4 - 6 MANOR ROAD

TEDDINGTON

FLOOD RISK ASSESSMENT ADDENDUM

Lulworth Homes

ISSUE: FINAL

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PROJECT NUMBER: 13078

WATER | ENVIRONMENT

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This Flood Risk Assessment (FRA) addendum was prepared to provide an update to the FRA (Final Issue, June 2016) following consultation with the Environment Agency regarding the updated national climate change allowances. Minor updates are also provided on other issues for completeness. This report relates to a planning application for the development at No. 4 and No. 6 Manor Road, Teddington.

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1 INTRODUCTION

General Information

1.1 The site is located at 4-6 Manor Road, Teddington (TW11 8BG). The rear of the site (No. 6) is currently occupied by two semi-detached dwellings located behind a new purpose-built block of flats at No 4. A planning application (reference: 16/2352/FUL) was submitted in June 2016, which seeks to add an additional storey at No. 4 and to redevelopment the site at No. 6 to provide a total of 12 new dwellings.

1.2 Further information and analysis was sought by the Environment Agency as part of the formal planning application consultation regarding the updated national climate change allowances. This report provides an addendum to the submitted Flood Risk Assessment (FRA) and aims to:

- Provide further analysis, as agreed with the Environment Agency, detailing the new national climate change allowances and projected flood water levels;
- Use this analysis to make modifications to the building design, where required, in order to demonstrate that the proposed development will be safe from flooding when considering the latest climate change allowances; and,
- Demonstrate through revised floodplain compensation analysis that the development will not increase the flood risk elsewhere, and as per the submitted FRA returns storage volume to the floodplain, therefore reducing local flood risk.

1.3 This addendum should be read in conjunction with the FRA.

Environment Agency Correspondence

1.4 Following submission of the planning application to the London Borough of Richmond, the Environment Agency were consulted. Responses from the Environment Agency planning team, dated 28th July and 8th September, requested further assessment of the new climate change allowances in order to ensure that the development and occupants remain safe over the lifetime of the development. This confirmed that the climate change allowances could be dealt with by updating the FRA "using the latest climate change allowances to inform the layout and design and demonstrate no loss of flood storage and safe access and refuge".

1.5 Since the Environment Agency's hydraulic model of the River Thames is yet to be updated to account for the increased climate change allowances, the Environment Agency have recommended that for new development proposals there are two possible approaches to account for flood risk impacts due to climate change[1]:

- Intermediate: Developer can use existing modelled flood and flow data to construct a stage-discharge rating curve, which can be used to interpolate a flood level based on the required peak flow allowance to apply to the 'design flood' flow.

[1] Based on Environment Agency responses: reference SL/2016/116043/01-L01, dated 28 July 2016 and reference SL/2016/116043/02-L01, dated 8 September 2016

- Detailed: Perform detailed hydraulic modelling, through either re-running Environment Agency hydraulic models (if available) or construction of a new model by the developer.

1.6 Further telephone and email correspondence confirmed that the Environment Agency were happy to accept the 'intermediate' approach to determine flood water levels. On this basis, the existing Environment Agency model of the River Thames can be used and rating curves developed to extrapolate water levels for increased climate change factors. Following submission of the analysis presented in this report to the Environment Agency for preliminary review, their response (25th October 2016[2]) confirmed that they were "happy with the approach taken to calculate the revised climate change allowances and would recommend that the Flood Risk Assessment (FRA) is updated on this basis". This FRA addendum formalises the analysis submitted to the Environment Agency.

Other Matters

1.7 This FRA addendum addresses the updated climate change allowances, and the impact on the proposed development. However, other matters were raised during consultation with the Environment Agency.

1.8 The 28th July 2016 response raises the issue of safe access and egress. This confirms that "these elements could be mitigated by an acceptable emergency flood plan, submitted to the London Borough of Richmond that deals with matters of evacuation, refuge and resilience measures to demonstrate that people will not be exposed to flood hazards". It has been agreed with London Borough of Richmond that this requirement can be dealt with via condition of a flood evacuation plan.

Climate Change Allowances

1.9 On 19th February 2016, the government released new climate change allowances for increases in river flows, sea levels and rainfall intensities. The range of allowances is based on percentiles:

- central allowance is based on the 50th percentile
- higher central is based on the 70th percentile
- upper end is based on the 90th percentile

1.10 The Environment Agency's anticipated changes in extreme rainfall intensity for the River Thames catchment are outlined in Table 1.

[2] Environment Agency response, dated 25th October 2016, reference SL/2016/ 116419/01-L01

Table 1 – Peak river flow allowances for the Thames river basin district

Allowance category	Total potential change anticipated for the '2020s' (2015 to 2039)	Total potential change anticipated for the '2050s' (2040 to 2069)	Total potential change anticipated for the '2080s' (2070 to 2115)
Upper End	25%	35%	70%
Higher Central	15%	25%	35%
Central	10%	15%	25%

1.11 The proposed residential development at 4-6 Manor Road is located within Flood Zone 3a, and is therefore considered to be "more vulnerable". As such, the national climate change guidance advises use of the "higher central and upper end to assess a range of allowances". The planned lifetime for the proposed development has been assumed to be 100 years and therefore, the residential development at 4-6 Manor Road is required to consider a 35% (Higher Central) and a 70% (Upper End) peak uplift in river flows.

1.12 The existing modelled 1 in 100 year + climate change fluvial flood water level takes into account a climate change uplift of 20%. The new climate change factors are higher than before, and therefore any new modelling would need to assess a 35% and 70% uplift in peak flow to take into account potential climate change. However, the River Thames hydraulic models are extensive and likely to take a significant period of time to be remodelled. The site at 4-6 Manor Road is considered to be "small-major development" and as such re-running of the whole River Thames model is unreasonable and unnecessary for a development of this scale. Following detailed discussions with the Environment Agency, it has been confirmed that the intermediate approach will be satisfactory in this case.

1.13 The intermediate modelling approach utilises the relationship between increases in peak flow and increases in stage to determine peak flood levels for a given climate change allowance. Existing modelled flood and flow data can be used to construct a stage-discharge rating curve for the catchment, and interpolate an increased flood water level for the +35% and +70% events.

2 INTERMEDIATE APPROACH METHODOLOGY

2.1 Following confirmation that the intermediate approach was acceptable, the following methodology was used to develop a rating curve and subsequent flood water levels.

Environment Agency Product 4 Data

2.2 Figure 1 shows an excerpt from the Environment Agency's Product 4 data for the Thames Lower Reach 4 model. This illustrates the location of model nodes adjacent to the site (both in-channel and within the floodplain).

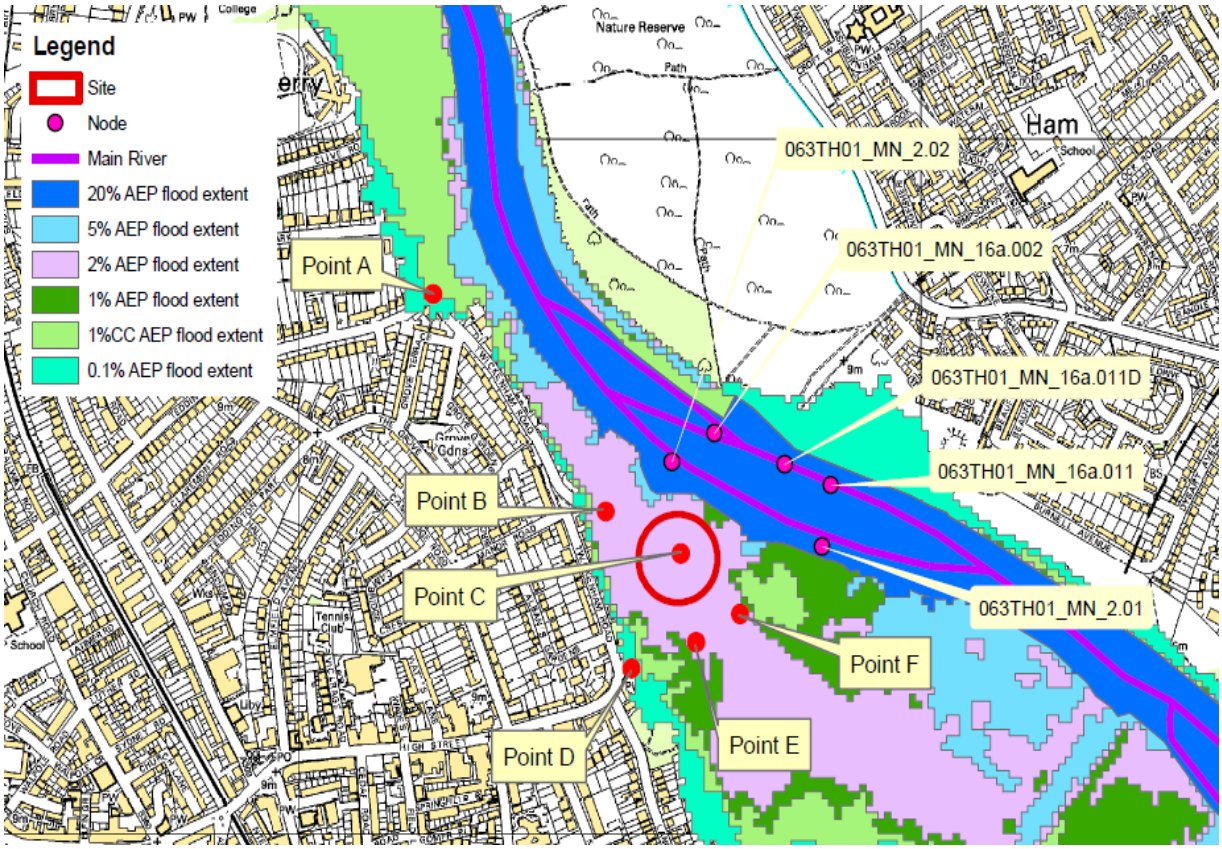


Figure 1 - Node Locations

2.3 There are two model nodes close to the site; 063TH01_MN_2.01 and 063TH01_MN_2.02, located upstream of the site and downstream of the site respectively. Due to the complexity of the hydraulics close to the site, including the presence of Teddington weir, the meeting of fluvial and tidal reaches, and the location of the site between two in-channel nodes, both will be included within this assessment.

2.4 Table 2 records the in-channel flows and associated flood water levels from two nodes closest to the site. The modelled information includes a full range of return period events, from 1 in 5 year to 1 in 1000 year. It also includes uplift for climate change of 20% on the 1 in 100 year event, as per previous guidance.

Table 2 – Modelled node data at Teddington

Node	Return period (years)	In-channel flows (m^3/s)	Flood water levels (m AOD)	Increase in flow at node for 20% climate change allowance
063TH01_MN_2.01	1 in 5	429.76	4.73	
	1 in 20	568.27	5.55	
	1 in 100	688.86	6.38	
	1 in 100 + 20%	760.48	6.97	**10.40%**
	1 in 1000	840.95	7.63	
063TH01_MN_2.02	1 in 5	429.31	4.50	
	1 in 20	574.87	5.30	
	1 in 100	734.14	6.08	
	1 in 100 + 20%	854.32	6.63	**16.37%**
	1 in 1000	997.47	7.24	

2.5 As detailed within the full submitted FRA, due to the location of Teddington at the downstream end of the fluvial model, an increase of 20% in the 1 in 100 year hydrological inflows to the model does not result in the same 20% increase in in-channel flows at Teddington. This relationship is not linear as a result of the complex nature of the watercourse, storage within the floodplain and the influence of multiple structures along the reach. The model shows that, for an increase of 20% in hydrological inflows, a 10.40% and 16.37% increase in flows is realised at the two nodes being considered (as shown in Table 2).

Rating Curve Development

2.6 The relationship between the relative increase at the top and bottom ends of the hydraulic model is important when considering the revised climate change allowances. For the River Thames, the new Higher Central allowance requires an increase in hydrological flows of 35% and the Upper End requires an increase of 70%. These percentages would be used to inflate the inflow hydrograph applied at the top end of the hydraulic model.

2.7 However, as illustrated above, increases of 35% and 70% at the top end of the model reach would not equate to the same increase in flow at Teddington weir. For the purposes of analysis, a linear relationship has been assumed between the 20%, 35% and 70% increases. For example, a 35% increase in flows at the top end of the model results in an 18.2% increase in flows at node 063TH01_MN_2.01. This assumption is conservative since, in reality, as flows increase a greater volume of water will spill out into the floodplain. As such, by the downstream end of the river the expected impact of increased flow is expected to be dampened.

2.8 The increase in flow for various climate change allowances can then be calculated for each node by scaling the 1 in 100 year peak flow. The resulting flows are presented in Table 3.

Table 3 – Increases in flow with climate change increases

Node	1 in 100 year flow (m^3/s)	Flow increase at top of model	Flow increase at node	1 in 100 year + climate change flow (m^3/s)
063TH01_MN_2.01	688.86	20%	10.40%	760.48
		35%	18.19%	814.20
		70%	36.39%	939.53
063TH01_MN_2.02	734.14	20%	16.37%	854.32
		35%	28.65%	944.46
		70%	57.30%	1154.77

2.9 Scaled flows indicate that at node 063TH01_MN_2.01, a 35% increase in flows will result in an in-channel flow of 814m^3/s, whilst a 70% increase will result in 940m^3/s. At downstream node 063TH01_MN_2.02, the same 35% increase in flow will result in 944m^3/s and a 70% increase equates to 1154m^3/s. The variance in flows between these two nodes is as a result of differences in in-channel hydraulics at each location due to interaction with the Teddington Weir complex.

2.10 The Environment Agency's modelled flows were plotted against the respective resulting water levels for all return periods, including the 1 in 100 year plus 20% climate change event. Results were plotted for both nodes in order to understand the relationship between flows and levels upstream and downstream of the site. Rating curves were also fitted to each of set of results, as shown in Figure 2.

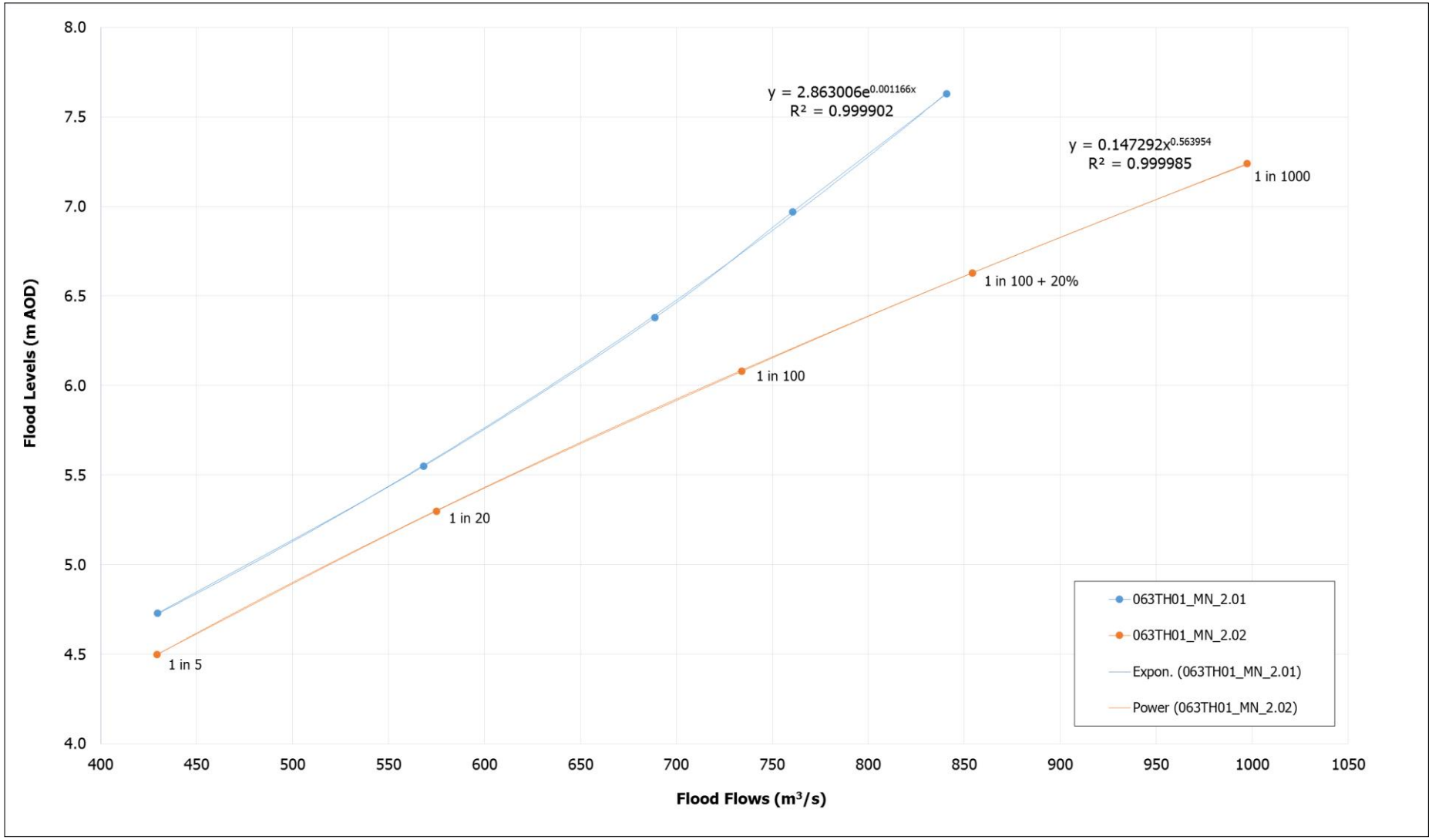


Figure 2 - Rating curve fitting at nearest nodes

2.11 Trend lines were plotted for data at both nodes in order to establish equations for each using the best fit. It was possible to fit accurate trend lines to both rating curves (R2 = 0.999902 and 0.999985 respectively). The relevant fit equations were then used to calculate extrapolated flood water levels for the +35% and +70% flows, as presented in Table 4.

Table 4 - Rating curve fitting at nearest nodes

Node	Flow increase at top of model	Flow increase at node	1 in 100 year + climate change flow (m^3/s)	1 in 100 year + climate change level (m AOD)	Fit equation
063TH01_MN_2.01	20%	10.40%	760.48	6.95	y=2.863006e^0.001166x
	35%	18.19%	814.20	7.40	
	70%	36.39%	939.53	8.56	
063TH01_MN_2.02	20%	16.37%	854.32	6.63	y=0.147292x^0.563954
	35%	28.65%	944.46	7.02	
	70%	57.30%	1154.77	7.86	

2.12 The data presented above shows the calculated flood water levels for different climate change allowances, using the equations developed from the rating curves. In order to test the validity of the rating curves, the 1 in 100 year plus 20% climate change flow was included and the resulting extrapolated level compared to the actual modelled levels. The fit was found to be good for node 063TH01_MN_2.01, with calculated level of 6.95m AOD matching closely with the modelled level of 6.97m AOD. The fit equation for node 063TH01_MN_2.02 was shown to be even more precise, matching exactly with the modelled water level (6.63m AOD). This provides confidence in both rating curves.

2.13 The Higher Central and Upper End flood water levels have been calculated for each node, as shown in Table 4. This calculates in-channel flood water levels to be 7.40m (+35%) and 8.56m AOD (+70%) upstream of the site, and 7.02m (+35%) and 7.86m AOD (+70%) downstream of the site.

3 CALCULATED FLOOD WATER LEVELS

On-Site Flood Levels

3.1 Flow data is only available for in-channel nodes, and hence extrapolation using the rating curve can only provides water levels within the River Thames itself, at nodes upstream and downstream of the site.

3.2 In addition to 1D in-channel data, the Environment Agency have provided flood water level from 2D nodes within the floodplain. These were used within the original FRA to set the 'design flood' level. The maximum 1 in 100 year plus 20% flood water level on the site is 6.66m AOD (Point C as shown in Figure 1). This is linked to an in-channel level upstream of the site of 6.97m AOD and downstream of the site of 6.63m AOD.

3.3 The flood water levels calculated in Table 4 therefore need to be converted to on-site flood water levels. This was calculated using the ratio of the known (1 in 100 year plus 20%) on-site water level to the corresponding upstream and downstream levels, and applying this relationship to the 35% and 70% allowances. Resulting on-site flood water levels are shown in Table 5.

Table 5 - In-channel and on-site flood water levels

Location	Previous (20%)	Higher Central (35%)	Upper End (70%)
Upstream (Node 063TH01_MN_2.01)	6.97	7.40	8.56
On-Site	**6.66**	**7.05**	**7.92**
Downstream (Node 063TH01_MN_2.02)	6.63	7.02	7.86

3.4 This analysis concludes that the Higher Central, 1 in 100 year plus 35% climate change flood water level at 4-6 Manor Road is 7.05m AOD. The Upper End limit (70% increase) is calculated to be 7.92m AOD on the site.

Design Flood Levels

3.5 The FRA submitted in June 2016, and reviewed by the Environment Agency, considered that – in absence of this further analysis – the 1 in 1000 year modelled flood water level represented the worst-case modelled data available. The 1 in 1000 year event resulted in an on-site flood water level of 7.41m AOD, and this was used to set the finished floor level for the development. This on-site level resulted from in-channel levels of 7.63m and 7.24m AOD, upstream and downstream of the site respectively.

3.6 Following this further analysis, undertaken at the request of the Environment Agency, it can be seen that the scaled Higher Central (35%) flood water level is considerably lower than the modelled 1 in 1000 year event, at 7.05m AOD on-site. The 70% Upper Central event, 7.92m AOD, is, however, higher.

3.7 The site at 4-6 Manor Road is not located in a sensitive location and despite its proximity to the River Thames, the site is outside of extent of the functional floodplain and is only at risk a 1 in 50 year event or greater. As discussed fully within the submitted FRA, the site is therefore not at risk of frequent flooding and, in addition, Teddington is at the far downstream end of the River Thames catchment. As such, there would be several days or even weeks of warning before the peak of a large flood event.

3.8 The scientific basis of the Higher Central and Upper End climate change factors also needs to be considered. The Higher Central is based on the 70% percentile, whereas the Upper End is based on the 90th percentage. Therefore, in relation to increases in flow, there is a 70% chance that the climate change factor will manifest as less than 35% uplift in flood flows and a 90% chance that the climate change factor will be less than 70% uplift. It is therefore considered reasonable to use the Higher Central allowance for analysis of the impact of climate change to this development.

3.9 The submitted FRA set finished floor levels for the proposed development to 7.41m AOD. The analysis presented within this FRA addendum confirms that this is 360mm higher than the extrapolated Higher Central flood water level and therefore the development is expected to remain dry in a 1 in 100 year plus 35% climate change event.

4 FLOODPLAIN STORAGE

4.1 As detailed within the FRA, previous correspondence with the Environment Agency stipulated that the development will not result in a loss of floodplain storage. As set out previously, the development will ensure that any loss of flood storage must be compensated for at the level from which is has been lost. The strategy detailed within the FRA, and revised below, was presented to the Environment Agency in the form of an extended letter in December 2015. The response received (19 February 2016) confirms that the development proposed is unlikely to result in a loss of flood storage and that, in principle, the Environment Agency are satisfied with the approach of allowing flood water to flow beneath the building thereby not requiring land lowering elsewhere.

4.2 Following analysis contained within this FRA addendum, discussions have been undertaken with the structural engineers who have confirmed that it is feasible to reduce the required depth of the slab beneath the finished floor level. As such, is has been possible to raise the slab soffit level to 7.05m AOD, the Higher Central flood water level.

4.3 Floodplain compensation calculations have therefore been revised for the updated design. This update follows the principles set out previously, and are undertaken on a volume for volume and level for level basis. All calculations use the 1 in 100 year Higher Central (+35%) climate change level, 7.05m AOD, as the design level on the site. This approach was chosen in order to be as conservative as possible within reasonable and realistic limits.

Existing Site

4.4 The existing dwellings at No. 6 have a total of 135.0m^2 built footprint. Based on a typical ground level of 5.30m AOD and design flood water level of 7.05m AOD, this equates to a flood depth on-site of 1.75m. As a result, the existing built, non-floodable volume within the floodplain is 236.3m^3. The building is uniform between the ground level and flood water level, and therefore can be split into 8 x 200mm slices plus an additional 150mm to reach the flood level. This equates to a total of 27.0m^3 of non-floodable volume within each 200mm slice.

Proposed Development

4.5 As detailed within the FRA, the proposed development has been designed with the entire development elevated above the flood water level, and the soffit level of the raised ground floor slab has been raised further as a result of the increased climate change levels. The proposed building has a larger overall footprint than the basecase, a total of 411.2 m^2, however, the underside of the building slab will be set to 7.05m AOD and the entire area beneath the building will be floodable. As a result, the only non-floodable area within the floodplain is due to the presence of support columns beneath the building and the lift shaft.

4.6 Direct level-for-level compensation is provided between 5.30m AOD (ground level) and 7.05m AOD (revised flood level). The total combined footprint of the support columns and the lift shaft below the flood water level is 12.5 m^2. Based on a flood

depth of 1.75m, this equates to a non-floodable volume of 21.9m^3. To illustrate the proposed design of the building below the modelled flood water level, an annotated excerpt of the updated southern elevation drawing is shown in as Figure 3. A copy of the relevant revised drawing is attached to this report.

Figure 3[3] - Proposed development (southern elevation)

4.7 The proposed support columns and lift shaft are vertically uniform and can therefore be split into 8 x 200mm slices, plus an additional 150mm. Within each of the 200mm slice, the non-floodable volume is calculated to be 2.5m^3, considerably less than the 27.0m^3 per slice calculated for the existing building on-site. Therefore, despite the overall increase in building size, the elevated design ensures that there is a significant increase in flood storage at every level. The proposed development returns a total of 214.4m^3 of floodplain storage to the site between ground level and the design flood water level.

4.8 Full details of the floodplain compensation strategy, including calculated blockage scenarios, are included within the submitted FRA. This strategy has been reviewed and accepted by the Environment Agency as part of formal consultation. Since the revised design involves raising the underside slab level above the new Higher Central flood water level, the principles of this strategy remain as agreed; no flood water is displaced as a result of the development and no additional floodplain compensation is required.

[3] Annotated excerpt from Brookes Architects Drawing, No. 4707|3|61 – Rev A, November 2016.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Following a planning application submitted in June 2016 for the site at 4-6 Manor Road, further detailed analysis was sought by the Environment Agency as a result of the revised climate change allowances. This FRA addendum provides an update to the original assessment and should be read in conjunction with the FRA report.

5.2 The existing Environment Agency hydraulic model of the River Thames uses a 20% uplift for climate change on the 1 in 100 year flood event. The new climate change factors for the River Thames have increased, providing a Higher Central allowance of 35% and an Upper End allowance of 70%, based on the 70th and 90th percentiles respectively. Since the River Thames model is yet to be updated, the Environment Agency have recommended that, in the case of this site, the 'Intermediate' approach should be taken and existing modelled data used to construct a stage-discharge rating curve.

5.3 This analysis concludes that scaling the in-channel flows upstream of the site results in flows of 814m^3/s and 940^3/s, for the Higher Central and Upper End events respectively. Downstream of the site, these flows will increase to 944m^3/s and 1154^3/s. Rating curves developed calculate the in-channel flood water levels to be 7.40m (+35%) and 8.56m AOD (+70%) upstream of the site, and 7.02m (+35%) and 7.86m AOD (+70%) downstream.

5.4 These in-channel flood water levels were converted to floodplain levels, using the known relationship between in-channel nodes and on-site levels for the modelled 1 in 100 year plus 20% event. This analysis provides an on-site flood water level of 7.05m AOD for the 1 in 100 year plus 35% (Higher Central) event. The Upper End limit (70% increase) is calculated to be 7.92m AOD on the site.

5.5 In the absence of this more detailed rating curve analysis, the submitted FRA set finished floor levels of the proposed development to 7.41m AOD, the modelled 1 in 1000 year flood water level. The analysis presented within this FRA addendum confirms that this is 360mm higher than the extrapolated Higher Central flood water level and therefore the development is expected to remain dry in a 1 in 100 year plus 35% climate change event. On the basis of the sensitivity of the development location and likely probability of such an event, it is considered reasonable to use the Higher Central factor for analysis of the impact of climate change.

5.6 The building soffit level has been raised as a result of this analysis, with the underside slab set to the Higher Central flood water level. Floodplain compensation calculations have therefore been revised. This update follows the principles set out previously, which have been reviewed and accepted by the Environment Agency. Since the revised design involves raising the underside slab level above the new Higher Central flood water level, the principles of this strategy remain as agreed. No flood water is displaced as a result of the proposed development and no additional floodplain compensation is required. As a result of the proposed design, the development returns a large volume of storage to the floodplain, therefore actively contributing to reducing flood risk elsewhere to the benefit of the wider community.

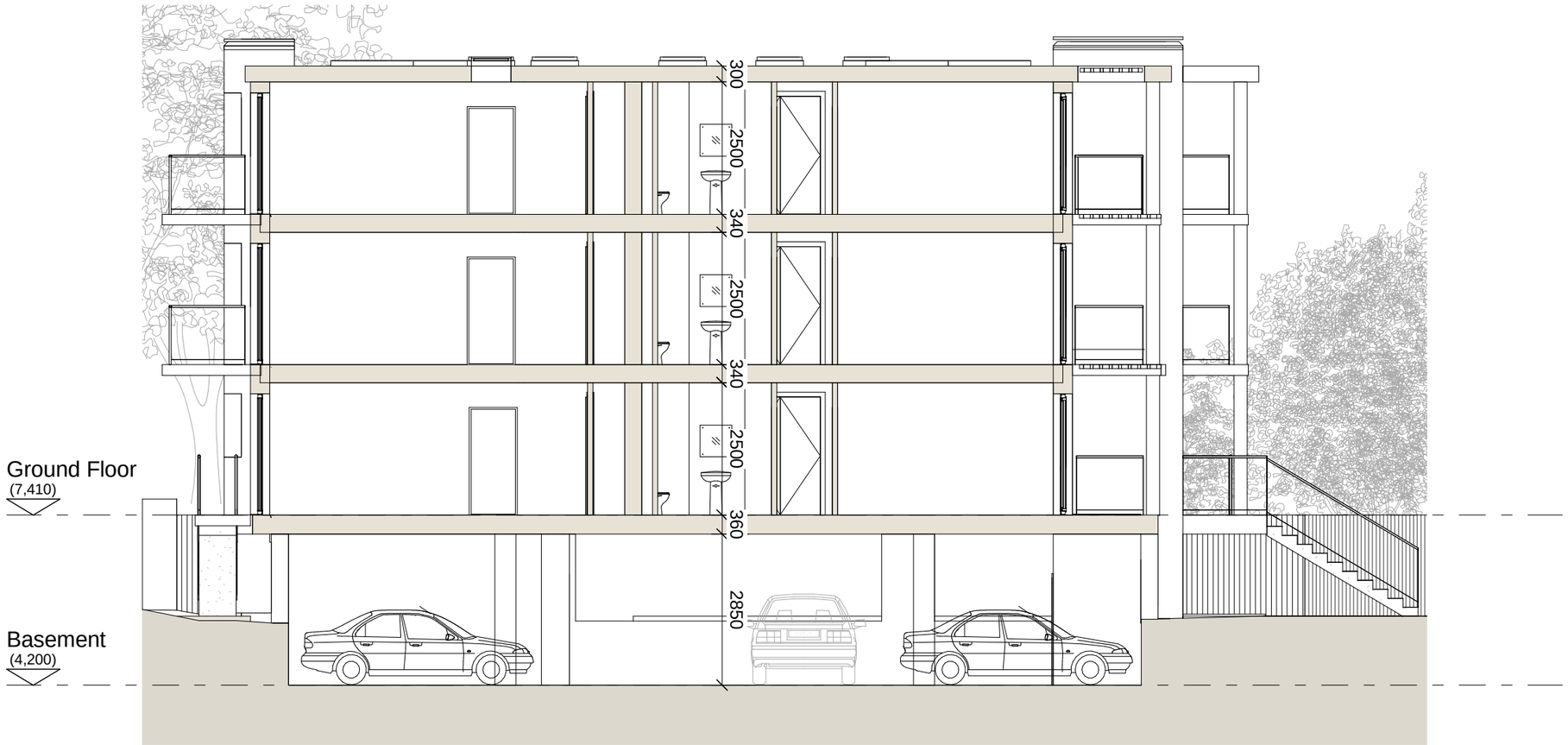
APPENDIX A – DRAWINGS

Drawing 1 – Revised Development Section

Brookes Architects, Drawing No.: 4707|3|61 – Rev A, November 2016

Section through proposed development, showing finished floor levels and reduced slab depth, increasing the soffit level to 7.05m AOD.

Do not scale from this drawing



PLANNING

Rev	Description	Issued	Dwn	Chk
A	Soffit of Ground Floor raised at Number 6.	04.11.16	IF	AW

Client 4 Manor Road and Lulworth Homes

Project 4 + 6 Manor Road
Teddington
TW11 8BG

Scale 1 : 100@A3 | Date Apr '16 | Dwn AWS | Chk IF

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Drawing No. 4707 | 3 | 32 | Rev. No. A