecological sensitive at least two forms of treatment are provided. The inclusion of SuDS within communal areas also enhances the amenity value of the areas and creates an opportunity for education benefits to the users of the communal gardens.

Figure 9-2: Wensum Edge - SuDS Examples

9.10.2 General arrangement

A summary of the SUDS arrangement for The Wensum Edge is summarised in Table 9 4. Further details and drawings are provided in Appendix H.

All permeable paving elements are to be Type C (no infiltration) due to the underlying ground conditions and calculations have been based on an aggregate void ratio of 30% and an operating depth of 1m unless specified.

Table 9-5: The Views - Drainage Arrangement

Area	Impermeable area (ha)	Discharge Rate (l/s)	Required Volume (m3)	Description
VIEW-001	0.61	1.6	595	Storage - Green roofs, permeable paving (use of attenuation creates could be considered if sufficient treatment provided) and communal pond / rain garden. Discharge location - Into marsh ditch to connect to CWS
VIEW-002	0.59	1.53	563	Storage - Green roofs, permeable paving (use of attenuation creates could be considered if sufficient treatment provided) and communal pond / rain garden. Discharge location - Into marsh ditch to connect to CWS
VIEW-003	0.75	1.95	719	Storage - Green roofs, permeable paving (use of attenuation creates could be considered if sufficient treatment provided) and communal pond / rain garden. Discharge location - Into marsh ditch to connect to CWS

9.11 SuDS Arrangement - Yare Newton

9.11.1 Overview

Yare Edge is split into two individual drainage zones either side of the Spine Road. Storage is to be provided under private highway and parking areas. Storage components will be linked with engineered swales or conventional pipe system. Street scene SuDS will be provided within landscaped areas to provide green breaks within the landscape.

Figure 9-3: Wensum Edge - SuDS Examples

9.11.2 General arrangement

A summary of the SUDS arrangement for The Yare Edge is summarised in Table 9 4. Further details are provided in Appendix H.

All permeable paving elements are to be Type C (no infiltration) due to the underlying ground conditions and calculations have been based on an aggregate void ratio of 30% and an operating depth of 1m unless specified.

Table 9-6: Yare Edge - Drainage Arrangement (1% AEP+CC45%)

Area	Impermeable area (ha)	Discharge Rate (l/s)	Required Volume (m3)	Description
YARE-001-A	0.61	1.6	595	**Storage** - Permeable paving (use of attenuation creates could be considered if sufficient treatment provided) and rain planters/ rain garden. **Discharge location** - Discharge into the River Yare adjacent to the site boundary.
YARE-001-B	0.59	1.53	563	**Storage** - Permeable paving (use of attenuation creates could be considered if sufficient treatment provided) and rain planters and communal rain garden. **Discharge location** - Discharge into the River Yare adjacent to the site boundary.

9.12 Exceedance flow paths

The SuDS scheme for the development is broken down into 13 zones. Therefore, simultaneous failure within each zone is highly unlikely, thus any exceedance zones will be managed within each individual zone.

Exceedance flow paths will be confirmed following the final vertical alignment of the public and private highway systems. Highways will be designed to convey flows away from residential and commercial properties and either into the marsh or river dependant on location within the site.

9.13 SuDS Arrangement - Additional

9.13.1 Small scale SUDS

Several small-scale SUDS features can be applied across the development. This are summarised in Table 9-7.

Table 9-7: Small Scale SuDS Examples

SuDS Component	Description	Example
Green / living roofs	Residential properties to be provided with bin and or bike stores. These are to be flat roofed structures which are compatible with green/living roofs.	
Green walls	Green walls can be fitted to the exterior of building walls to intercept run-off from roof areas.	

9.13.2 Water recycling

In the future as populations increase water resources will become further stretched. The provision of water recycling will aim to reduce demand on mains water and provide an aspect of source control.

The following options are to be considered as part of development proposals:

- Water butts serving residential properties for use for watering gardens and connect green areas.
- Rainwater recycling and collection for communal use (i.e. washing of refuse areas in communal tower blocks and irrigation)
- Rainwater harvesting for using in communal toilet facilities.
- Direct connections of downpipes to green street scene areas to reduce amount of watering.

All calculations have not included these features and is considered as an additional benefit to the proposed development.

9.13.3 Amenity and education provision

The SuDS strategy is closely linked to the landscape plan for the proposed development. Given the proximity to water with the Rivers and Marsh, water plays a prominent role in shaping the development. Elements of SUDS will be present within communal areas and areas of play. Opportunities to enhance educational and amenity aspects have been integrated into the landscape plan including:

- Water related play apparatus and natural play materials.
- Historical features such as old water pumps.
- Educational boards and infographics highlighting the importance of water.

9.14 SuDS Treatment

9.14.1 Simple Index Tool

All treatment calculations have been undertaken using the SIA tool (Appendix H). The SIA tool demonstrates all components of the proposed development provide sufficient treatment for the areas served. Discharge points in water sensitive areas (CWS) provide two stages of treatment before discharging into the CWS.

9.14.2 Nutrient neutrality

The proposed SUDS scheme will act to reduce the sediment, metal and nutrient load within surface run off. It is also envisaged that additional nutrient neutrality mitigation will be provided via the Norfolk Environmental Joint Venture Scheme.

9.15 SuDS Maintenance

For all components included within the SuDS scheme for the proposed development a preliminary maintenance plan in provided in Appendix H.

In all private areas maintenance will be carried out by a management company. SUDS relating to the adopted public highway are to be put forward for adoption and therefore management by the local highway's authority.