1 Appendix D - Cumulative impact of planned development

This chapter provides a summary of catchments with highest flood risk and summarises strategic solutions applicable to Greater Norwich Local Plan Area.

1.1 Introduction

Under the revised 2019 NPPF, strategic policies and their supporting Strategic Flood Risk Assessments (SFRAs), are required to '*consider cumulative impacts in, or affecting, local areas susceptible to flooding*' (para. 156).

When allocating land for development, consideration should be given to the potential cumulative impact of the loss of floodplain storage volume. Whilst the loss of storage for individual developments may only have minimal impact on flood risk, the cumulative effect of multiple developments may be more severe.

Conditions imposed by NCC and District Councils should allow for mitigation measures so any increase in runoff as a result of development is properly managed and should not exacerbate flood risk issues, either within, or outside of the Council's administrative areas.

The cumulative impact of development should be considered at both the Local Plan making and the planning application and development design stages. Appropriate mitigation measures should be undertaken to ensure flood risk is not exacerbated, and where possible the development should be used to reduce existing flood risk issues.

1.2 Cross-boundary issues

The majority of rivers within the study area join the Rivers Waveney, Yare and Bure and flow into the sea through the Borough of Great Yarmouth. The River Waveney flows into the study area from Mid Suffolk District in the south of the study area. The River Yare flows into the study area from Breckland District, to the east. The River Wensum flows into the study area from North Norfolk District via Breckland District and the River Bure flows into the study area from North Norfolk District. As such, future development both within and outside Greater Norwich Local Plan area can have the potential to affect flood risk to development and surrounding areas, depending on the effectiveness of SuDS and drainage implementation. The Greater Norwich study area has boundaries with the following Local Authorities, which can be seen in Figure 1-1:

- North Norfolk District
- Great Yarmouth District
- East Suffolk District
- Mid Suffolk District
- Breckland District

GIS data provided for the Level 2 SFRA was used to consider the effect of proposed development in neighbouring authorities on flood risk in the Local Plan area.

This data showed no significant development in neighbouring authorities on catchments draining into the study area.

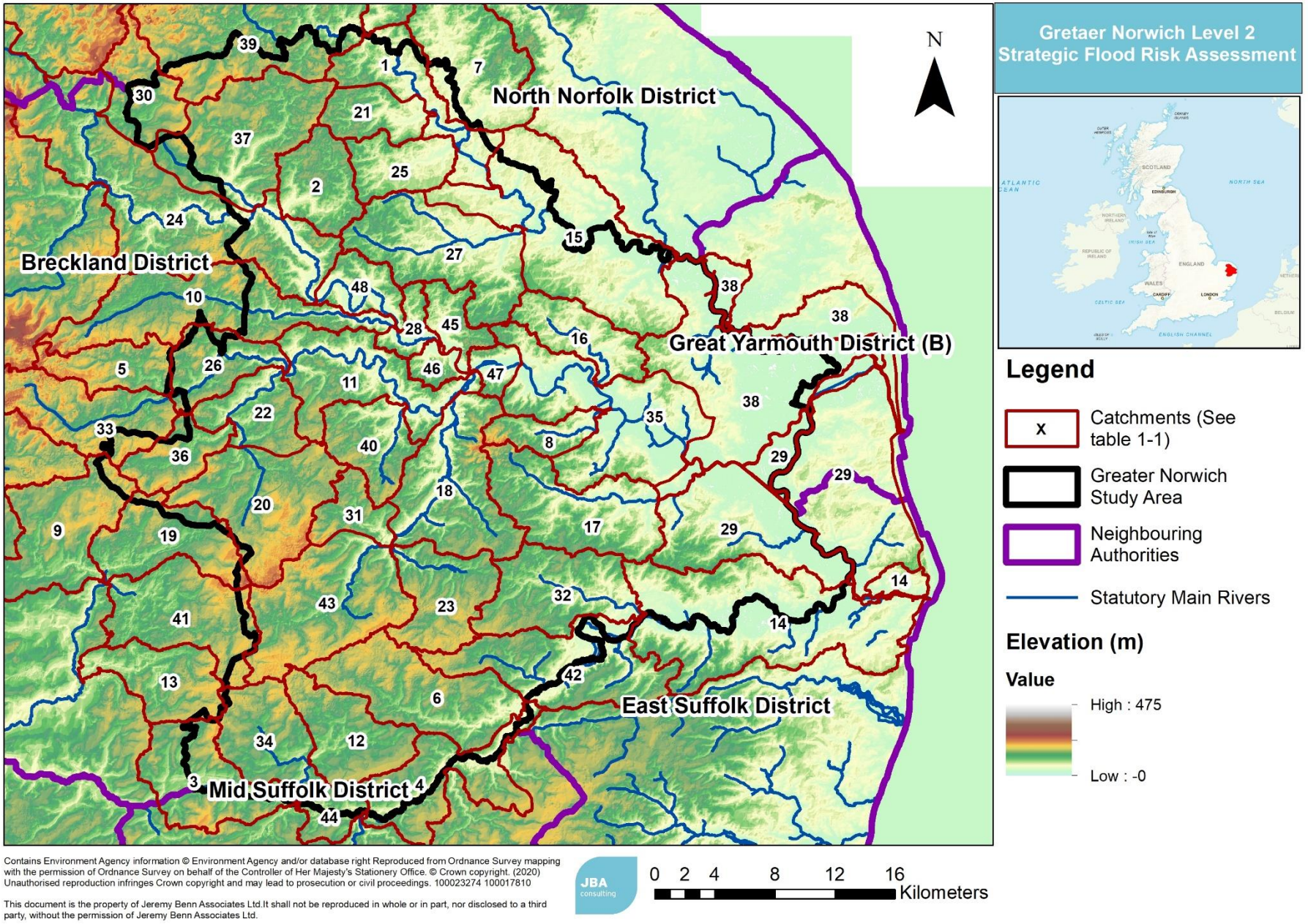

Figure 1-1 A map identifying catchments within the GNLP area and Neighbouring Authorities. Please refer to Table 1-1 for catchment names, as referred to in this assessment

Table 1-1 Catchment numbers and labels related to Figure 1-1

No.	Catchment	No.	Catchment
1	Bure (Scarrow Beck to Horstead Mill)	**25**	Hevingham Watercourse
2	Swannington Beck	**26**	Yare (u/s confluence with Tiffey - Lower)
3	Waveney (u/s Frenze Beck)	**27**	Spixworth (and Dobbs) Beck
4	Waveney (R Dove - Starston Brook)	**28**	Wensum Through Norwich (West)
5	Yare (u/s confluence with Tiffey - Upper)	**29**	River Waveney (Oulton Dyke to Breydon water) (not a WB Catchment)
6	Starston Brook	**30**	Foulsham Tributary
7	King's Beck	**31**	Tributary of Tas
8	Hellington Beck	**32**	Broome Beck
9	Stow Bedon Stream	**33**	Blackwater (Yare)
10	Tud	**34**	Frenze Beck
11	Yare (Tiffey to Wensum)	**35**	Yare (Wensum to tidal west)
12	Dickleburgh Stream	**36**	Hackford Watercourse
13	Whittle	**37**	Blackwater Drain (Wensum)
14	Waveney (Ellingham Mill - Burgh St. Peter)	**38**	River Bure (Cow Holm to Breydon water) (not a WB Catchment)
15	Bure (Horstead Mill to St Benet's Abbey)	**39**	Bure (u/s confluence with Scarrow Beck)
16	Witton Run	**40**	Intwood Stream
17	Chet	**41**	Buckenham Stream
18	Tas (Tasburgh to R. Yare)	**42**	Waveney (Starston Brook - Ellingham Mill)
19	Thet (US Swangey Fen)	**43**	Tas (Head to Tasburgh)
20	Tiffey (u/s Wymondham)	**44**	Waveney (Frenze Beck to Dove)
21	Mermaid Stream	**45**	Wensum Through Norwich (Catton Grove & Sewell)
22	Tiffey	**46**	Wensum Through Norwich (Nelson and Town Close)
23	Hempnall Beck	**47**	Yare (Wensum to tidal east)
24	Wensum US Norwich	**48**	Wensum US Norwich (Drayton)

1.3 Broadscale Cumulative Impact Assessment

The Greater Norwich Level 1 Strategic Flood Risk Assessment did not include a Cumulative Impact Assessment, therefore this report includes both a broadscale and catchment level assessment. The broadscale assessment determines where the cumulative impacts of development may have the biggest effect on flood risk based on historic and predicted flood risk. Catchments at the highest risk are taken forward to a catchment level analysis.

Future development sites within the Greater Norwich Area were provided by Norfolk County Council. This assessment used historic flooding data provided in September 2020 by Norfolk County Council. We are aware that flooding occurred in the GNLP area in December 2020, however point data was not available for use in this assessment. As there was a large number of historic flood incidents in the record (390), with the highest catchments having 20-40 recorded incidents, inclusion of the December 2020 record is unlikely to have significantly impacted the final rankings. Details of datasets used can be found in Table 1-2.

Table 1-2 Summary of datasets used within the Broadscale Cumulative Impact Assessment

Dataset	Coverage	Source of data	Use of data
Catchment Boundaries	Greater Norwich Study Area	Water Framework Directive Catchments Flood Estimation Handbook Norwich Surface Water Management Plan (2014)	Surface Water and Development Flood Risk
National Receptor Database (2014)	Greater Norwich Study Area	Environment Agency	Assessing the number of properties at risk of surface water flooding within each catchment
Risk of Surface Water Flooding Mapping	Greater Norwich Study Area	Environment Agency	Assessing the number of properties at risk of surface water flooding within each catchment
Future development areas	Greater Norwich Study Area	Norfolk County Council	Assessing the impact of proposed future development on risk of flooding.
Historic Flooding Incidents	Greater Norwich Study Area	Norfolk County Council	Assessing incidences of historic flooding within the GNLP study area.

1.3.1 Assessing sensitivity to surface water flood risk

To understand how sensitive a catchment is to potential increases in surface water flood risk, the relative increase in properties at risk in the 1,000-year event compared to the 100-year event was calculated. This does not show the absolute impact of development but it is used as an indicator of which catchments are more sensitive than others to anything that could increase flood

risk, which could include climate and land use changes alongside new development.

1.3.2 Assessing historic flooding incidents

Historic flooding data was supplied by Norfolk County Council as LLFA, detailing 'X, Y' coordinate data of historic flooding incidents within the Greater Norwich study area. The total number of historic flooding incidents within each catchment was recorded.

1.3.3 Assessing impacts of future development

Sites for future development within the Greater Norwich study area were provided by Norfolk County Council. The percentage of land covered by future development in each catchment was calculated. To ensure this was as up to date as possible, data on recent site completions, previous allocations and developments with planning permission that are not yet built out was also included in the assessment.

1.3.4 Assessment assumptions and limitations

The study has been undertaken using the best available data. The assumptions made in assessing and ranking the impacts of cumulative development on catchments within the Greater Norwich Study Area are summarised in Table 1-3.

Table 1-3 Assumption made in the broadscale cumulative impact assessment

Assessment aspect	Assumption made	Details of limitation in method	Justification of method used
Surface water flood risk	Total number of properties flooded	Assumption that all properties have been included in the 2014 NRD dataset. It may not include all new build properties.	This was the most up to date and accurate data available.
Historic Flooding incidents	Total number of historic events and severity of flooding	Only flooding incidents recorded that could be georeferenced with XY coordinates to produce GIS files. Each point represents a location where it is known there has been at least one flood incident. The severity of the historic flooding event relating to the point has not been considered, just the total number of points within each catchment where there has been a flood incident.	GIS data provided the most accurate results for the location of historic flooding incidents in the Greater Norwich local Plan Area.
Area of Catchment Covered by Future Development	All sites taken forward	All sites, including currently allocated and preferred and reasonable sites were included when calculating the area covered by future development.	This provides a reasonable worst case scenario for future development and allows the assessment to inform future decision making around sites not currently allocated but which may be included in future.

Assessment aspect	Assumption made	Details of limitation in method	Justification of method used
Area of Catchment Covered by Future Development	Brownfield sites included	Brownfield sites were assumed to have the same impact on surface water runoff as development in greenfield land. In reality, development on brownfield land is unlikely to significantly increase runoff and may actually cause runoff to decrease with the implementation of appropriate SuDS techniques.	This provides a conservative reasonable worst-case scenario. Furthermore, brownfield sites were generally far smaller than greenfield sites so this is unlikely to have significantly changed the final results.

1.3.5 Broadscale Cumulative Impact Assessment Outcomes

The final results of this assessment gave a rating of low, medium or high risk for each metric, for each catchment within the study area, the boundaries of which were derived from WFD and FEH datasets. Some catchments, notably those within the city centre, were divided to allow areas previously identified as Critical Drainage Areas in the Norwich Surface Water Management Plan to be studied in more detail. The rating of each catchment in each of these assessments was combined to give an overall ranking.

Table 1-4 shows the percentage of properties identified as high risk due to the increased risk of surface water flooding within each catchment, Table 1-5 shows the percentage of the catchments covered by future planned development and Table 1-6 shows the highest risk catchments based on the number of historic flooding incidents recorded.

Table 1-4 Percentage of properties in a catchment sensitive to increased surface water flood risk

Catchment	Properties sensitive to increased surface water flood risk (%)
Tributary of Tas	6.0
Dickleburgh Stream	5.9
Foulsham Tributary	5.9
Broome Beck	5.7
Wensum Through Norwich (Nelson & Town Close)	5.4
Waveney (R Dove - Starston Brook)	5.4
Starston Brook	5.3
Wensum Through Norwich (Catton Grove & Sewell)	5.1
Waveney (Frenze Beck to Dove)	4.9
Tas (Tasburgh to R. Yare)	4.8
Whittle	4.7
Hempnall Beck	4.6
Tas (Head to Tasburgh)	4.6

Frenze Beck	4.1
Thet (Upstream of Swangey Fen)	4.0

Table 1-5 Percentage of catchment covered by future planned development

Catchment	Area of catchment for development (%)
Tiffey (Upstream of Wymondham)	15.8
Yare (Tiffey to Wensum)	12.9
Wensum Upstream of Norwich (Drayton)	7.0
Wensum Through Norwich (West)	6.0

Table 1-6 Number of recorded historic flooding incidents within a catchment

Catchment	No. of historic incidents
River Waveney (Oulton Dyke to Breydon water) (not a WB Catchment)	44
Spixworth (and Dobbs) Beck	34
Wensum Through Norwich (Catton Grove & Sewell)	34
Witton Run	32
Wensum Through Norwich (West)	25
Thet (Upstream of Swangey Fen)	23
Wensum Through Norwich (Nelson and Town Close)	21
Yare (Wensum to tidal east)	19
River Bure (Cow Holm to Breydon water) (not a WB Catchment)	19

As can be seen from the above tables, there are catchments that are at high risk in multiple categories. Rankings from each assessment have been combined to give an overall ranking.

A map of this is shown in Figure 1-2 and results are outlined below.

The catchments rated as high-risk in the broadscale Assessment are:

- Wensum through Norwich (Catton Grove & Sewell)
- Wensum through Norwich (Nelson & Town Close)
- Wensum through Norwich (West)
- Tiffey (Upstream of Wymondham STW)
- Yare (Tiffey to Wensum)

26 catchments were identified as medium risk. These are identified within Figure 1-2, however those identified at highest risk within the medium band were:

- Spixworth (and Dobbs) Beck
- Wensum Upstream of Norwich (Drayton)
- Yare (Wensum to Tidal)

Policy recommendations for these catchments can be found in section 1.8.

Catchments identified as high risk were taken forward for further the Catchment Level Cumulative Impact Assessment.

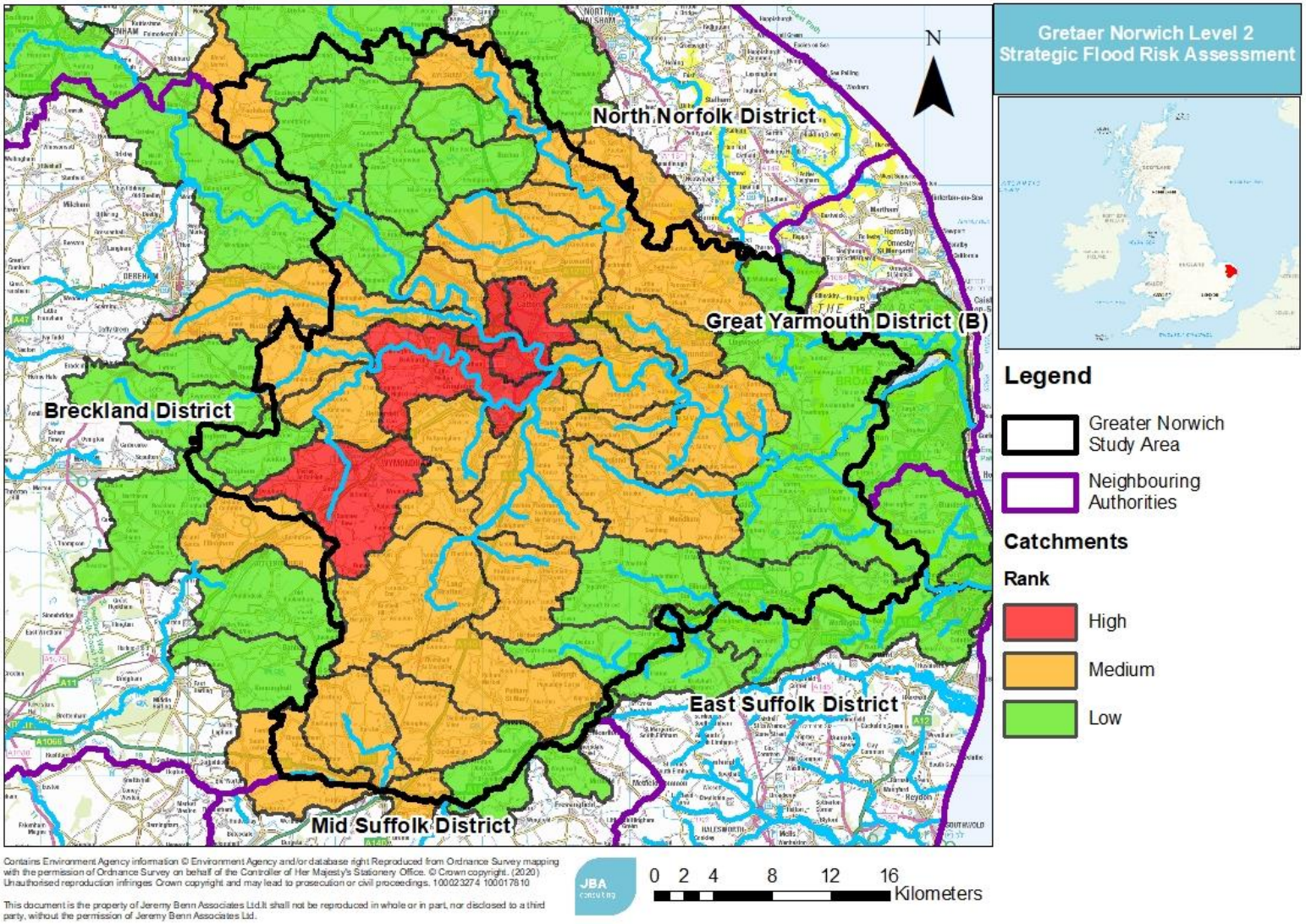

Figure 1-2 Map showing the results of the broadscale cumulative impact assessment for each catchment within the Greater Norwich study area

1.4 Proposed development in Greater Norwich

For the broadscale assessment, a conservative approach was taken, including all allocated and preferred and reasonable sites for development. For the catchment level assessment this was refined to focus on currently allocated sites.

Of the currently allocated sites (including those adopted under the Long Stratton & Wymondham, and The Growth Triangle area action plans) 89 of these sites fall within the high-risk catchment boundaries. 79 of these sites lie wholly within a single catchment whilst ten sites extend across multiple catchment boundaries. Table 1-7 displays the allocated development sites and the catchments that each site falls within.

Table 1-7 Site Areas within high-risk catchments

Site Ref	Catchment 1	area within catchment (ha)	% site within catchment	Catchment 2	area within catchment (ha)	% site within catchment
BAW 1	Yare (Tiffey to Wensum)	0.38	100%	-	-	-
CC1	Wensum Through Norwich (Nelson & Town Close)	0.19	100%	-	-	-
CC10	Wensum Through Norwich (Nelson & Town Close)	1.08	100%	-	-	-
CC11	Wensum Through Norwich (Nelson & Town Close)	0.32	100%	-	-	-
CC12	Wensum Through Norwich (Catton Grove & Sewell)	0.23	100%	-	-	-
CC13	Wensum Through Norwich (Catton Grove & Sewell)	1	100%	-	-	-
CC14	Wensum Through Norwich (Catton Grove & Sewell)	0.45	100%	-	-	-
CC15	Wensum Through Norwich (Catton Grove & Sewell)	1.52	100%	-	-	-
CC16	Wensum Through Norwich (Catton Grove & Sewell)	2.22	100%	-	-	-
CC18 (CC19)	Wensum Through Norwich (West)	0.36	100%	-	-	-
CC2	Wensum Through Norwich (Nelson & Town Close)	0.18	100%	-	-	-
CC20	Wensum Through Norwich (West)	0.23	100%	-	-	-
CC21	Wensum Through Norwich (Nelson & Town Close)	0.84	100%	-	-	-
CC22	Wensum Through Norwich (Nelson & Town Close)	0.42	100%	-	-	-
CC23	Wensum Through Norwich (Nelson & Town Close)	0.07	100%	-	-	-
CC24	Wensum Through Norwich (Nelson & Town Close)	0.4	100%	-	-	-
CC25	Wensum Through Norwich (Nelson & Town Close)	0.28	100%	-	-	-
CC26	Wensum Through Norwich (Nelson & Town Close)	0.18	100%	-	-	-
CC27	Wensum Through Norwich (Nelson & Town Close)	1.5	100%	-	-	-
CC28	Wensum Through Norwich (Nelson & Town Close)	0.13	100%	-	-	-
CC29	Wensum Through Norwich (Nelson & Town Close)	0.5	100%	-	-	-
CC3	Wensum Through Norwich (Nelson & Town Close)	0.11	100%	-	-	-

Site Ref	Catchment 1	area within catchment (ha)	% site within catchment	Catchment 2	area within catchment (ha)	% site within catchment
CC30	Wensum Through Norwich (Nelson & Town Close)	0.3	100%	-	-	-
CC4a	Wensum Through Norwich (Nelson & Town Close)	1.2	100%	-	-	-
CC4b	Wensum Through Norwich (Nelson & Town Close)	2.39	100%	-	-	-
CC5	Wensum Through Norwich (Nelson & Town Close)	0.11	100%	-	-	-
CC6	Wensum Through Norwich (Nelson & Town Close)	2.07	100%	-	-	-
CC7	Wensum Through Norwich (Nelson & Town Close)	0.35	100%	-	-	-
CC8	Wensum Through Norwich (Nelson & Town Close)	0.21	100%	-	-	-
CC9	Wensum Through Norwich (Nelson & Town Close)	0.18	100%	-	-	-
COL 1	Yare (Tiffey to Wensum)	38.79	100%	-	-	-
COL 3	Yare (Tiffey to Wensum)	44.32	100%	-	-	-
COS 1	Yare (Tiffey to Wensum)	29.74	100%	-	-	-
EAS 1	Yare (Tiffey to Wensum)	34.02	65%	Tud	18.31	35%
GNLP0068	Wensum Through Norwich (Catton Grove & Sewell)	0.12	100%	-	-	-
GNLP0133BR	Yare (Tiffey to Wensum)	1.29	100%	-	-	-
GNLP0133C	Yare (Tiffey to Wensum)	0.89	100%	-	-	-
GNLP0133DR	Yare (Tiffey to Wensum)	3.96	100%	-	-	-
GNLP0133E	Yare (Tiffey to Wensum)	1.6	100%	-	-	-
GNLP0140C/COL2	Yare (Tiffey to Wensum)	4.24	100%	-	-	-
GNLP0177A/HET1	Yare (Tiffey to Wensum)	49.39	75%	Intwood Stream	16.31	25%
GNLP0253	Yare (Tiffey to Wensum)	24.99	100%	-	-	-
GNLP0282	Wensum Through Norwich (Catton Grove & Sewell)	0.27	100%	-	-	-
GNLP0307	Yare (Tiffey to Wensum)	44.07	100%	-	-	-
GNLP0327	Yare (Tiffey to Wensum)	4.89	58%	Intwood Stream	3.58	42%
GNLP0331BR	Yare (Tiffey to Wensum)	1.26	100%	-	-	-
GNLP0331CR	Yare (Tiffey to Wensum)	5.59	100%	-	-	-
GNLP0354R	Tiffey (Upstream of Wymondham)	5.39	100%	-	-	-
GNLP0360/3053/R10*	Wensum Through Norwich (Nelson & Town Close)	2.41	11%	Yare (Tiffey to Wensum)	18.94	89%
GNLP0401	Wensum Through Norwich (Nelson & Town Close)	0.83	100%	-	-	-
GNLP0409AR/CC17b	Wensum Through Norwich (Catton Grove & Sewell)	1.61	100%	-	-	-
GNLP0409B/CC17a	Wensum Through Norwich (Catton Grove & Sewell)	2.17	100%	-	-	-
GNLP0451	Wensum Through Norwich (Nelson & Town Close)	0.38	100%	-	-	-
GNLP0497	Yare (Tiffey to Wensum)	6.9	100%	-	-	-
GNLP0506	Wensum Through Norwich (Catton Grove & Sewell)	4.75	99%	Wensum Through Norwich (West)	0.04	1%
GNLP1019/HEL4	Wensum Through Norwich (West)	7.67	66%	Spixworth (and Dobbs) Beck	3.97	34%
GNLP1020/HEL3	Wensum Through Norwich (West)	0.01	1%	Wensum US of Norwich (Drayton)	1.26	0.991105
GNLP2043/0581	Yare (Tiffey to Wensum)	62.42	100%	-	-	-
GNLP2114	Wensum Through Norwich (Catton Grove & Sewell)	0.55	100%	-	-	-

Site Ref	Catchment 1	area within catchment (ha)	% site within catchment	Catchment 2	area within catchment (ha)	% site within catchment
GNLP2163	Wensum Through Norwich (Catton Grove & Sewell)	0.13	100%	-	-	-
GNLP2164	Wensum Through Norwich (Catton Grove & Sewell)	0.19	100%	-	-	-
GNLP3054	Wensum Through Norwich (West)	1.05	100%	-	-	-
HEL2	Wensum Through Norwich (West)	23.67	50%	Wensum US of Norwich (Drayton)	23.27	50%
HEL5	Wensum Through Norwich (Catton Grove & Sewell)	2.73	100%	-	-	-
HET 4	Yare (Tiffey to Wensum)	5.83	100%	-	-	-
HET2	Yare (Tiffey to Wensum)	4	100%	-	-	-
HETHEL 1/2**	Tiffey (Upstream of Wymondham)	51.53	82%	Tributary of Tas	10.48	17%
KES 1	Yare (Tiffey to Wensum)	0.53	100%	-	-	-
KES 2	Yare (Tiffey to Wensum)	13.02	100%	-	-	-
LIT 1	Yare (Tiffey to Wensum)	1.97	100%	-	-	-
R1	Yare (Tiffey to Wensum)	4.51	100%	-	-	-
R11	Wensum Through Norwich (Catton Grove & Sewell)	4.64	100%	-	-	-
R12	Wensum Through Norwich (Catton Grove & Sewell)	0.96	100%	-	-	-
R13	Wensum Through Norwich (Catton Grove & Sewell)	0.3	100%	-	-	-
R14/15	Wensum Through Norwich (Catton Grove & Sewell)	1.65	100%	-	-	-
R16	Wensum Through Norwich (Catton Grove & Sewell)	0.11	100%	-	-	-
R17	Wensum Through Norwich (Catton Grove & Sewell)	0.54	100%	-	-	-
R18	Wensum Through Norwich (Catton Grove & Sewell)	0.86	100%	-	-	-
R19	Wensum Through Norwich (Catton Grove & Sewell)	0.19	100%	-	-	-
R2	Yare (Tiffey to Wensum)	0.78	100%	-	-	-
R20	Wensum Through Norwich (Catton Grove & Sewell)	0.27	100%	-	-	-
R21	Wensum Through Norwich (Catton Grove & Sewell)	3.47	100%	-	-	-
R22	Wensum Through Norwich (Catton Grove & Sewell)	0.86	100%	-	-	-
R23	Wensum Through Norwich (Catton Grove & Sewell)	0.23	79%	Wensum Through Norwich (West)	0.06	21%
R24	Wensum Through Norwich (West)	0.47	100%	-	-	-
R25	Wensum Through Norwich (West)	0.58	100%	-	-	-
R26	Wensum Through Norwich (West)	1	99%	Wensum Through Norwich (Nelson & Town Close)	0.01	1%
R27	Wensum Through Norwich (Nelson & Town Close)	1.2	100%	-	-	-
R28	Wensum Through Norwich (West)	0.36	100%	-	-	-
R29A/B	Wensum Through Norwich (Catton Grove & Sewell)	2.28	100%	-	-	-
R3	Yare (Tiffey to Wensum)	3.43	100%	-	-	-
R30	Wensum Through Norwich (West)	1.33	100%	-	-	-

Site Ref	Catchment 1	area within catchment (ha)	% site within catchment	Catchment 2	area within catchment (ha)	% site within catchment
R31	Wensum Through Norwich (West)	1.37	100%	-	-	-
R32	Wensum Through Norwich (West)	0.46	100%	-	-	-
R33	Wensum Through Norwich (West)	0.14	100%	-	-	-
R34	Wensum Through Norwich (West)	0.61	100%	-	-	-
R36	Wensum Through Norwich (West)	4.4	100%	-	-	-
R37	Wensum Through Norwich (West)	5.3	100%	-	-	-
R38	Yare (Tiffey to Wensum)	25.22	100%	-	-	-
R39	Yare (Tiffey to Wensum)	2.19	100%	-	-	-
R4	Yare (Tiffey to Wensum)	0.44	100%	-	-	-
R40	Yare (Tiffey to Wensum)	1.79	100%	-	-	-
R41	Yare (Tiffey to Wensum)	2.85	100%	-	-	-
R42	Yare (Tiffey to Wensum)	3.4	100%	-	-	-
R5	Yare (Tiffey to Wensum)	1.08	100%	-	-	-
R6	Wensum Through Norwich (Nelson & Town Close)	0.22	100%	-	-	-
R7	Wensum Through Norwich (Nelson & Town Close)	0.89	100%	-	-	-
R8	Wensum Through Norwich (Nelson & Town Close)	1.12	100%	-	-	-
R9	Wensum Through Norwich (Nelson & Town Close)	2.03	31%	-	-	-
R9	Yare (Tiffey to Wensum)	6.59	100%	-	-	-
TROW 1	Yare (Tiffey to Wensum)	9.37	100%	-	-	-
WYM 1	Tiffey (Upstream of Wymondham)	0.53	100%	-	-	-
WYM 2	Tiffey (Upstream of Wymondham)	1.88	100%	-	-	-
WYM 3	Tiffey (Upstream of Wymondham)	5.62	100%	-	-	-
WYM 3 & 13	Tiffey (Upstream of Wymondham)	58.14	100%	-	-	-
WYM 5	Tiffey (Upstream of Wymondham)	11.05	100%	-	-	-
WYM 5	Tiffey (Upstream of Wymondham)	10.86	100%	-	-	-
WYM 6	Tiffey (Upstream of Wymondham)	5.16	100%	-	-	-

*15% also Yare (Wensum to Tidal) **<1% also in Intwood Stream Catchment

1.5 Methodology

In the catchment level assessment, a detailed analysis of the high risk catchments, as identified in the broadscale assessment, is undertaken. Hydrographs are plotted to determine the impact of development on peak flows within the catchment. Other factors, such as the catchments existing urban extent, topography and location within the wider river drainage network, are also considered to determine policy recommendations to address the specific risks within the catchment.

1.5.1 Impact of proposed development

To ascertain the impact of the proposed development on downstream flows, catchment descriptors from the FEH Webservice were downloaded for each catchment. These catchment descriptors were then amended to account for modification to the catchment boundaries based on topography data and for the proposed development in the catchment. The URBEXT (urban extent) value was increased in line with the total area of development proposed in the catchment. The imperviousness factor was assumed to be 0.4 across all catchments. This value assumes that 40% of built up areas in the catchment is covered by impermeable surfaces.

From this information hydrographs showing the flood response in both a pre-development and post-development scenario in each catchment were generated for the 100-year flood event. It should be noted that these hydrographs have been derived from ReFH2 using catchment descriptors only, a detailed hydrological assessment to obtain these hydrographs has not been undertaken.

The pre- and post-development hydrographs produced with REFH2 were compared to calculate the additional volume of storm water passing through the catchment as a result of increased impermeable surfaces from development. This value represents the volume of on-site storage required across the whole catchment to limit peak flow rates to the existing greenfield response. An additional scenario was calculated for each catchment hydrograph to show the potential impacts of the installation of SuDS across a catchment in a post-development scenario. Peak hydrograph flow was limited to pre-development levels and the additional volume generated in the post-development scenario was added onto the falling limb of the hydrograph. The results display how SuDS can limit the peak flow and release excess stormflows through the catchment at a lower rate, potentially reducing flood risk downstream.

1.5.2 Assessing the storage need at potential development sites

The UK SuDS Website provides a variety of tools for the design and evaluation of sustainable drainage systems. The surface water storage volume estimation tool was used to provide estimates of storage volume requirements needed to meet best practice criteria from Environment Agency guidance "Rainfall runoff management for developments", SC030219 (2013), the SuDS Manual C753 (CIRIA, 2015) and the non-statutory technical standards for SuDS (Defra, 2015). It should be noted that the estimates from this tool should not be used for the detailed design of drainage systems and sewer modelling is recommended when designing a drainage scheme.

The tool works by selecting a point on a map for the calculation and entering characteristics for the proposed development site. For this assessment, the most downstream point of each catchment was selected, the site area was entered, and a developable area/ impermeable area was assumed based on council recommendations and similar values from neighbouring authority SHLAA methodologies. The impermeable area of the site was assumed to be 70% of the total site area for both residential and employment sites.

All other variables in the tool were left as default, to avoid a large number of assumptions. The REFH2 method to calculate surface water storage requirements was used to allow comparison to the catchment scale assessment.

Where a site only partially fell into a high risk catchment, storage estimations have been provided for two scenarios: the first assuming that the entire site will discharge into the chosen catchment and the second assuming only the proportion of the site within the catchment will discharge to this catchment, with the rest discharging to another catchment. In reality, a site will generally discharge all to one catchment and where a site will discharge to is not yet known, this should be considered at a site-specific stage.

These analyses are carried out for the purpose of developing strategic planning policy by highlighting the need for considering drainage amongst sites or groups of sites within a catchment. It is not intended at this stage to set out the absolute level of storage that must be provided at site level because specific information about development sites is not yet known, such as how much of the site will be developed and in what way, as well as information on underlying geological and soil conditions based on ground investigations. At a site-level, developers will need to undertake detailed drainage strategies to refine calculations of the amount of storage required on site. In line with national planning policy and national requirements for SuDS, storage will always be required for the 100-year plus applicable climate change event. Whether any additional storage would benefit downstream areas depends on where the site is located within the catchment.

1.6 Cumulative impact within high risk catchments

1.6.1 Tiffey Upstream of Wymondham

Two main rivers flow through the Catchment. The Tiffey rises in the east of the catchment and flows west through rural land towards Wymondham.

The Bays river rises near Spooner Row in the southwest of the Catchment and flows North through rural land towards Wymondham, joined by multiple small streams and channels, before joining the Tiffey at Wymondham.

After the confluence the Tiffey flows north, west of Wymondham, before crossing under the B115.

There are nine sites currently allocated or included within the South Norfolk Area Action plan that lie within, or partially within the Tiffey (Upstream of Wymondham) catchment. Eight of the sites within the catchment are located around Wymondham in the lower catchment, close to the confluence with Bays River. The remaining site, HETHEL 1 is located in the east of the catchment near the headwaters of the Tiffey. These cover 2.5% of the catchment area, with HETHEL 1 crossing into the neighbouring catchment of a Tributary of the Tas, as shown in Table 1-7. Three further sites (GNLP2168, GNLP0515, and GNLP1055) were identified as preferred and reasonable sites. These cover 13.3% of the catchment, comprising land immediately south and east of Wymondham.

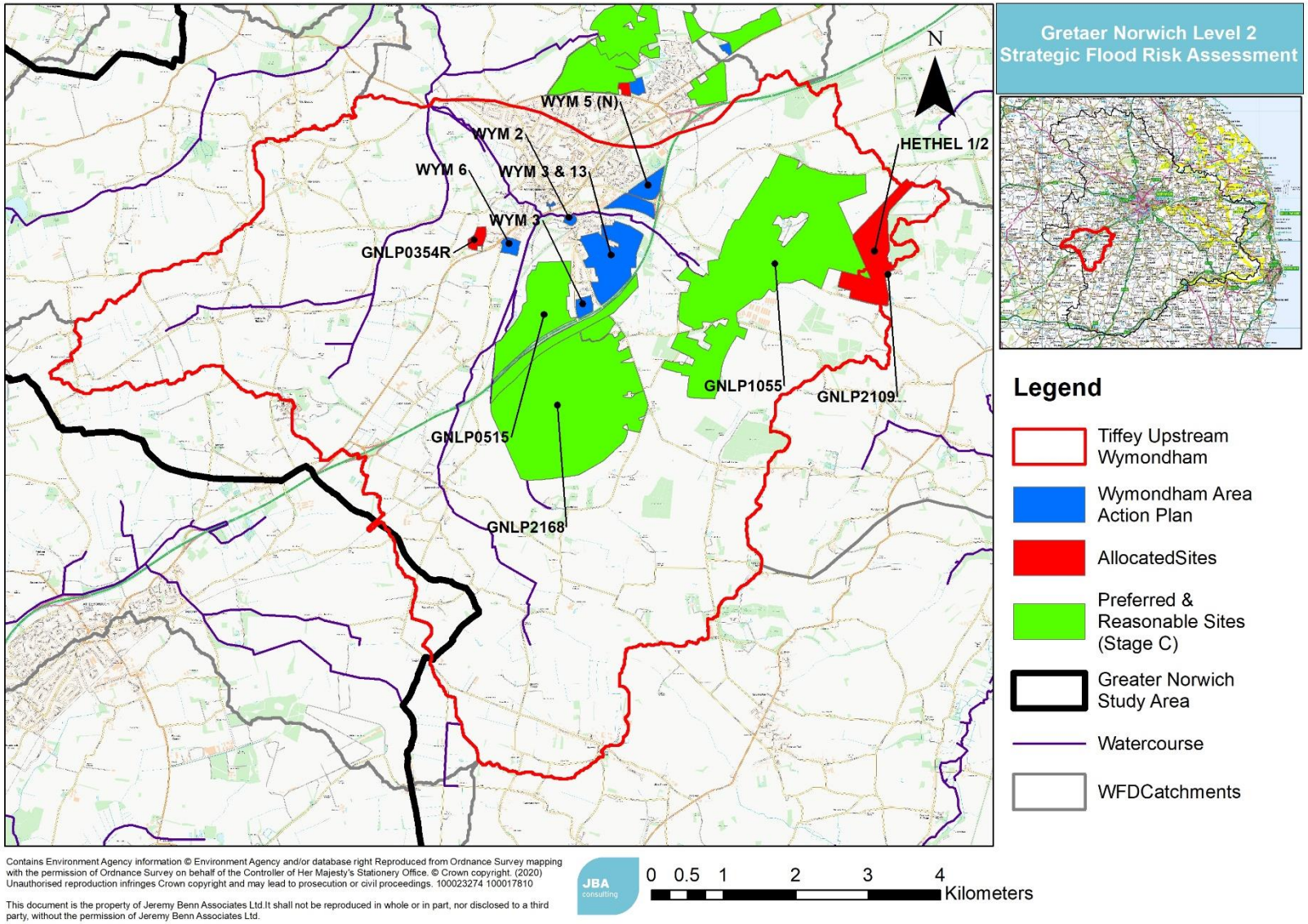

Figure 1-3 A map of proposed development within the Tiffey (Upstream of Wymondham) catchment

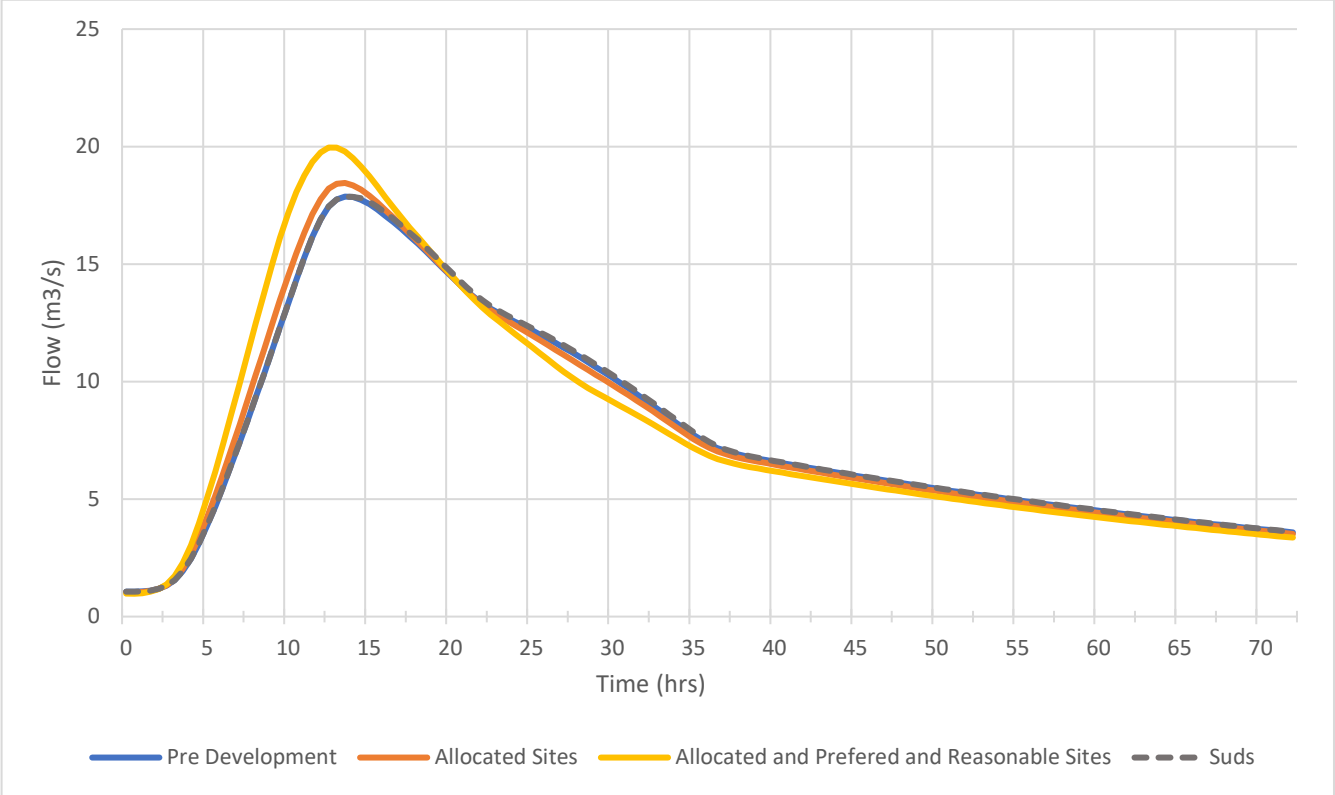

Figure 1-4 Pre- and post-development and SuDs hydrographs in the Tiffey (Upstream of Wymondham) catchment

The Tiffey (upstream of Wymondham) is a relatively small catchment, draining approximately 59.7km^2 at the confluence with Dyke Beck. The catchment is also predominantly rural, currently estimated to contain an urban extent of just 1.9km^2. As such, currently proposed development within the catchment can be seen to have a substantial impact on peak flows from the hydrograph (Figure 1 4). Assuming no mitigation takes place, development of the currently allocated sites could increase peak flows by around 3% during the 100-year event. Furthermore, should the large sites (GNLP2168, GNLP0515, and GNLP1055) be taken forward, without mitigation peak flows could increase by as much as 10% in the 100-year event. SuDS can help to reduce flood risk by storing excess runoff caused by urbanisation and discharging it slowly. The hydrograph above demonstrates how SuDS applied appropriately to development in the catchment could limit peak flows to their current levels and ensure there is no increase in risk downstream as a result of development.

Table 1-8 Estimated storage volumes required at sites in the Tiffey (Upstream of Wymondham) catchment, taken from the UK SUDS website

Settlement	Site	Attenuation Storage 1 in 100 years (m^3)	Long Term Storage 1 in 100 years (m^3)	Total Storage 1 in 100 years (m^3)
Wymondham	GNLP0354R	2385	0	2385
	HETHEL 1/2	9770*	0	9770
		11757**	0	11757*
	WYM 1	192	0	192
	WYM 2	329	0	329
	WYM 3	2486	0	2486
	WYM 3 & 13	25721	0	25721
	WYM 5 (South)	4888	0	4888
	WYM 5 (North	4805	0	4805
	WYM 6	2283	0	2283

**Storage assuming only site area within the Tiffey (Upstream of Wymondham) is being discharged to the catchment, with the remaining site area discharging to another catchment*

***Storage assuming entire site is discharged into the Tiffey (Upstream of Wymondham) catchment*

1.6.2 Yare (Tiffey to Wensum)

The River Yare is joined by the Tiffey just east of Barford and flows east through rural land toward Norwich. In the lower catchment, the area becomes more urbanised. The Yare joins the Wensum just south of Norwich city centre.

There are 37 sites that lie within, or partially within the Yare (Tiffey to Wensum) catchment, shown in Figure 1-5Figure 1-5. Several sites are located on the north edge of Hethersett, several large greenfield sites are located along the A47, which cuts across the centre of the catchment from north to south. The remaining sites are generally smaller sites within the existing urban area on the east bank of the river. These cover 9.5% of the catchment area, with four sites crossing into neighbouring catchments, as shown in Table 1-2.

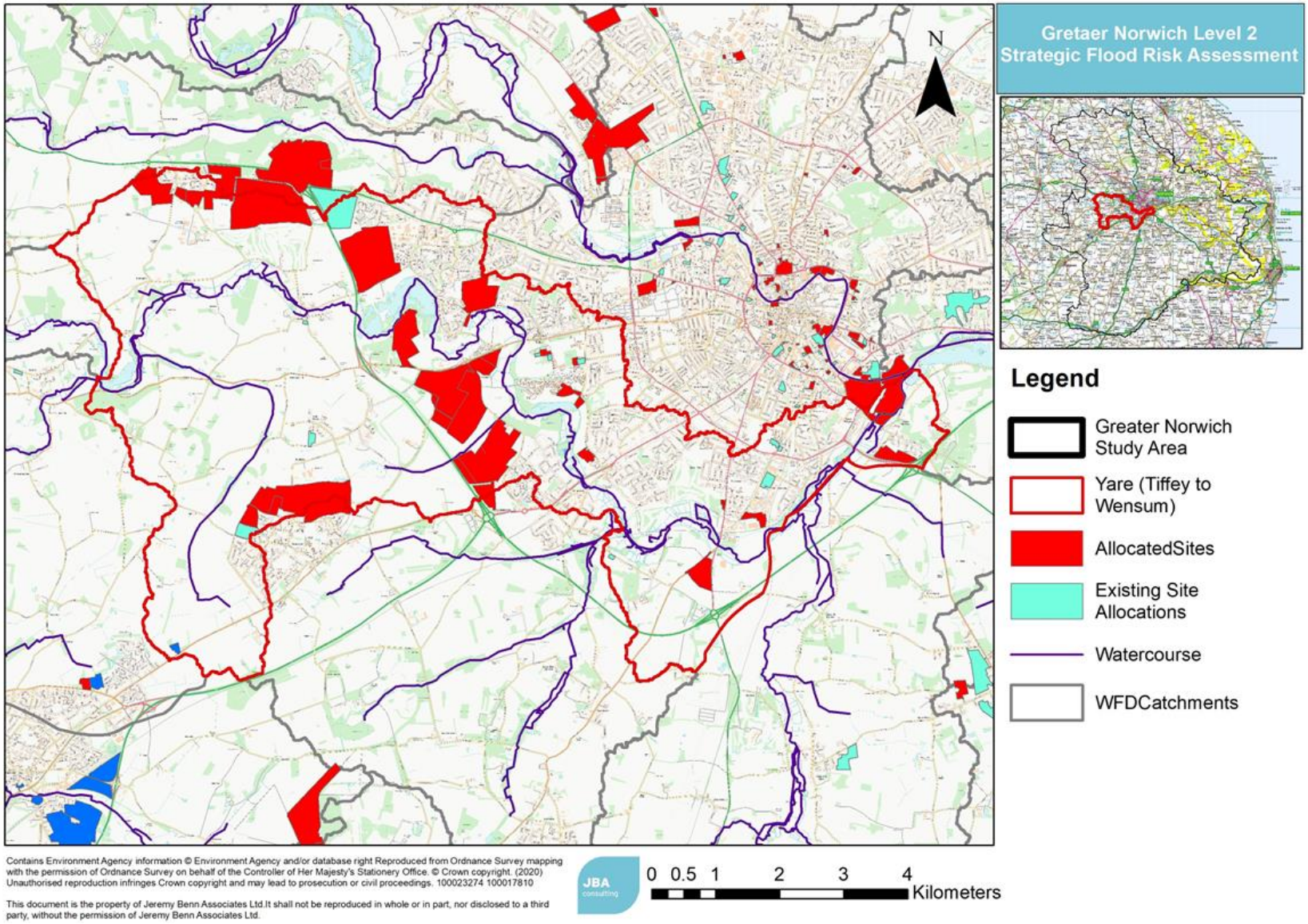

Figure 1-5 A map of proposed development with the Yare (Tiffey to Wensum) catchment

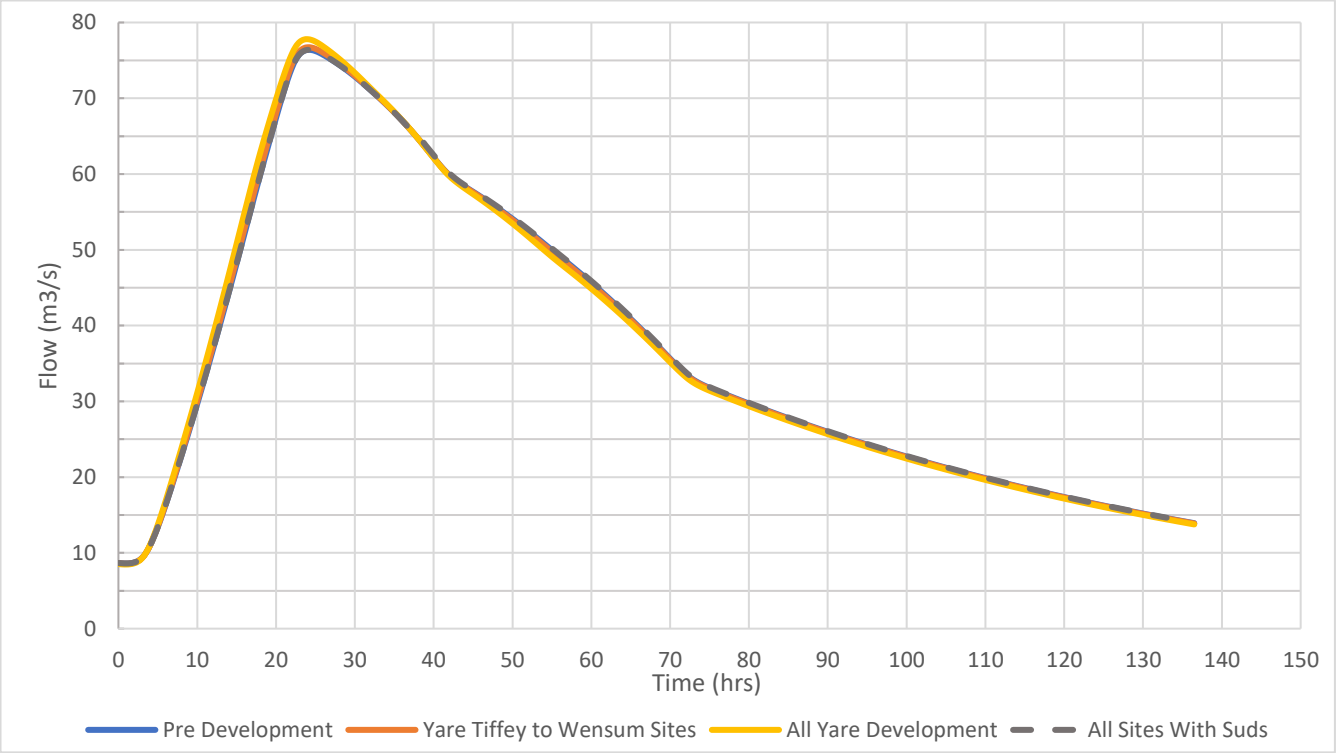

Figure 1-6 Pre- and post-development and SuDs hydrographs in the Yare (Tiffey to Wensum) catchment

The Yare is a large catchment, draining approximately 470km^2 at the confluence with River Wensum. The catchment is also predominantly rural, currently estimated to contain an urban extent of just 18.5km^2. As such, currently proposed development within the Yare (Tiffey to Wensum) sub-catchment will have only a minimal impact on flows within the river Yare. As can be seen from the hydrograph (Figure 1-6), even when developments within the whole Yare catchments are taken into account, there remains only a minimal increase in peak flows within the Yare. Regardless, use of SuDS is still necessary to help manage surface risk in line with national and local requirements.

As the Yare (Tiffey to Wensum) sub-catchment is relatively low in the Yare catchment and several sites are located within close proximity to the river, loss of floodplain storage has greater potential to increase flood risk downstream than increased runoff. As such, site specific storage volumes have not been calculated in this assessment. Any development within Yare (Tiffey to Wensum) sub-catchment should identify potential areas of floodplain loss as a result of development and either avoid developing in those areas or provide compensatory storage onsite.

1.6.3 Wensum through Norwich

The River Wensum flows through Norwich city centre towards its confluence with the River Yare just south of the city. For the broadscale assessment, the catchment was divided into three parts (East, Catton Grove & Sewell and Nelson & Town Close) to allow existing Critical Drainage Areas to be assessed independently. As all three constituent catchments were independently ranked as high risk during the broadscale assessment, they are considered together for the catchment level assessment. There are 75 currently allocated sites that lie within, or partially within the Wensum (Through Norwich) catchment, shown in Figure 1-7. A further 6 sites were previously identified as preferred or reasonable sites. These sites are spread throughout the city centre and are generally clustered around the river. There are also several sites in the north of the catchment, along the A140. Collectively, the sites cover 141.0 ha (4.3% of the catchment area).

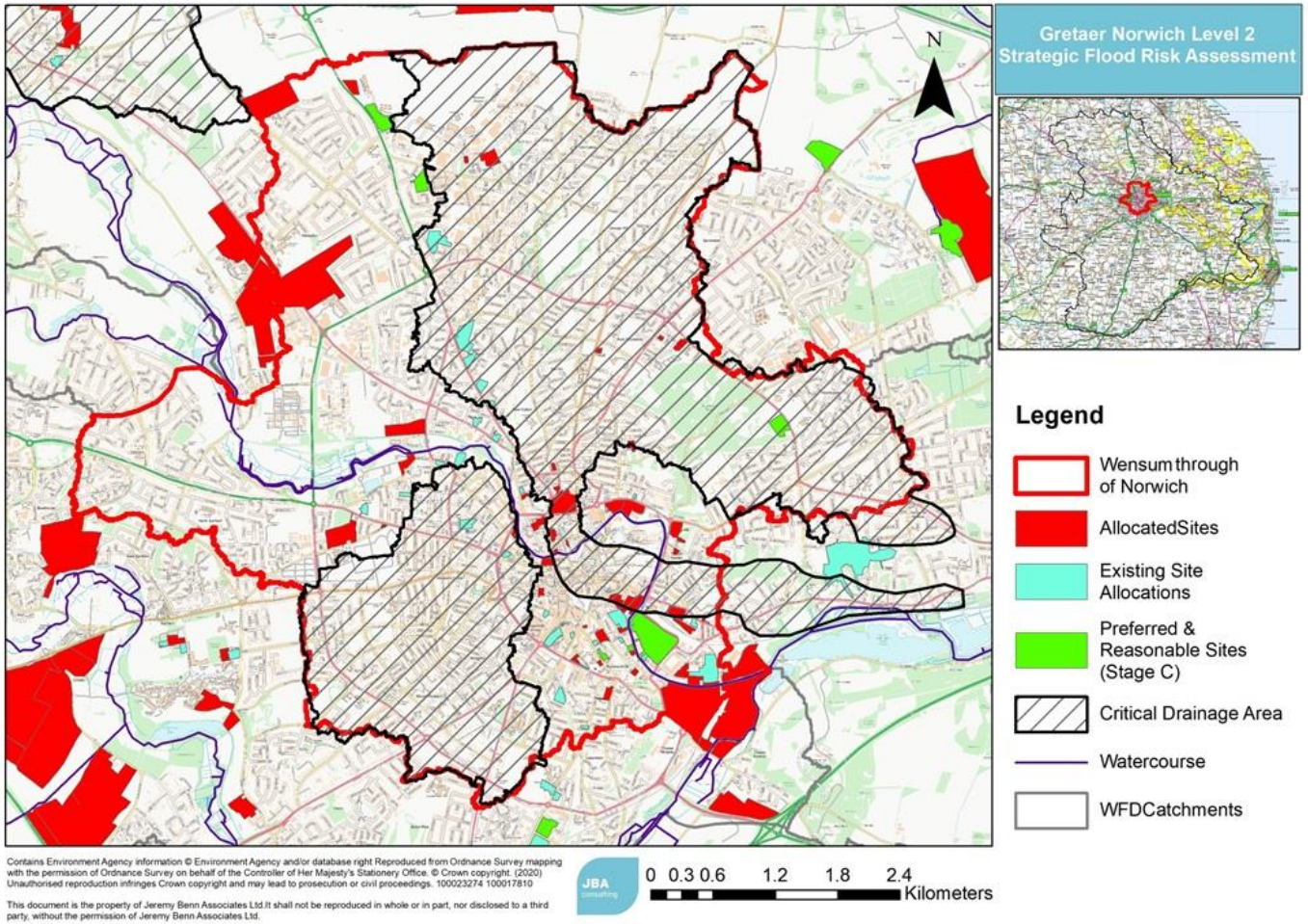

Figure 1-7 A map of proposed development within the Wensum (Through Norwich) catchment

FEH Webservice catchment descriptor data is unavailable for these catchments because the river is subject to tidal influences in this area. Therefore, hydrographs cannot be plotted.

As the majority of sites within this catchment are brownfield, there is likely to be a limited increase in runoff rates as a result of development. Furthermore, should development include SUDS elements, it is possible that runoff rates may actually decrease.

As Norwich is relatively low in the Wensum catchment and several sites are located within close proximity to the river, loss of floodplain storage has greater potential to increase flood risk downstream than increased runoff. As such, site specific storage volumes have not been calculated in this assessment.

1.7 Neighbouring District Developments

Excepting a small part of the Tiffey (Upstream of Wymondham) catchment, the catchments identified as high risk do not cross into neighbouring authorities, and therefore there is very little risk of developments within neighbouring authorities increasing flood risk within these catchments.

Several catchments identified as medium risk do cross into neighbouring authorities however and consideration should be taken to the cumulative impacts of developments proposed within these catchments by neighbouring authorities. In particular, most of the upper Tud catchment is within Breckland District. Several sites are located in the lower part of the catchment, which could be impacted by larger developments upstream.

1.8 GNLP Area wide policy recommendations on cumulative impact

The cumulative impact analysis has highlighted the importance of managing both the rate and volume of surface water runoff from new developments to mitigate the impact of flood risk along watercourses. Where reasonably practical, all new development should control both the rate and volume of runoff to greenfield characteristics. Where the developer can demonstrate it is not reasonably practical, runoff must be discharged at a rate that does not adversely affect flood risk. There are two general alternative approaches to meeting this requirement:

- Long Term Storage - the development should discharge surface water for the 1 in 1 year rainfall event and the 1 in 100-year rainfall event at peak greenfield runoff rates for the same event and discharge the difference in runoff volume pre- and post-development for the 100-year six hour event in long-term storage at a maximum rate of 2 l/s/ha.
- Restricted Discharge – the development shall discharge surface water at 2 l/s/ha or Qbar, whichever is greater, for all storms up to the critical 100-year event.

The size of development sites and their location within a catchment will impact the effect that it will have on catchment response to storm events. In line with national planning policy and the national requirements for SuDS, storage will always be required for the 100-year plus applicable climate change allowance event. Whether any additional storage would benefit downstream areas depends on where the site is located within the catchment and has been explored below.

In rural catchments draining towards urban areas, particularly those upstream of central Norwich, LPAs should work closely with the Environment Agency and LLFA to identify any areas of land that should be safeguarded for the future use of natural flood management features and flood storage.

It is also important to note that in rural catchments, farming practices can also have a significant impact on runoff rates and flood risk downstream, and Local Authorities

should seek to promote Catchment Sensitive Farming and Natural Flood Management techniques within rural upstream catchments.

1.9 Catchment specific recommendations for storage and betterment

From analysing the results produced above, high-level recommendations for flood storage and betterment have been proposed for sites in each of the high-risk catchments. These recommendations should be considered by developers as part of a site-specific assessment, but more detailed modelling must be undertaken by the developer to ascertain the true storage needs and potential at each site at the planning application stage. Developers should also include a construction surface water management plan to support the Construction Drainage Phasing Plan. This should provide information to the Environment Agency, LLFA and the LPA regarding the proposed management approach during the construction phase to address surface water management during storm events.

1.9.1 Tiffey upstream of Wymondham

There are nine sites currently allocated or included within Wymondham Area Action Plan. Seven of the sites are located around the south of Wymondham, in the lower catchment, and two are located further to the west. A further three large sites were previously identified as preferred and reasonable sites for development and are located immediately south and east of Wymondham. Should these sites be developed in future, this should be accompanied by an overall Surface Water Management Masterplan and Strategy. Details of what this should include can be found in 1.9.2.

The opportunity should be taken to store additional water on development sites in this catchment to alleviate flooding in the wider area, in addition to long term storage requirements. As the sites are primarily greenfield, it is important that any development aims to limit runoff to the current rate.

As the catchment drains through Wymondham and toward Norwich, LPAs should work closely with the Environment Agency and LLFA to identify any areas of land that should be safeguarded for any future flood alleviation schemes and natural flood management features.

1.9.2 Yare (Tiffey to Wensum)

There are 37 currently allocated sites that lie within, or partially within the Yare (Tiffey to Wensum) catchment. Several sites are located on the north edge of Hethersett, several large greenfield sites are located along the A47, which cuts across the centre of the catchment from north to south. The remaining sites are generally smaller sites within the existing urban area on the east bank of the river.

As there are multiple large greenfield sites in the catchment, in particular GNLP0307 and GNLP2043/0581, it is important that any development aims to limit runoff to the current rate. Large urban extensions on greenfield land should be accompanied by an overall Surface Water Management Masterplan and Strategy, which should cover:

- How the cumulative effects of potential peak rates and volumes of water from development sites would impact on peak flows, duration of flooding and timing of flood peaks on receiving watercourses. This should be used to develop and implement appropriate drainage sub catchments and specific runoff rate and volume requirements for each phase of the development.
- The risk of flooding from all sources, including for rainfall events greater than the design standard of the surface water drainage system should be taken into account to ensure there is no flood risk to new properties and that exceedance flows in extreme events are safely routed around those properties.

- The consideration of how SuDS, natural flood management techniques, green infrastructure and green-blue corridors can be designed into the development master plan to facilitate drainage flood risk management and ensure wider benefits such as biodiversity, amenity, water quality and recreation are realised.
- Based on the above, a Drainage Phasing Plan should be developed, based on the SuDS train method (considering firstly how water can be infiltrated/stored at a plot level, then conveyed through the site and any regional storage needs at a settlement level).
- The provision of drainage during the building phase shall be based on the Drainage Phasing Plan to ensure adequate drainage is provided and implemented throughout the development life.
- The LLFA, Environment Agency and LPA should be consulted during the development of the Surface Water Management Masterplan and Strategy.

As the loss of floodplain storage has the potential to increase downstream flood risk, any development within Yare (Tiffey to Wensum) sub-catchment should identify potential areas of flood plain loss as a result of development and either avoid developing in those areas or provide compensatory storage onsite.

As the upper catchment drains towards and through Norwich, it is recommended the LPAs work closely with the Environment Agency and LLFA to identify any areas of land that should be safeguarded for any future flood alleviation and natural flood management features. There are likely to be opportunities in the upper catchment for NFM techniques to improve upstream storage, which are additional to those included within developments.

1.9.3 Wensum Through Norwich

There are 75 currently allocated sites that lie within, or partially within the Wensum Through Norwich catchment and a further 6 sites were previously identified as preferred or reasonable sites.

Due to the largely urbanised nature of the catchment, there are limited opportunities for flood storage and natural flood management.

Much of the catchment is located within already designated Critical Drainage Areas. This means that a detailed Flood Risk Assessment is required for all development within these areas, regardless of size. It is recommended that the Council consider expanding and joining the existing Critical Drainage Areas to cover the Richmond Hill and Cathedral Quarter areas where much development is currently proposed but which currently falls between the Catton Grove and Sewell and Nelson and Town Close Critical Drainage Areas.

As the majority of sites within the catchment are brownfield, development is less likely to increase current runoff rates however as the catchment is particularly vulnerable to increasing surface water flooding as a result of climate change, it is recommended that future development proposals identify opportunities to reduce runoff rates through implementation of SUDS features. Whilst new and redeveloped properties are not eligible for the Council's CATCH project, which provides slow release water butts and rain planters, developers should seek to incorporate rainwater harvesting and reuse within developments as part of the surface water management strategy.

There are known runoff pollution issues within Norwich Urban area, in particular from industrial sites within the Lionwood area, and development sites within the Norwich urban area should demonstrate through a drainage strategy that development will not exacerbate, and where possible seek to alleviate, these known issues.

As the loss of floodplain storage has the potential to increase flood risk in the City Centre, any development within this area should identify potential areas of flood plain loss as a result

of development and either avoid developing in those areas or provide compensatory storage onsite.