Haymarket Media

Teddington Riverside

Flood Risk Assessment
(Main Report)

Report K0358/1

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EXECUTIVE SUMMARY OF REPORT

This report documents work undertaken by Hydro-Logic Services for Haymarket Media between April 2013 and December 2013.

The purpose of the work was:

- to prepare a Flood Risk Assessment for the proposed Teddington Riverside development; and
- to generally advise the design team on issues relating to flood risk and surface drainage.

The key outcomes of the work are summarised in Section 5 of the FRA and include:

- the site layout to satisfy Environment Agency and London Borough of Richmond upon Thames (LBRT) requirements in relation to finished floor levels, flood storage, runoff, emergency access and other issues.
- an Emergency Plan, prepared in line with LBRT requirements in Appendix B

The work delivered the following outputs:

- This Report
- Chapter on flood risk and drainage for the Environmental Statement

This FRA has been revised in response to comments received from the Environment Agency and LBRT in May 2014.

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Terry Marsh of the Centre for Ecology and Hydrology (CEH) also provided useful information on the history of Thames floods

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1	Dec 2013	P Webster	P Webster	Draft following internal review
2	Feb 2014	P Webster	P Webster	Issue version
3	Jun 2014	P Webster	P Webster	Revised in response to EA/LBRT comments

Limitation of liability and use

The work described in this report was undertaken for the party or parties stated; for the purpose or purposes stated; to the time and budget constraints stated. No liability is accepted for use by other parties or for other purposes, or unreasonably beyond the terms and parameters of its commission and its delivery to normal professional standards.

TABLE OF CONTENTS

1. Introduction 1
1.1 Purpose of this Report 1
1.2 Background 1
1.3 Sources of Information and Consultation 2
1.4 Structure of Report 2

2. Spatial Planning Considerations 3
2.1 Location Plan and Site Plan (B1a) 3
2.2 Environment Agency Flood Zone (B3a) 6
2.3 The SFRA and Sequential/Exception Tests (B1B, B1C, B1D, B3B) 7

3. Flood Hazard for Existing Site 9
3.1 Catchment Characteristics 9
3.2 Source Of Flood Risk (B2a) 11
3.3 Flood Mechanisms (B2b) 11
3.3.1 Fluvial flooding 11
3.3.2 Tidal 14
3.3.3 Groundwater 15
3.3.4 Sewers 15
3.3.5 Surface Water 17
3.3.6 Infrastructure 17
3.4 Existing Surface Water Drainage Arrangements (B2c) 21
3.5 Probability Of site Flooding (B3c) 22
3.5.1 General 22
3.5.2 Modelled flood levels 23
3.5.3 Recommended levels 25
3.6 Summary 25

4. Review of Development Proposals 26
4.1 Development Process (B5) 26
4.2 Flood Risk Management Measures (B5, B6) 26
4.2.1 Finished Floor Levels 26
4.2.2 Access/Egress arrangements 29
4.2.3 Car Parks 32
4.2.4 Realignment of existing defences 33
4.2.5 Benefits to wider community 35
4.3 Off Site Impacts (B7a, B3d, B7b) 36
4.3.1 Flow paths 36
4.3.2 Flood Plain storage 40
4.3.3 Runoff 51
4.4 Residual Risks (B8a, B8b) 59
4.4.1 Failure of flood management infrastructure 60
4.4.2 Event exceedance 60
4.4.3 Maintenance 61
4.5 Risks During Construction 61
4.6 Climate Change (C4a) 62

5. Summary and Recommendations 63

6. References 67

Appendix A Pro-Forma for Undertaking a Flood Risk Assessment (Appendix B of Practice Guide (CLG, 2009)) 70

Appendix B Flood Emergency Plan 73
B.1 Introduction 73
B.2 General 73
B.3 Flood Procedures 85
B.4 Management of the Flood Emergency Plan 95

Appendix C Allowances for climate change in NPPF 99

Appendix D Pre-Application Response from the Environment Agency 100

Appendix E Teddington Riverside: Illustrative Landscape Master Plan 105

Appendix F Teddington Riverside: Landscape Layout 106

Appendix G MicroDrainage Simulation output 107

1. Introduction

1.1 Purpose of this Report

This Report presents a Flood Risk Assessment (FRA) for the proposed redevelopment of the Teddington Studios to residential accommodation. The FRA is to form part of the Planning Application to be reviewed by the London Borough of Richmond on Thames (LBRT). This FRA will also be subject to scrutiny by the Environment Agency.

Hydro-Logic Services (HLS) has been appointed to undertake the assessment on behalf of The Haymarket Group. This follows from preliminary investigations undertaken by HLS in 2011. HLS staff have worked closely with the design team throughout the project, to ensure that flood risk issues have been incorporated at all relevant stages in the design process.

1.2 Background

The proposed development is summarised as follows: the demolition of existing buildings with the exception of Weir Cottage and the erection of part four/part five/part six storey buildings to provide 219 flats, erection of 6 three storey houses to Broom Road frontage, use of Weir Cottage for residential purposes, provision of 259 car parking spaces at basement and ground level, closure of existing access and provision of two new accesses from Broom Road, provision of publically accessible riverside walk together with cycle parking and landscaping.

The principal issues to be demonstrated in any flood risk assessment are as follows (#22, DCLG, 2010):

- whether any proposed development is likely to be affected by current or future flooding from any source;
- satisfying the LPA that the development is safe and where possible reduces flood risk overall;
- whether it will increase flood risk elsewhere; and
- the measures proposed to deal with these effects and risks. Any necessary flood risk management measures should be sufficiently funded to ensure that the site can be developed and occupied safely throughout its proposed lifetime;

The Planning Guidance for Development and Flood Risk was recently revised, with the NPPF, the National Planning Policy Framework (DCLG, 2012) replacing Planning Policy Statement 25 (PPS25, DCLG, 2010). The policy principles however remain unchanged and the associated Practice Guide (DCLG, 2009) remains in place. A suggested proforma for undertaking FRAs was included in the Practice Guide, which has been reproduced as Appendix A of this report, with the content highlighting the sections in the FRA that address specific points in the pro-forma.

The conditions that apply to development in the London Borough of Richmond upon Thames (LBRT) are presented in the Strategic Flood Risk Assessment (SFRA). This was published in 2010 by LBRT, in conjunction with the Environment Agency and this summarises the guidelines for developers appropriate to different flood zones. These requirements are discussed further in Section 2.3. The SFRA is currently being revised by LBRT.

1.3 Sources of Information and Consultation

The Environment Agency has provided appreciable material in support of this FRA, mostly under Data Request WT8646 provided on 1 May 2013 and WT11411 in October 2013. This was supplemented by modelled information from the TE2100 study under NE36687JH, also provided in October 2013.

These provisions have included model files plus associated reports for the 2010 Lower Thames Reach 4 Isis Tuflow files. Pre-application advice was also sought from the Environment Agency in July 2013; their response is provided in Appendix D . Environment Agency staff have provided comments at key points in the preparation of the FRA, in particular allied to a site meeting in early September 2013 attended by Environment Agency and LBRT officials.

Thames Water have provided maps of water and drainage infrastructure in support of this FRA.

LBRT and Environment Agency staff have also provided valuable guidance in the preparation of this FRA and comments on earlier drafts.

1.4 Structure of Report

The Report has been structured in order to deal with each of the points raised in Appendix B of PPS25 Practice Guide (reproduced as Appendix A of this Report). Each of the points is referenced in the appropriate headings. Thus, B3a refers to section B3a of Appendix B of The Practice Guide to PPS25 (CLG, 2009).

- Section 2 refers to spatial planning considerations by reference to the proposed land use and flood zoning
- Section 3 presents an assessment of the existing flood risk at the application site.
- Section 4 presents an assessment of flood risks associated with the proposed development along with any mitigation that may be required.
- Section 5 presents a summary of the main findings.

Additional Appendices are provided that deal with the following:

- Requirements of an FRA (Appendix A);
- The Flood Emergency plan is provided in Appendix B ;
- Allowances for Climate Change (Appendix C);
- Pre-Application Advice received from the Environment Agency (Appendix D);
- Teddington Riverside: Illustrative Landscape Master Plan (Appendix E); and
- Teddington Riverside: Landscape Layout (Appendix F).
- Results of MicroDrainage model simulations (Appendix G)

2. Spatial Planning Considerations

2.1 Location Plan and Site Plan (B1a)

The Teddington Riverside site is widely known as the iconic location of Teddington Studios. In addition to this well publicised role, it is also used for offices by The Haymarket Group. The general location is shown in Figure 2-1 and the planning application boundary shown in Figure 2-2. Grid reference and post code details are given in Table 2-1.

It is understood that film studios have existed at the site since the early 20th Century, originally in the grounds of Weir House, Teddington. A review of historical mapping indicates that in the late 19th Century, the site consisted of a large residential property and associated grounds (Weir House) bordered to the north by the River Thames. By the 1930s a 'Film Studio' complex is indicated within the grounds of Weir House and by the 1960s Weir House itself appears to have been demolished to make way for continued development of the Teddington Film and TV Studio complex which has been progressively developed and enlarged during the latter half of the 20th Century

The site abuts the Thames just downstream of Teddington Lock, which is the tidal limit for the Thames. The site is located on a large meander on the River Thames which flows in a north-westerly direction at that point. This gives rise to a geographical anomaly that the site is locally on the southern bank of the River. For the avoidance of confusion, this FRA refers to the Teddington or Ham bank to distinguish the banks, rather than "north" or "south".

Figure 2-1 General location of the proposed development

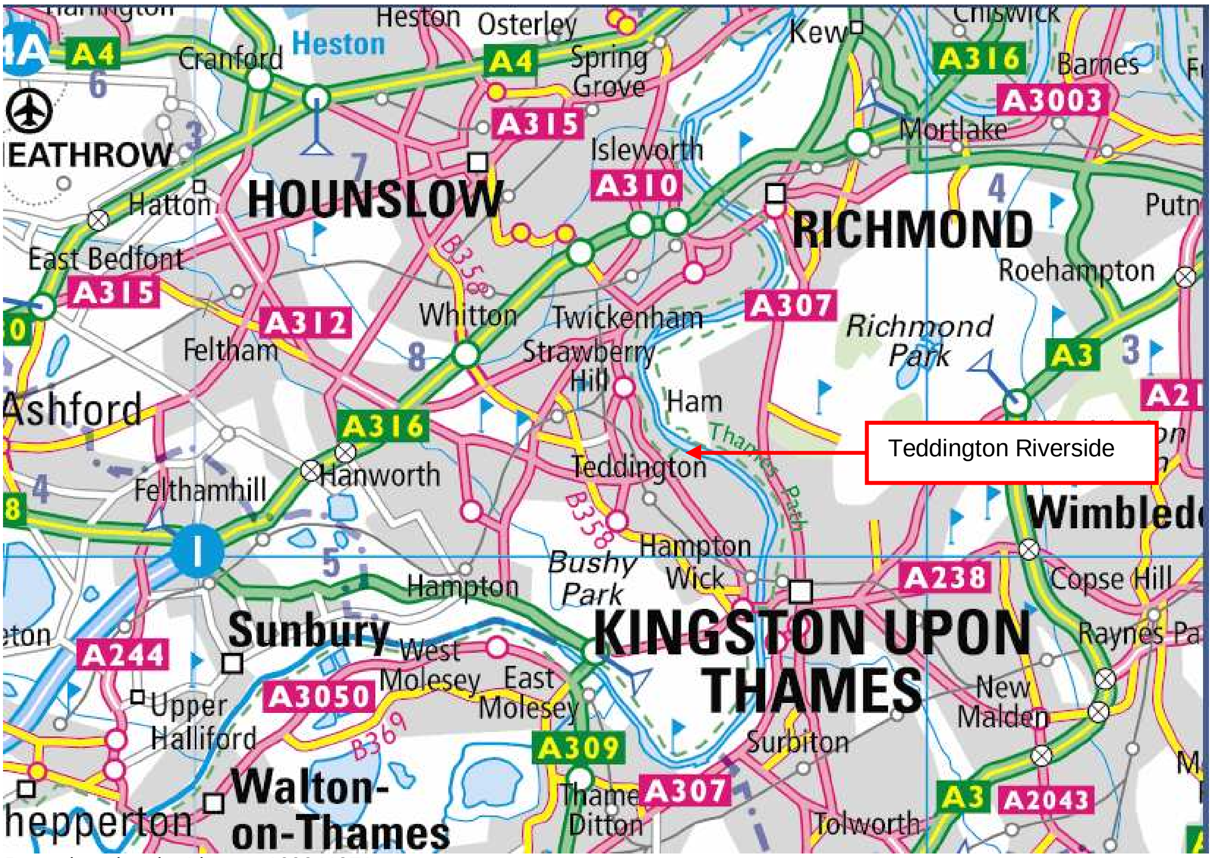
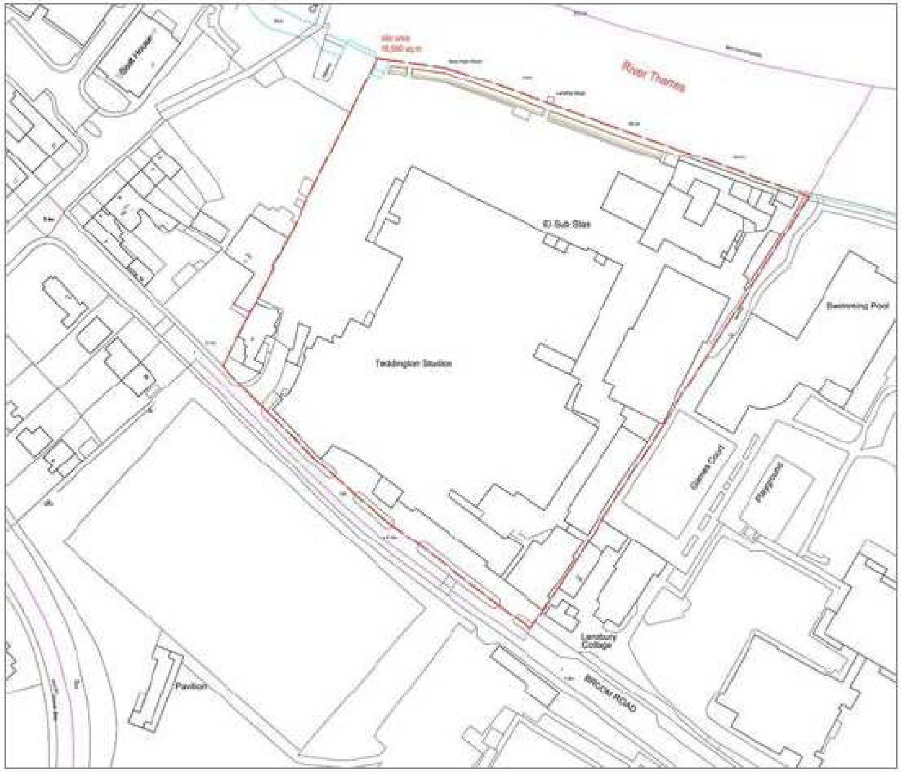
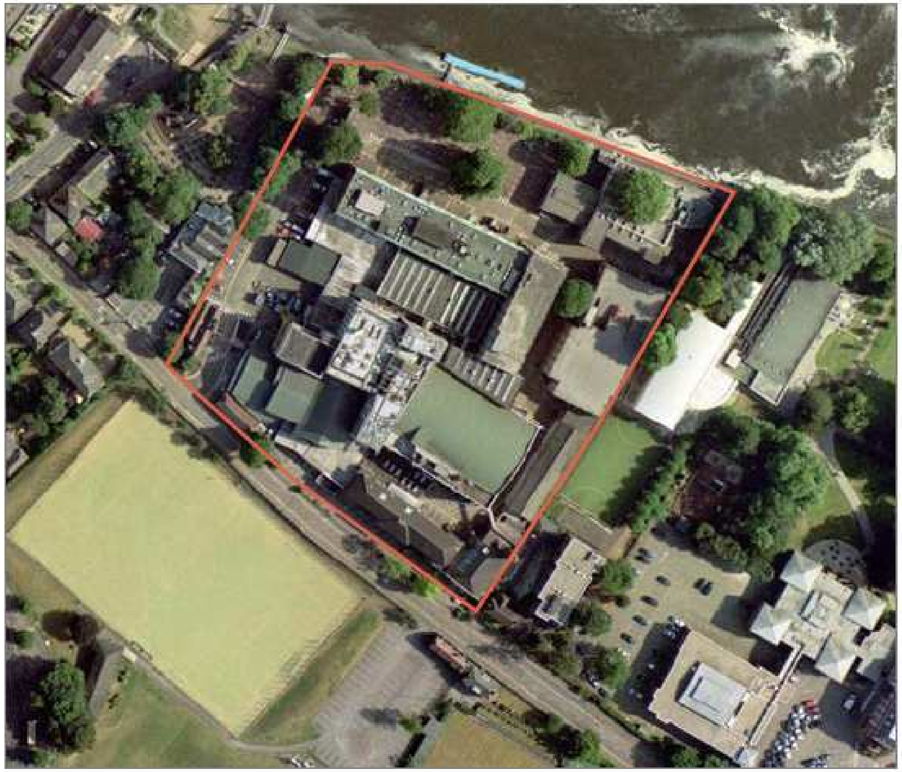


Figure 2-2 Location of the development



OS map of the proposal site with the boundary outlined in red



The same proposal site seen from the air

Table 2-1 Grid reference details for the site (www.streetmap.co.uk)

Reference	Value
OS X (Eastings)	516830
OS Y (Northings)	171365
Nearest Post Code	TW11 9BE
Lat (WGS84)	N51:25:45 (51.429256)
Long (WGS84)	W0:19:15 (-0.320866)
LR	TQ168713

The current commercial land use is classed as Less Vulnerable (LV) for flood risk purposes. The proposed land use of residential is classed as More Vulnerable (MV) as shown in Table 2-2. This change is significant in relation to the flood zoning presented in Section 2.2.

Table 2-2 Flood risk vulnerability classification

Essential Infrastructure (EI)
Essential transport infrastructure (including mass evacuation routes) which has to cross the area at risk.
Essential utility infrastructure which has to be located in a flood risk area for operational reasons, including electricity generating power stations and grid and primary substations; and water treatment works that need to remain operational in times of flood.
Wind turbines
Highly Vulnerable (HV)
Police stations, Ambulance stations and Fire stations and Command Centres and telecommunications installations required to be operational during flooding.
Emergency dispersal points.
Basement dwellings.
Caravans, mobile homes and park homes intended for permanent residential use.
Installations requiring hazardous substances consent.[19] (Where there is a demonstrable need to locate such installations for bulk storage of materials with port or other similar facilities, or such installations with energy infrastructure or carbon capture and storage installations, that require coastal or water-side locations, or need to be located in other high flood risk areas, in these instances the facilities should be classified as 'Essential Infrastructure'[20]).
More Vulnerable (MV)
Hospitals.
Residential institutions such as residential care homes, children's homes, social services homes, prisons and hostels.
Buildings used for: dwelling houses; student halls of residence; drinking establishments; nightclubs; and hotels.
Non–residential uses for health services, nurseries and educational establishments.
Landfill and sites used for waste management facilities for hazardous waste.
Sites used for holiday or short-let caravans and camping, **subject to a specific warning and evacuation plan**.
Less Vulnerable (LV)
Police, ambulance and fire stations which are not required to be operational during flooding
Buildings used for: shops; financial, professional and other services; restaurants and cafes; hot food takeaways; offices; general industry; storage and distribution; non–residential institutions not included in 'more vulnerable'; and assembly and leisure.
Land and buildings used for agriculture and forestry.
Waste treatment (except landfill and hazardous waste facilities).
Minerals working and processing (except for sand and gravel working).
Water treatment works which do not need to remain operational during times of flood
Sewage treatment works (if adequate measures to control pollution and manage sewage during flooding events are in place).

Part of Table 2 from NPPF Technical Guide (DCLG, 2012b)

2.2 Environment Agency Flood Zone (B3a)

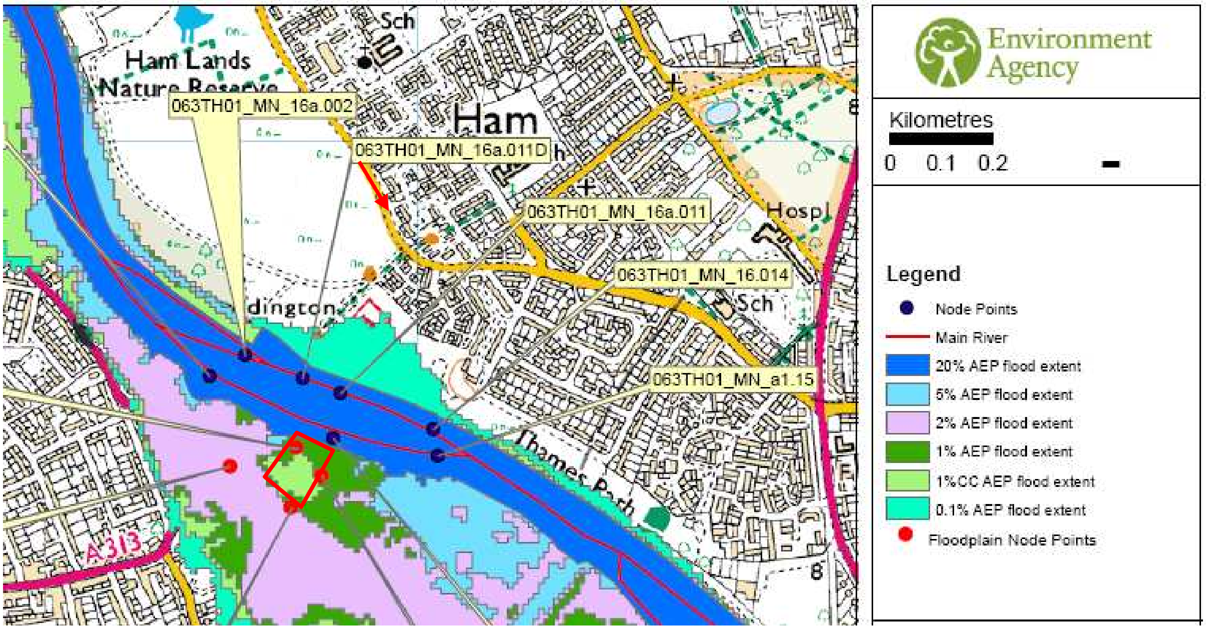
The definitions of flood zones adopted by PPS25/NPPF are as follows:

- ***Zone 1: 'Low Probability'*** *– This zone comprises land assessed as having a less than 1 in 1000 annual probability of river or sea flooding in any year (<0.1%).*
- ***Zone 2: 'Medium Probability'*** *– This zone comprises land assessed as having between a 1 in 100 and 1 in 1000 annual probability of river flooding (1% - 0.1%) or between a 1 in 200 and 1 in 1000 annual probability of sea flooding (0.5%-0.1%) in any year.*
- ***Zone 3a: 'High Probability'*** *– This zone comprises land assessed as having a 1 in 100 or greater annual probability of river flooding (>1%) or a 1 in 200 or greater annual probability of flooding from the sea (>0.5%) in any year.*
- ***Zone 3b: 'The Functional Floodplain'*** *– This zone comprises land where water has to flow or be stored in times of flood. SFRAs should identify this Flood Zone (land which would flood with an annual probability of 1 in 20 (5%) or greater in any year or is designed to flood in an extreme (0.1%) flood, or at another probability to be agreed between the LPA and the Environment* Agency, including water conveyance routes).

The Environment Agency have provided maps of the flood zones (Figure 2-3). These show that the site lies mainly in flood zone 3 (dark green on the figure), that is with an annual probability of flooding of 1% or greater. A small portion of the site is shown in pale green that is within the 1% CC (climate change zone). For planning purposes, this, along with the turquoise at the edge of the coloured zones, comprises flood zone 2, with an annual probability of flooding of 0.1% or greater.

It is also important for planning purposes, to establish if any of the site lies in the functional flood plain (termed flood zone 3b). This is shown as in pale blue on the map and has an annual probability of flooding of 5% or greater (1 in 20). It is clear from the Figure and has been confirmed by LBRT and the Environment Agency the site lies outside the functional floodplain of the River Thames.

Figure 2-3 Detailed map provided by Environment Agency (created 03/10/2013 – WT11411)



2.3 The SFRA and Sequential/Exception Tests (B1B, B1C, B1D, B3B)

As stated above, the SFRA has been prepared by LBRT (2010) in conjunction with the Environment Agency. This has provided a useful source of information to guide this FRA. In particular, a check list of issues dealing with Spatial Planning and Development Control, which is included in Section 5, is particularly important. The SFRA is currently being revised by LBRT. One of the most important issues relevant to this FRA has already been discussed, namely the revised flood plain zoning around the site.

The NPPF includes a table to highlight whether particular types of development are appropriate in each flood zone. This is reproduced as Table 2-3. As the proposed development is classed as "More Vulnerable" (Table 2-2), it would be permitted in Zone 3a, subject to the Exception Test, but not in Zone 3b. This highlights the importance of the flood zone classification that was presented in Section 2.2.

Table 2-3 Flood risk vulnerability and flood zone compatibility

Flood Zone	Definition	Essential Infrastructure	Water compatible	Highly Vulnerable	More Vulnerable	Less Vulnerable
1	T>1,000	✔	✔	✔	✔	✔
2	$100<T_{fluv}<1,000$ $200<T_{tidal}<1,000$	✔	✔	Exc	✔	✔
3a	$T_{fluv}<100$ $T_{tidal}<200$	Exc.	✔	✕	Exc	✔
3b (functional floodplain)	$T_{fluv}<20$	Exc	✔	✕	✕	✕

Table 3 from the NPPF Technical Guide (DCLG, 2012b)

Notes:

✔	development is appropriate	T	return period (fluv = fluvial)
✕	development should not be permitted	Exc	exception test should be applied

Although the proposed development is permitted in Zone 3a, the application needs to satisfy both the **Sequential Test** and **Exception Test**. The overall aim of decision-makers should be to steer new development away from Flood Zone 3, ideally to Flood Zone 1. Where there are no reasonably available sites in Flood Zone 1, then sites would be considered in Flood Zone 2 and then 3. The Sequential Test requires an assessment of available and equivalent sites in the LBRT area to ascertain if others are available that are at lower risk of flooding. This Test has been undertaken by CgMs Consulting (2013). Following a review of sites in the LBRT Housing Land Supply 2013/23 document, it is concluded that there are no reasonably available, sequentially preferable sites within the Borough that are both at a lower probability of flooding and that would be appropriate for the type of development proposed.

The Sequential Test is therefore deemed to have been satisfied, subject to review by LBRT and the Environment Agency.

The Exception Test now has two parts and the extent to which it satisfies these elements is described below:

(a) That the development supports wider sustainability benefit to the community that outweigh flood risk, informed by the SFRA.

CgMs Consulting (2013) indicate that the development will be highly sustainable, meeting BREEAM “excellent” and Code for Sustainable Homes Level 4, whilst also reducing flood risk in the area, as outlined in this FRA.

(b) that the site can be safely developed without increasing flood risk elsewhere

This FRA provides the confirmation in Section 4 that there is no increase in flood risk elsewhere and can be made safe for residents.

Evidence is thus provided, or referred to in this FRA, to demonstrate that both the Sequential and Exception Tests have been satisfied.

3. Flood Hazard for Existing Site

This Section reviews the characteristics of the catchment area that affect the site. This provides the context for reviewing the sources of flooding to the site and the flood risk.

3.1 Catchment Characteristics

The dominant hazard to the site is from the Thames where high water levels can result from a combination of fluvial and tidal extremes. The catchment area of the Thames at Teddington is shown in Figure 3-1 and the characteristics are shown in Table 3-1. The catchment has an area of 9,938 km^2 making it one of the largest catchment areas in England. Other characteristics of note are shown in bold in the Table and are as follows:

- The catchment has an average annual rainfall of 706 mm;
- The proportion of the catchment classed as urban is about 7%;
- The runoff index (SPRHOST) is around 27%. This is intermediate in a UK context where values range from less than 10% for catchments on permeable geology to over 50% for clay catchments. This reflects the varied geology of the Thames catchment that includes permeable geologies of chalk and limestone as well as appreciable areas of clay.

There is a small watercourse (Broom Water) close to the site that is shown in Figure 3-2, with characteristics shown in Table 3-1. Its size and location are such that it will not have any material effect on the site but it is included here for completeness.

Figure 3-1 Catchment boundary for Thames (FEH CD-ROMv3)

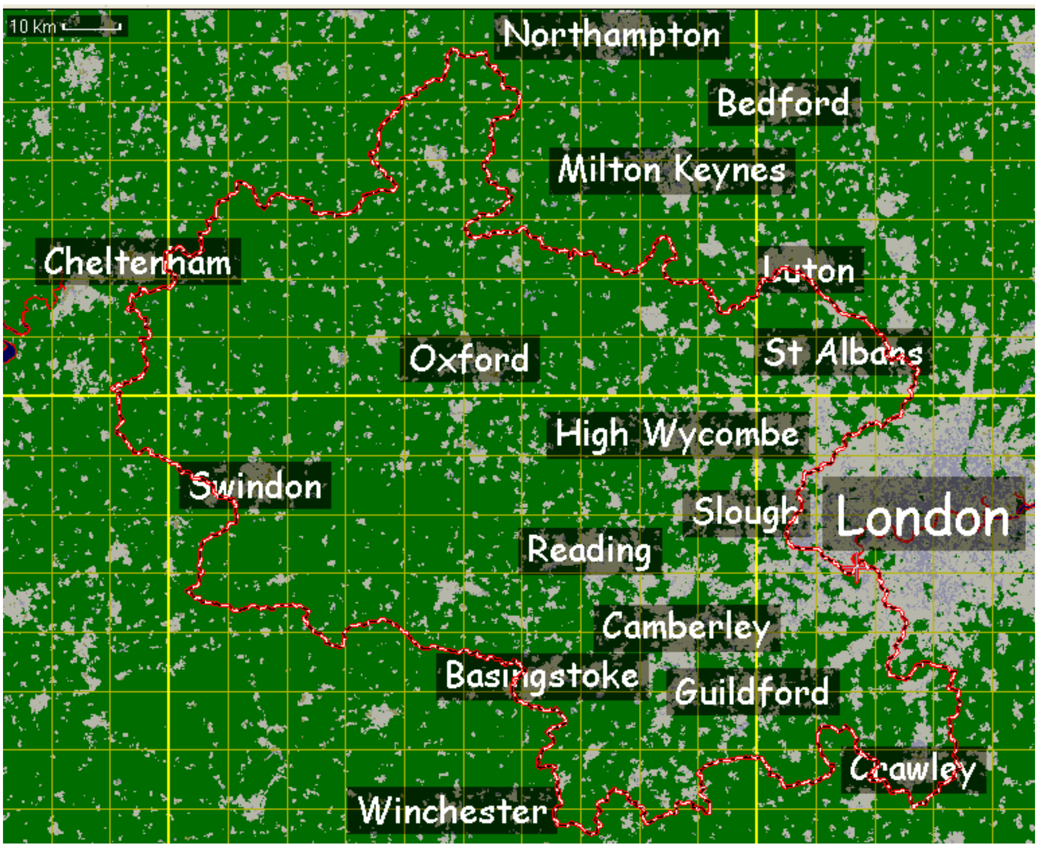


Figure 3-2 Catchment boundary for Broom Water (FEH CD-ROMv3)

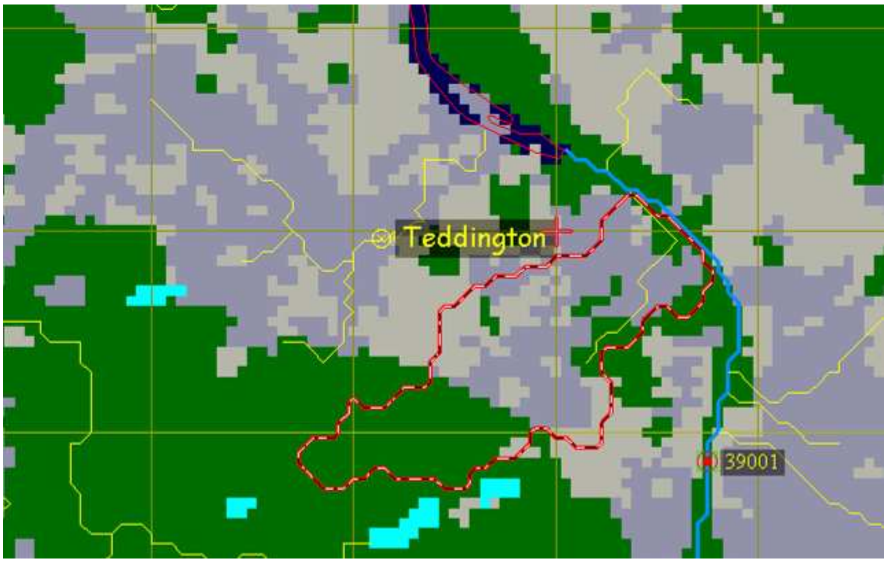


Table 3-1 Characteristics of the catchments

	Location:	Teddington Weir	Thames confl.
	River:	Thames	Broom Water
	NGR:	TQ 17100 71350	TQ 17400 71150
AREA	**Catchment area (km2)**	**9938**	**1.25**
ALTBAR	Mean elevation (m)	109	6
ASPBAR	Mean aspect	108	64
ASPVAR	Variance of aspect	0.08	0.5
BFIHOST	Base flow index	0.653	0.851
DPLBAR	Mean drainage path length (km)	141.76	1.53
DPSBAR	Mean drainage path slope	42	6.4
FARL	Index of lakes	0.942	1
FPEXT	Prop. of catchment in 1% FP	0.148	0.804
FPDBAR	Mean flood depth (catchment)	1.45	12.772
FPLOC	Avg dist of FP to outlet	0.973	0.828
LDP	Longest drainage path (km)	271.54	3.25
PROPWET	Proportion of time soil is wet	0.3	0.29
RMED-1H	Median 1 hour rainfall (mm)	10.8	10.7
RMED-1D	Median 1 day rainfall (mm)	32.7	32.1
RMED-2D	Median 2 day rainfall (mm)	41.5	41.3
SAAR	**Average annual rainfall (mm)**	**706**	**600**
SAAR4170	Ditto for 1941-1970 (mm)	724	600
SPRHOST	**Percentage runoff**	**26.94**	**19.55**
URBEXT1990	Urban extent 1990	0.0428	0.34
URBEXT2000	**Urban extent 2000**	**0.0667**	**0.482**
QMEDcds	(m^3/s)	322.92	0.05

3.2 Source Of Flood Risk (B2a)

A summary of the key sources of flood risk is provided in Table 3-2. Each of the sources is reviewed in more detail in Section 3.3. This has been based on information provided by the Environment Agency and supported by published information in the SFRA and other sources as indicated.

Table 3-2 Possible sources of flood risk

Key sources of flooding	Possibility at Site
Fluvial (Rivers)	*River Thames is dominant source of flood risk to the site, the risks from which are reviewed extensively in this Section.*
Tidal	*Teddington is the upstream tidal limit for the Thames, so provides an additional source of risk, the risks from which are also reviewed in detail.*
Groundwater	*Groundwater flooding considered by Environment Agency to be unlikely. More detail is provided in this Section.*
Sewers	*The elevated position of the site in relation to surrounding land and lack of public sewers on the site suggest that sewer flooding is unlikely.*
Surface water	*The elevated position of the site in relation to surrounding land and suggest that surface water flooding is unlikely.*
Infrastructure failure	*The key local infrastructure is the existing tidal defence, the failure of which would have minor impacts on the developed site. Since these defences may be raised during the lifetime of the development, this risk is also reviewed in this Section.*

Based on CLG (2009)

3.3 Flood Mechanisms (B2b)

3.3.1 Fluvial flooding

The dominant flood risk to the site and the area in general is from fluvial flooding resulting from prolonged heavy rainfall over the Thames catchment. There have been major flood events noted anecdotally in Table 3-3, based on information provided by Terry Marsh and in Marsh et al (2009). Whilst heavy rainfall is the dominant cause of Thames floods, snowmelt and frozen ground can play a part. Marsh quotes from Jackson's Oxford Journal of 28th January 1809 *"The cause of the 1809 flood was unusual in that a form of precipitation termed glaze played a significant part. On the 19th January, rain falling immediately froze on touching the ground surface … a thick layer of snow was deposited on the glaze … on the 24th January, intense rainfall together with the snow which was quickly melted were rapidly conveyed to the Thames… a flood of disastrous proportions was produced.*"

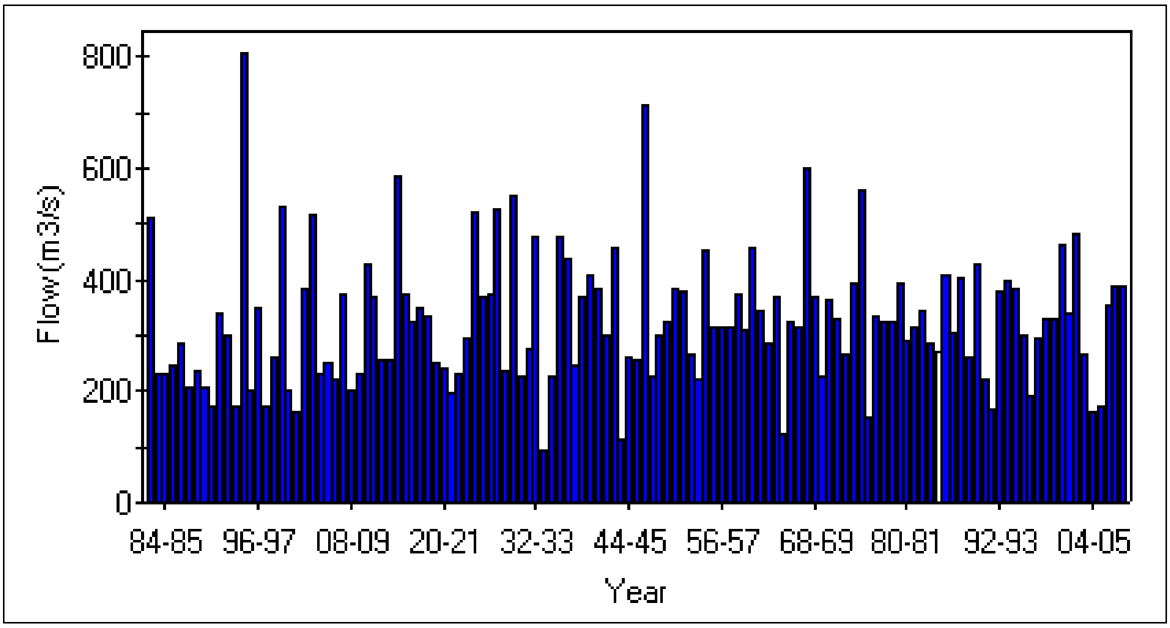
More formal records are available from the Environment Agency river flow gauge at Kingston, approximately 1 km upstream of the site (Figure 3-3). The flood extents for the

1947 flood have also been provided by the Environment Agency, but these are likely to be subject to interpolation in some areas.

Table 3-3 Major Thames floods

Date	Comment
1774	Similar in magnitude to 1894 (snowmelt/frozen ground)
1809	Similar in magnitude to 1894 (snowmelt/frozen ground)
1821	Greater than 1894 flood
1894	Estimated peak flow of 805 m^3/s (Marsh et al, 2005)
1947	Peak of 714 m^3/s (snowmelt/frozen ground)

Figure 3-3 Peak flows for Kingston (39001)

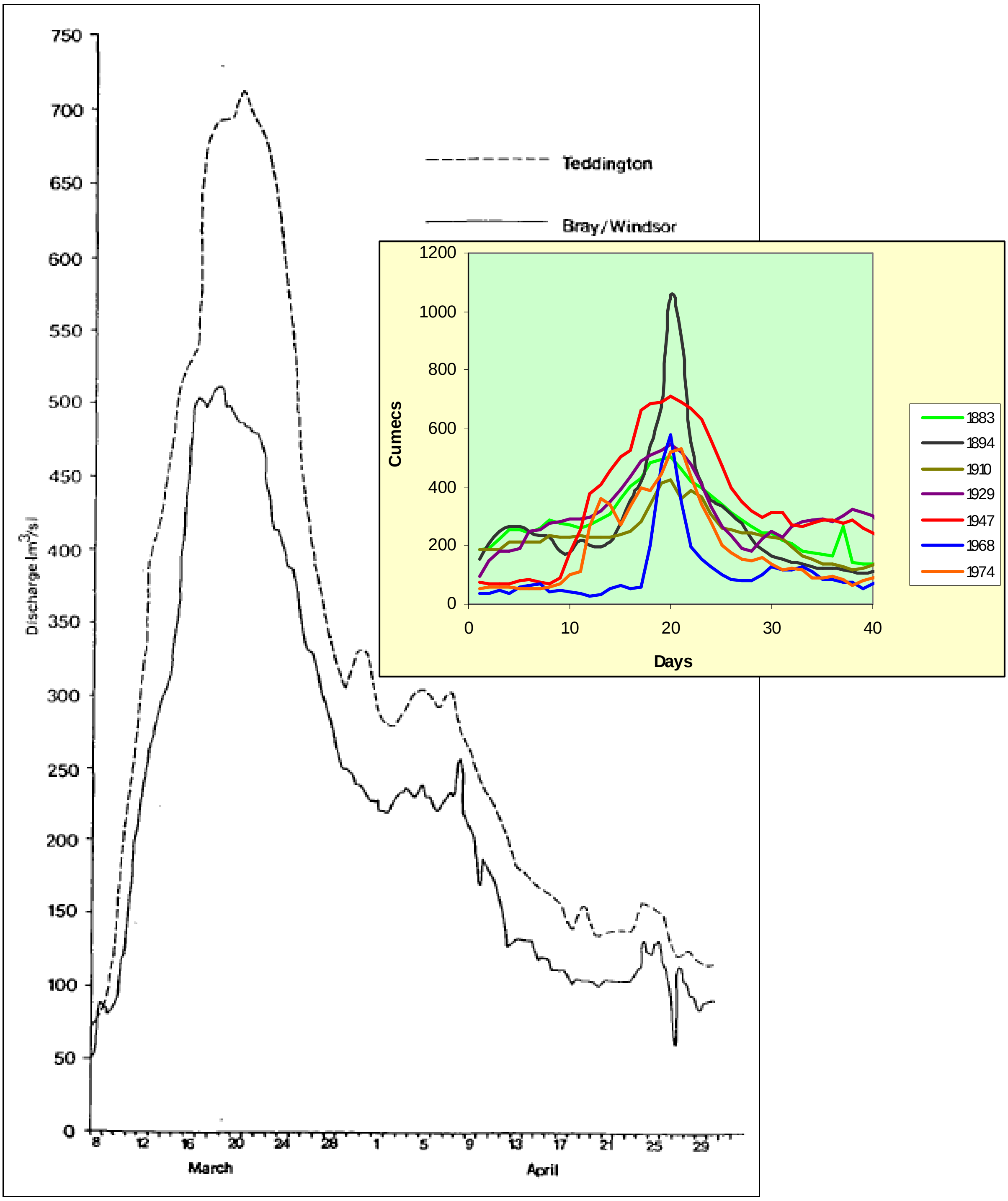


http://www.environment-agency.gov.uk/hiflows/station.aspx?39001

Noteworthy features of the flooding in the vicinity of the site are as follows:

- The floods, being driven by the response of a large catchment of around 10,000 km^2, have a long duration. This is clear from the gauged hydrograph for the 1947 flood (Figure 3-4).
- The valley of the Thames forms a flow constriction approximately 500 m downstream of the site resulting in all water being concentrated at this point. The site is located in the pool that would form upstream of the constriction.
- Although the site is elevated above the general level of the flood plain, there are low lying areas which would be subject to inundation before the site was affected. These include the Lensbury Hotel grounds, the St Mary's sports field and Ferry/Manor Roads and are shown in lilac and light blue on Figure 2-3.
- For higher floods, when the site has been inundated, these same areas act as preferential flow paths with deep, fast flowing water.

Figure 3-4 Hydrograph for the 1947 flood (Institute of Hydrology, 1988)



Inset shows comparison by Marsh et al of recent Thames floods; note that the peak of the 1894 flood has been reassessed

Although this Section refers to fluvial flooding, the extent of flooding will be influenced to some extent by tidal conditions. This is a particularly complex area of river hydraulics and it is one that benefits from the availability of computational models that can be used to investigate a wide range of boundary conditions – that is, different combinations of fluvial flood with tidal extremes. This has been undertaken by consultants working on behalf of the Environment Agency (Halcrow, 2009) and the results from their work form the basis for design flood levels adopted in this FRA.

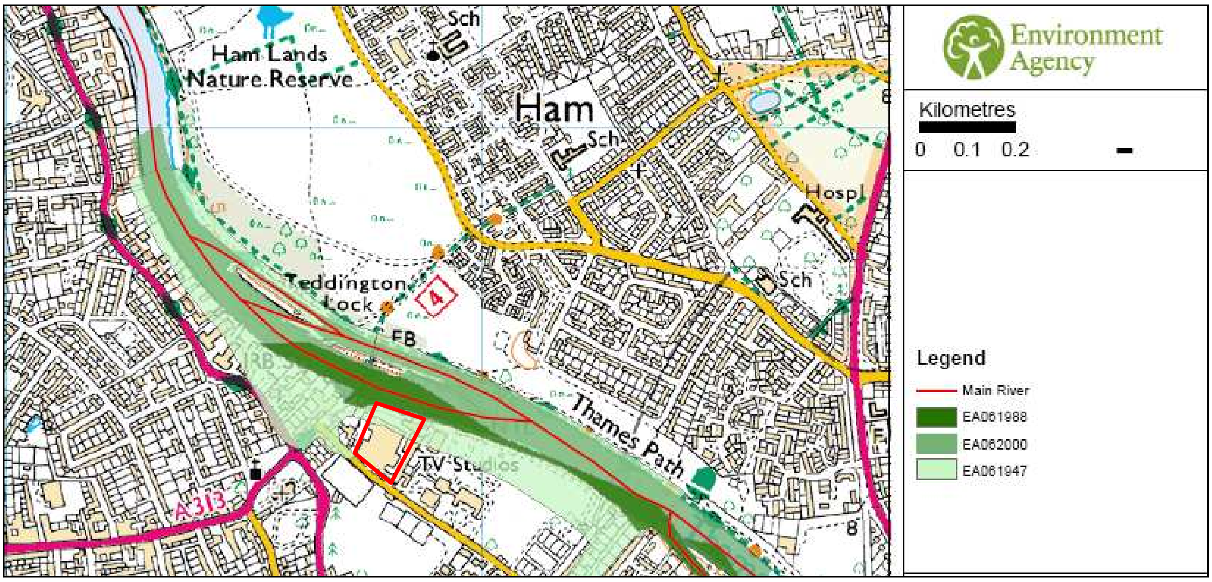
The tidal conditions are especially complex in their influence as they result from the combined influence of:

- Astronomical tides
- Surge conditions
- Operation of the Thames Barrier

The modelling strategy has sought to explore these influences in a systematic way to arrive at design flood levels. This is described in more detail in Section 3.5.

The Environment Agency has provided a map of the historic flood extent for the 1947 flood (Figure 3-5). Whilst this shows partial inundation of the site, the reliability of the map is open to question, in view of the likely limited availability of reliable observations on which to base the flood outline.

Figure 3-5 Historic Flood Map for TW11 9BE - created 03/10/2013



3.3.2 Tidal

Teddington is the upstream tidal limit of the River Thames. The site is protected by formal defences to a level of 6.1 mAOD (see Section 3.3.6) that provide a standard of protection, originally stated as the 0.1% level. More recent information from the Environment Agency from October 2013 (eg the revised flood zone map in Figure 2-3), shows that the standard of protection is more like 5% (1 in 20) when viewing combined fluvial and tidal effects. In a design context, the separation of fluvial and tidal effects is challenging but some extent academic as it is their joint combination that determines many of the extremes. There is an important exception to this which is described further in Section 3.5.

Tidal information is available for Richmond from PLA (2013) and this shows the following information for Richmond:

- Chart datum is 0.61 m (say 0.6 m) below Ordnance Datum, Newlyn
- HAT (Highest astronomical tide) = 5.4 mACD = 4.8 mAOD
- MHWS (Mean High Water Springs) = 4.9 mACD = 4.3 mAOD
- MHWN (Mean High Water Neaps) = 3.6 mACD = 3.0 mAOD

Whilst these levels are for Richmond, the values for HAT from sites from Chiswick to Brentford lie in a range from 4.68 to 4.99 mAOD. The use of values for Richmond is thus a reasonable approximation for Teddington. Low water values are not appropriate for Teddington as at low water, the levels are dependent upon the fluvial flow.

Actual tidal levels can be affected by surge conditions in the North Sea that will propagate up the Thames, varying in magnitude with the topography of the channel and floodplain. The Environment Agency cite a single case of tidal flooding at Teddington when the site was subject to tidal flooding on the night of the 6th and morning of the 7th January 1928. There was overtopping in the area during a storm surge (which coincided with high fresh water flows). An approximate level in the Thames at the time was 5.58 mAODNewlyn.

3.3.3 Groundwater

Groundwater Information provided by the Environment Agency indicates that the site is located on drift deposits of Kempton Park Gravel Member, which overlie a bedrock of London Clay. The Aquifer Designations are as follows:

- Kempton Park Gravel Member is Principal
- London Clay is Unproductive

The Groundwater Vulnerability Designation at the site is Major_HU, in view of the fact that the Kempton Park Gravel Member forms a major (Principal) aquifer. Since the soil class at the site has Unknown Leaching Potential it is assumed to be High until proven otherwise. This is addressed in the Ground Contamination work by Campbell Reith (2013) that has been submitted as part of the Environmental Statement. A localised risk from Ground Contamination has been identified at the site. This is primarily associated with localised potential sources of contamination inferred by the presence of features such as fuel tanks.

In relation to groundwater flood risk, the site is situated on a bedrock of London Clay. These deposits are classed as unproductive strata. As such they are unlikely to hold much groundwater, so the Environment Agency have no information on groundwater levels or flow.

The Environment Agency reports only one incidence of groundwater flooding within 1 km of the site since their records began in November 2000, related to water in an air-raid shelter in a garden 0.92 km from the site in January 2001.

As the site lies on unproductive bedrock strata, the Environment Agency consider groundwater flooding at the site to be unlikely. Water logging would be possible following heavy or prolonged rainfall due to the low permeability geology, but this is not groundwater flooding. A perched water table may occur locally in the Kempton Park Gravel Member due to the low permeability of the underlying London Clay. This may either occur during periods of heavy or prolonged rainfall, or at times of high river levels.

3.3.4 Sewers

An enquiry was made to Thames Water who provided information in relation to sewers and water supply mains. The relevant maps are shown in Figure 3-6 and Figure 3-8. These show that there are no public sewers on the site, although there are three surface water sewers and one foul sewer in Broom Road adjacent to the site.

The supply shows a distribution main along Broom Road with a Supply main and fire main to the site.

The flood risks arising from blockage or failure of either of these systems is considered to be small. The site is elevated above the surrounding land. Furthermore, the finished floor level of the proposed development will be significantly above the general ground level ensuring that risks to property are minimal. There is no record of sewer flooding at this site.

Figure 3-6 Drainage and Water Enquiry Sewer Map- CDWS/CD WS Standard/2013_2485544

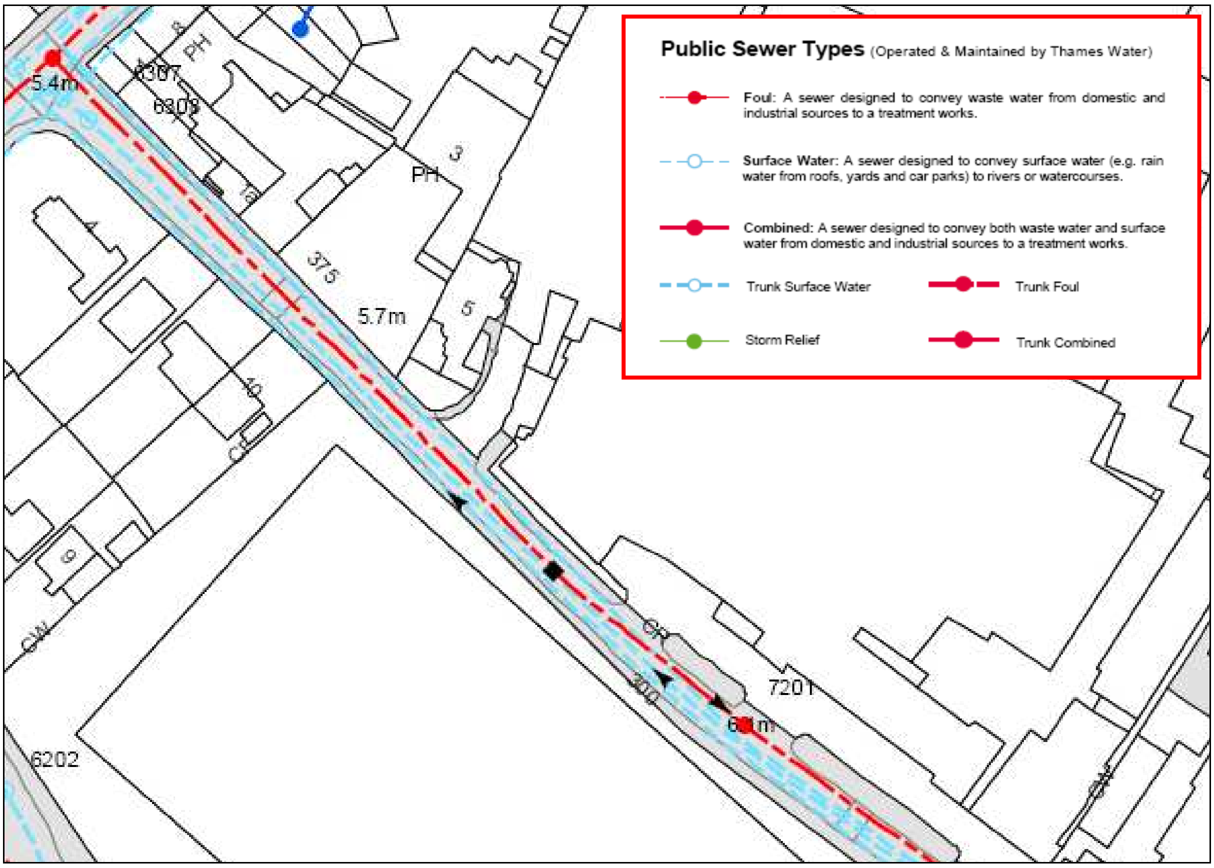


Figure 3-7 Streets in vicinity of the Teddington Studios

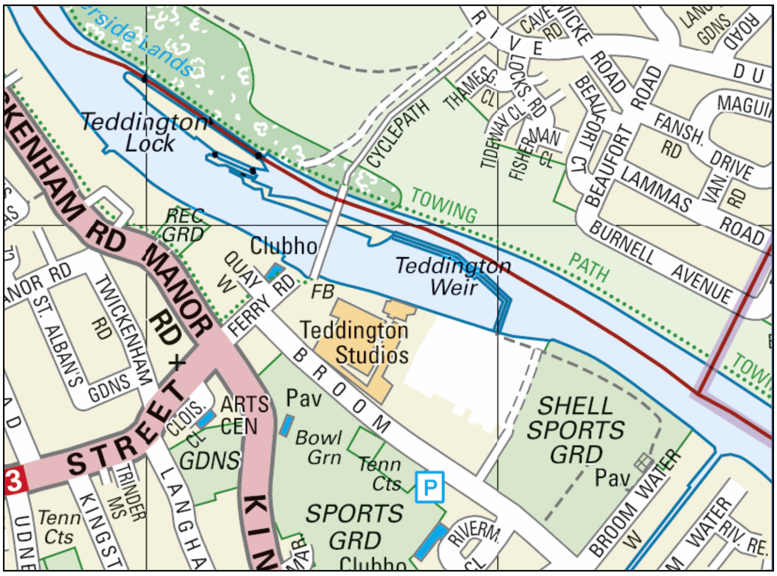
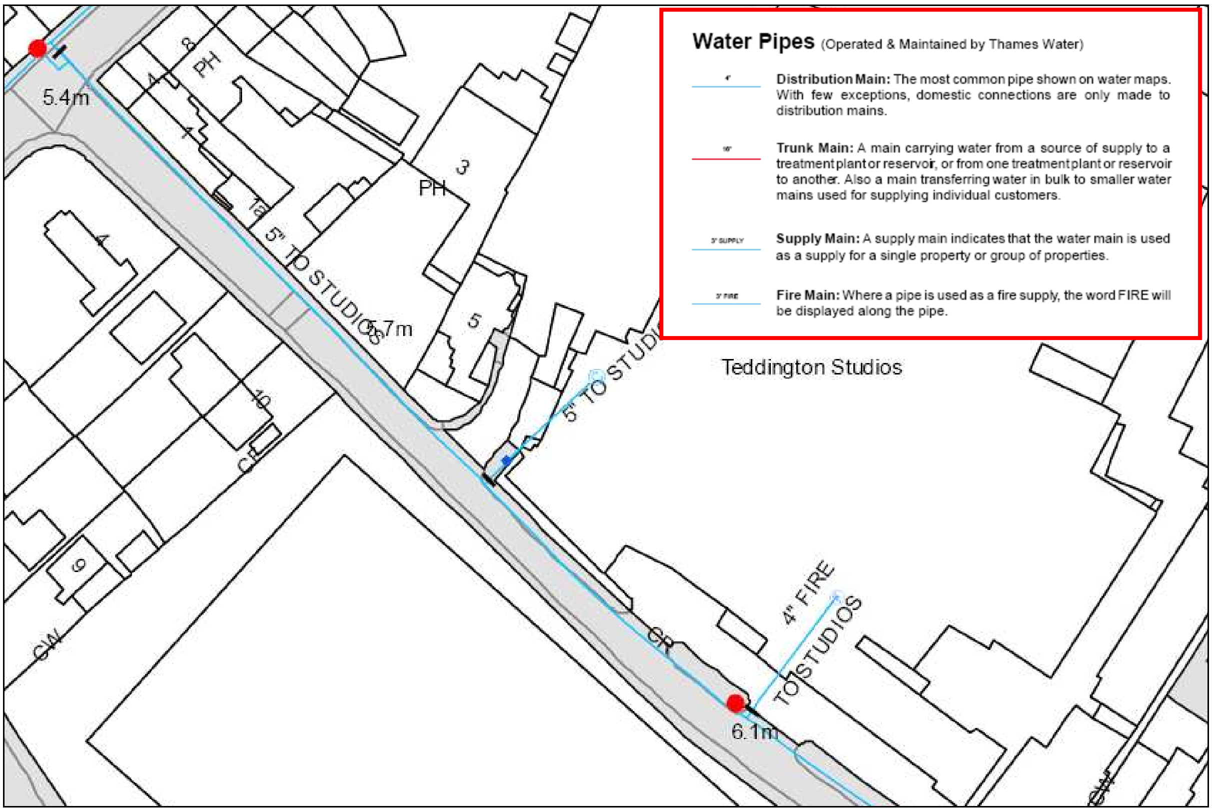


Figure 3-8 Drainage and Water Enquiry Water Map-CDWS/CDWS Standard/2013_2485544



3.3.5 Surface Water

The SFRA reports that surface water flooding problems have been experienced in Manor Road and Ferry Road (Figure 3-7). These have not been investigated but likely reflect the accumulation of excess water, unable to enter the formal drainage network. The accumulation and problems are in low-lying areas. As indicated previously, the site benefits from a generally elevated position, as is clear from the flood zone map (Figure 2-3) and is thus unlikely to be affected by surface water flooding.

3.3.6 Infrastructure

The site currently benefits from tidal defences, a general description of which has been provided by the Environment Agency:

> *The defences along the tidal Thames in this area are all raised, man-made and privately owned. We inspect them twice a year to ensure that they remain fit for purpose. They must be maintained by their owners to a crest level of 6.1m AODN (the Statutory Flood Defence Level in this reach of the Thames). The overall condition grade for defences in the area is 2 (good), on a scale of 1 (very good) to 5 (very poor).*

The standard of protection of the defences has also been described as follows, noting that the probability referred to is purely tidal:

> *The river Thames defences along this section of the river provide a standard of protection of 1 in 1000. This means that the defences protect against a tidal flooding event that has a 0.1% annual probability of occurring. This remains true up to the year 2070. After 2070 the standard of protection will decrease over time. However*

the Thames Estuary 2100 project has studied options to manage flood risk in the Thames estuary up to the year 2100.

The topographic survey undertaken as part of the development proposal has provided an opportunity to review the crest level of the defences. Crest levels are compared with the 5% design flood level in Table 3-4 which has been used to prepare Figure 3-9. The 5% design level is based on modelled data provided by the Environment Agency with linear interpolation between nodes a1.15 and 2.01u and extrapolation downstream of 2.01u (Figure 2-3). This confirms that the defences are ABOVE the modelled flood levels with an annual probability of flooding of 5% that is used to identify the extent of functional flood plain (zone 3b). Paragraph 4.90 of PPS25 (DCLG, 2009) states that:

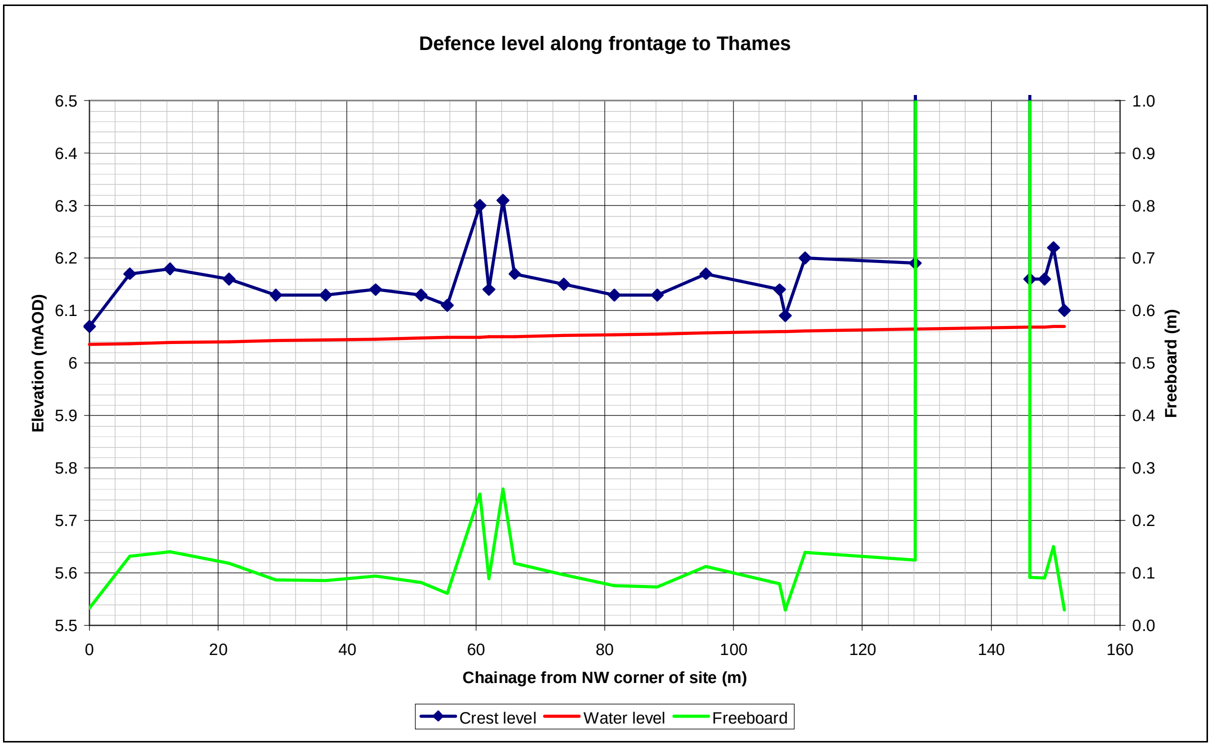
The definition in PPS25 allows flexibility to make allowance for local circumstances and should not be defined on rigid probability parameters. Areas which would naturally flood with an annual exceedence probability of 1 in 20 (5 per cent) or greater, but which are prevented from doing so by existing infrastructure or solid buildings, will not normally be defined as functional floodplain.

This has been confirmed by officials from the Environment Agency and LBRT.

Table 3-4 Crest Level of Tidal Defences adjacent to the site

Chainage (m)	**Crest level (mAOD)**	**Water level (5%) (mAOD)**	**Freeboard (m)**	**Comment**
0	6.07	6.036	**0.034**	NW Corner (Anglers)
6.26	6.17	6.037	0.133	
12.48	6.18	6.039	0.141	
21.67	6.16	6.041	0.119	
28.98	6.13	6.043	0.087	
36.71	6.13	6.044	0.086	
44.41	6.14	6.046	0.094	
51.48	6.13	6.048	0.082	
55.54	6.11	6.048	0.062	
60.63	6.3	6.050	0.250	
62.01	6.14	6.050	0.090	Steps
64.25	6.31	6.050	0.260	
66.04	6.17	6.051	0.119	
73.62	6.15	6.053	0.097	
81.54	6.13	6.054	0.076	
88.18	6.13	6.056	0.074	
95.68	6.17	6.057	0.113	
107.16	**6.14**	**6.06**	0.080	**Node 2.01u**
108.01	6.09	6.060	**0.030**	Steps
111.16	6.2	6.061	0.139	
128.22	6.19	6.065	0.125	
128.7	12.57	6.065	6.505	Building
145.96	12.57	6.069	6.501	Building
145.97	6.16	6.069	0.091	
148.28	6.16	6.069	0.091	
149.72	6.22	6.070	0.150	Steps
151.38	6.1	6.070	**0.030**	
510	**n/a**	**6.15**	**n/a**	**Node a1.15**
Gradient between nodes:		***0.000223***		

Figure 3-9 Crest Level of Tidal Defences adjacent to the site



There are three locations where the freeboard falls below 0.05 m and below the nominal defence level of 6.10 mAOD. Extracts from the topographical survey are shown in Figure 3-10 for these locations.

The existence of defences raises an additional issue in relation to their failure. The Environment Agency has provided the results of breach analysis in Figure 3-11. This shows that the site would be partially inundated by a breach during the 0.5% AEP (annual exceedance probability) event in 2005. However, under conditions in 2107, with increased frequency of extreme high sea levels, the entire site would be affected by a breach in the defences. The absence of modelling results by the Environment Agency does not reflect the lack of likelihood of any such breach. The raising of the floor levels above general site level will mean that the risks are significantly reduced to property following any such breach. Further, the risk of defences being overtopped for fluvial and combined events is significant. The flood extent for breached conditions is thus little different from that for overtopping events.

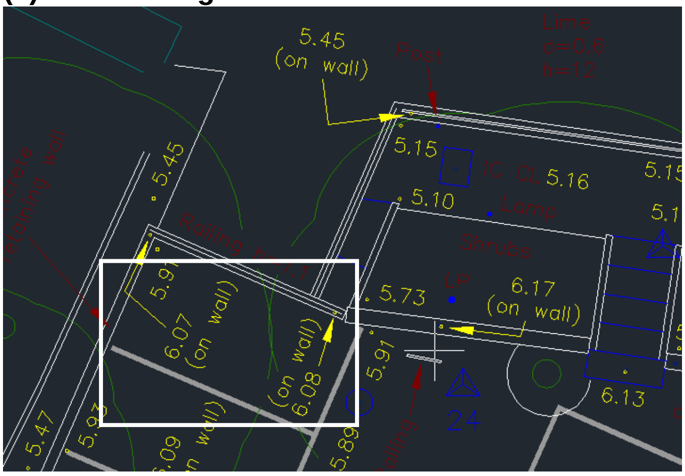
The Environment Agency Pre Application response (Appendix D) has indicated that under plans for Thames Estuary 2100, there is a possibility that defence levels may be increased to 6.9 mAOD in the vicinity of the site. This has two implications. Firstly, there is a need to ensure that any planned infrastructure can accommodate any such increase. Secondly, whilst the increased defence level will reduce the frequency of flooding, the impacts of breaching will be more profound. This is accordingly highlighted in the Emergency Plan as an issue to be addressed once it becomes clear that the Defences are likely to be raised.

The Environment Agency has further indicated that there may be a possible flow route around the tidal defences. Since the defences “on site” are to the required level, except where shown above, this can only be due to overtopping in the vicinity of the site. The site would be unaffected by this process – since levels along Broom Road are locally at 5.9

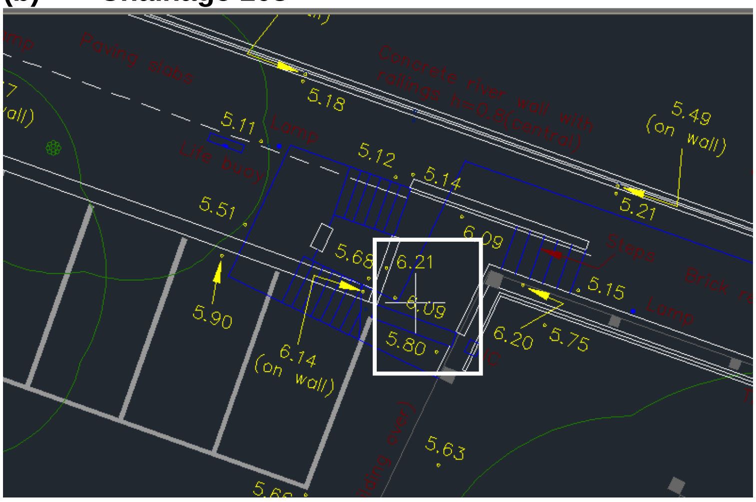
mAOD, but soon rise above that. Access may be affected and this is considered further in Section 4.2.2.

Figure 3-10 Locations where freeboard is less than 0.05m

(a) Chainage 0



(b) Chainage 108



(c) Chainage 151

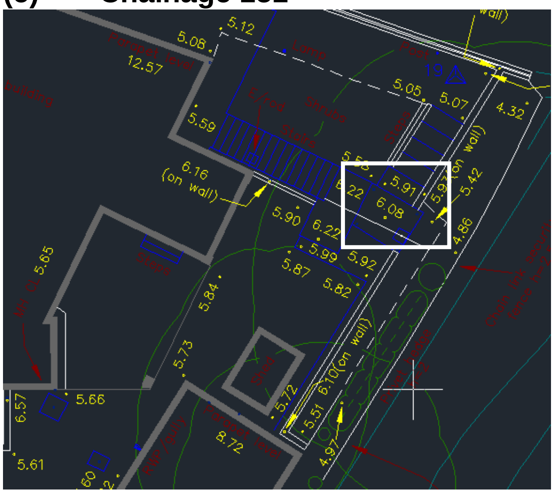
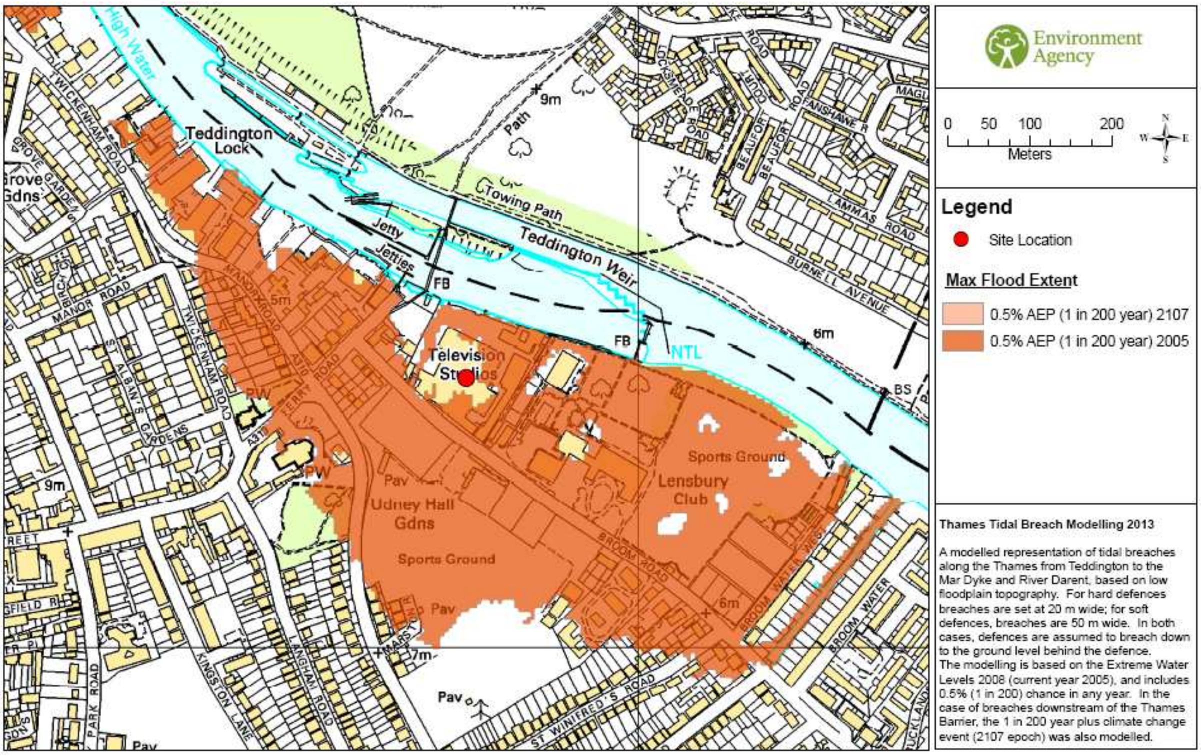


Figure 3-11 Breach Modelling Map for TQ1679071328 - created 17/04/2013 - WT8646



Note: Identical with map issued under NE36687JH on 7 October 2013

3.4 Existing Surface Water Drainage Arrangements (B2c)

During one of the site visits, an inspection was made of the surface water drainage arrangements, accompanied by staff responsible for maintenance of drainage. It was noted that surface runoff from rooves and hardstanding are disposed of either to the sewers in Broom Road (Figure 3-6 and Figure 3-12), or to a storm tank in the north-west corner of the site, which outfalls to the Thames via a flap valve (Figure 3-13). There are no details available on the dimensions of the existing tank. It is recommended that these be obtained during site investigations along with an assessment of the condition of the tank.

There are no reports from the current users of the site of problems with surface water drainage, other than temporary accumulations on car parks following intense storms.

Figure 3-12 Surface water drainage facilities

Figure 3-13 Flapped outfall from balancing storage in north-west corner of site

3.5 Probability Of site Flooding (B3c)

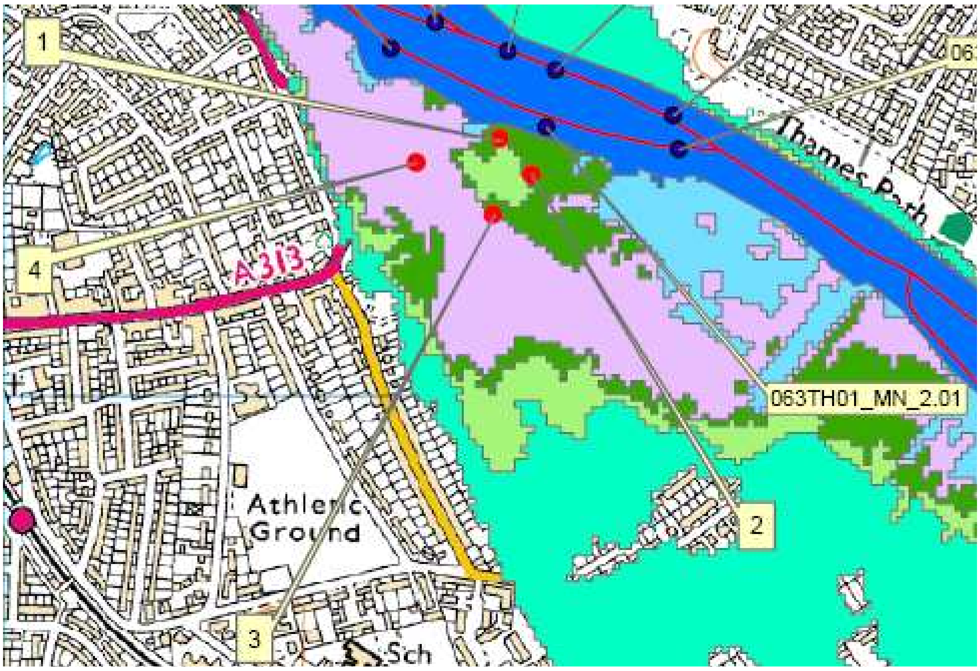
3.5.1 General

The probability of site flooding has been based entirely on flood level information provided by the Environment Agency in response to the various data requests. These levels are for a model node (063TH01_MN_2.01u in Figure 3-14) which is downstream of the Teddington weir and adjacent to the site.

The design water levels feature a shallow gradient, consistent with shallow gradient of the Thames at this location. Theoretically, one could evaluate the change in water levels along the river frontage. However, for practical purposes, this variation is small in both absolute terms and in relation to the uncertainty associated with such levels. The modelled levels for Node 2.01u are therefore assumed to apply along the entire river frontage

The levels provided by the Environment Agency also include levels for selected nodes on the flood plain, labelled 1, 2, 3 and 4 in Figure 3-14. These modelled levels for the floodplain are approximately 0.2 m “lower” than those for the river at Node 2.01u. These differences in level are discussed within the FRA. However, for consistency and as a precautionary measure, the levels for the river have been assumed to apply across the entire site. This clearly imparts a degree of conservatism to the analysis.

Figure 3-14 Model nodes for river and flood plain



3.5.2 Modelled flood levels

The relevant levels have been provided by the Environment Agency for a range of return periods and projections. The levels of most relevance to the FRA are the 5% (1 in 20) and 1% (1 in 100). Given a design life of, nominally, 100 years for residential use, the projection to 2100/2107 is also relevant.

The most recent levels provided by the Environment Agency are from the following sources:

- Combined modelling and fluvial only modelling (data requests WT8646 and WT11411) in Table 3-5
- TE2100 (data request NE36687JH) in Table 3-6

The modelling background is complex and this is compounded by the availability of three data sets and the management regime for the Thames Barrier. The term “combined modelling” indicates that the design levels have been based on the combined influence of fluvial and tidal factors. This has been undertaken using a probabilistic method that reconciles the combined probabilities of the fluvial and tidal extremes used in any individual model run. The modelling has also investigated “fluvial only” events and it is shown that these results are important at extreme probabilities.

Table 3-5 Design flood levels (node 2.01u)

	WT8646	WT8646	WT8646	WT11411	WT11411	Comment
AEP	2005	2055	2107	Present	2107	
10%	5.87	6.04	5.98			
5%	**6.06**	6.23	6.18	5.55		6.06 is a fluvial/tidal maximum
2%	6.3	6.48	6.46			
1%	6.5	6.68	6.66	6.38	**6.97**	6.97 is a fluvial maximum
0.50%	6.67	6.88	6.85			
0.20%	6.91	7.13	7.1			
0.10%	7.08	7.29	7.24			

Table 3-6 Design flood levels from TE2100 (node 2.01)

Description	Level (mAOD)
Present day: Extreme water level	7.36
2065-2100: Design water level	6.05
2100: Design water level	6.50

The modelling for 2107 shown in Table 3-5 gives a design flood level of 6.97 mAOD. There is considerable modelling and analytical complexity around the derivation of this and other levels. However, it is essentially a fluvial maximum and results from a 1% (1 in 100) flood, the flow rate for which has been increased by 20% to allow for the effects of climate change.

The TE2100 levels result from a large body of work commissioned by the Environment Agency in relation to flood risk management of the Thames Estuary. The operation of the Thames Barrier is critical in this strategy and the recent modelling addresses the frequency of Thames Barrier operation. Further, and of relevance to flooding in Richmond, it reviews the way in which the Thames Barrier will be operated to mitigate flooding in the estuary and the Thames Tideway. In recent times, the Barrier has been deployed to help mitigate the effects of fluvial flooding, in areas such as Richmond, as happened in 2012. It is believed that such deployment will not occur in the future in line with the projected maintenance schedule for the Thames Barrier.

These TE2100 levels recently provided do not have return periods. The Environment Agency present them as “absolute maximum levels” and clarify this as follows:

> *The levels upstream of the barrier are the highest levels permitted by the operation of the Thames Barrier. If levels and flows are forecast to be any higher, the Thames Barrier would shut, ensuring that the tide is blocked and the river maintained to a low level. For this reason the probability of any given water level upstream of the Barrier is controlled and therefore any associated return period becomes irrelevant. The Thames Barrier and associated defence system has a 1 in 1000 year standard which means it ensures that flood risk is managed up to an event that has a 0.1% annual probability. The probability of water levels upriver is ultimately controlled by the staff at the Thames Barrier.*

When these absolute levels are compared to that from combined modelling, it is found that the TE2100 levels are lower for the medium projection (2065) and long term projection (2100). However, for the present day water levels, a maximum of 7.36 mAOD is provided. This is nearly 40 cm above the 1% level from combined modelling, including the effects of climate change and around 1 m higher than the 1947 flood.

In this FRA, preference has been given to the results from combined modelling, rather than the TE2100 values. The reasons for this are as follows:

(i) It is inconceivable that the operators of the Thames Barrier, in their efforts to reduce the use of the Barrier to mitigate fluvial flooding, would permit flooding to occur of severity **greater** than for the 1% climate change event at this location.

(ii) The projected absolute levels are unworkable from a planning perspective. The present day levels (of 7.36 mAOD) impose a massive constraint on current applications. However, this absolute level falls by over 1 m to 6.05 mAOD for 2065-2100, rising again to 6.50 mAOD by 2100. This provides an exceptionally difficult context within which the planning process can take place.

(iii) The TE2100 levels refer to “absolute” maxima, with no return period or risk ascribed to it. This is precautionary in the extreme.

(iv) It is understood that there is ongoing debate over these levels, the results of which are not available at this time, but which is highly relevant to this application.

One of the important provisions of the TE2100 data release is the information on the future flood defence programme. In this, the intention to raise defences in the vicinity of the site to 6.9 mAOD by 2100 is stated. This issue is discussed in Section 4.

3.5.3 Recommended levels

In summary, the recommended flood level for design purposes is 6.97 mAOD. This corresponds to the 1% level with allowance for climate change of 20%, appropriate to the design life of the scheme of 100 years. It is based on the fluvial maximum under Data request WT11411. This level has been rounded to a nominal **7.0 mAOD** in the remainder of this FRA.

3.6 Summary

This Section has reviewed the flooding mechanisms at the site from a historical and design perspective. Flooding at the site is due to the combined effects of fluvial and tidal mechanisms. The FRA has benefitted greatly from the availability of computational models of the Thames. The have been used to explore the interactions between fluvial and tidal maxima via a combined analysis.

Whilst the interaction between fluvial and tidal factors for a single event is complex, extreme water levels (for 1 in 100 or 1% probability with allowance for climate change) at the site are essentially the result of fluvial maxima. The model results for the 1% (1 in 100) flood with a 20% allowance for climate change have been used as the basis for design. The level is 6.97 mAOD, nominally **7.0 mAOD**.

This is higher than the TE2100 levels for the medium and long term projections. However, it is lower than the TE2100 Present Day absolute maximum. The Present Day TE2100 levels have not been used for reasons that are articulated in this Section.

4. Review of Development Proposals

4.1 Development Process (B5)

The proposed development is summarised as follows:

- the demolition of existing buildings with the exception of Weir Cottage
- the erection of part four/part five/part six storey buildings to provide 217 flats (Blocks A to D)
- erection of 6 three storey houses to Broom Road frontage (Blocks E1 to E6),
- 12 affordable housing units to Broom Road frontage (Block E-7),
- use of Weir Cottage for residential purposes (Block F)
- provision of 259 car parking spaces at basement and ground level
- closure of existing access and provision of two new accesses from Broom Road
- provision of publicly accessible riverside walk together with cycle parking and landscaping.

The development is summarised in numerous plans that accompany the planning application. An illustrative master plan is shown in Figure 4-1, which shows that the proposed development will comprise four blocks (A, B, C and D) plus town houses and affordable housing (Blocks E). The existing cottage is shown as Block F and will retain its existing footprint. The image is also included in Appendix E at a larger scale. The landscape layout is shown in Appendix F .

In this Section, the development proposal is reviewed in relation to the key requirements of NPPF/PPS25, namely:

- Finished floor level (Section 4.2.1);
- Safe Access/Egress (Section 4.2.2);
- Flow paths (Section 4.3.1);
- Flood plain storage Section (4.3.2);
- Runoff (Section 4.3.3); and
- Residual Risks (Section 4.4).

4.2 Flood Risk Management Measures (B5, B6)

This Section deals with the measures to mitigate flood risk to the site itself. In general, this refers to finished floor levels and the access/egress arrangements.

4.2.1 Finished Floor Levels

In Section 3.5, the basis for the flood levels was outlined. The design flood level for the 1% (1 in 100) probability with allowance for climate change was 6.97 mAOD, nominally 7.0 mAOD. This has been assumed to apply across the entire site, though in practice, and as confirmed by model results provided by the Environment Agency, equivalent levels on Broom Road adjacent to the site may be around 6.75 mAOD. It is demonstrated in this FRA that the proposed development satisfies the Environment Agency requirements in relation to flood plain storage (Section 4.3.1) and in relation to flow paths through the site (Section 4.3.2). The modelled flood levels referred to in the previous Section are therefore considered appropriate for the post development situation.

Figure 4-1 Teddington Riverside – general development concept

The finished floor level for the four principal Blocks (A, B, C and D) plus the Affordable Housing (Block E-7) has been set 300 mm above the design flood level at **7.3 mAOD**. This is in line with LBRT requirements.

For the proposed townhouses along Broom Road (Blocks E), this floor level was at variance with design considerations. Accordingly, the finished floor level for these properties has been set at 6.2 mAOD. It was noted in Section 3.5 that flood levels on the flood plain are approximately 0.2 m below those of the river, that is at around 6.8 mAOD. These properties will be built such that they are "resistant" to flooding to a level of at least 7.1 mAOD, that is 300 mm above the design flood estimate at this location on site. Since this is a new-build, a very high standard of specification and construction can be used to minimise the risk to these properties. Flood resistance measures to be used would be in accordance with BSI PAS 1188-1 - Flood protection products - Building apertures. The principal measures that will be incorporated in the construction include:

- flood resistant "stable" doors to the front elevations that will be exposed to the flood plain;
- flood resistant "stable" doors to the rear elevations – this is precautionary, since the rear gardens will be protected behind a flood wall. There is a risk of flooding from water percolating through the ground though this will be mitigated by permanently installed sump-pumps in this part of the site;
- non-return valves on drainage outlets, capable of dealing with sewage
- masonry with strong water resistance properties
- solid floors to prevent movement of water from the ground into the ground floors

These are classed as "passive" measures and so do not require any action on the part of occupiers to be effective, other than conventional "locking" of the external doors, that activates the flood seals.

Flood "resilient" measures should also be incorporated into the ground floor of these dwellings. This will involve:

- Use of hard floors, capable of withstanding exposure to water;
- Raised electrical sockets
- Internal wall finishes capable of withstanding prolonged exposure

Weir Cottage has an existing floor level of around 6.92 mAOD, based on the topographic survey. There is therefore a requirement for flood resistance measures to be incorporated into the refurbishment of the cottage. Strictly, this is to protect against flood levels that are only expected with the impacts of climate change and are thus not required immediately. However, given the refurbishment work that will be undertaken at the Cottage, it would seem sensible to include them in the current programme of works. These should provide protection to 7.1 mAOD (300 mm above the design flood level for this location on site) and could be similar to the measures outlined above. Given the age of the property, it is possible that the masonry walls are not particularly watertight at present. Flood resistance and resilience measures should be undertaken to a high standard for Weir Cottage. This will require an inspection by a suitably qualified flood surveyor, to identify possible routes of water entry and appropriate mitigation measures.

There are entrances to Blocks A, B and C from the gardens into stairwells, incorporating lifts. The gardens are at a general level of 5.6 mAOD, but there will be ramps to a level of around 6.0 mAOD. The stairwells will be protected by deployment of demountable flood barriers. The barriers will be stored in the Basement and will be deployed by Site Management Staff. Note that these entrances do NOT form part of the emergency access/egress route.

4.2.2 Access/Egress arrangements

The access/egress arrangements are described in Appendix B , which has been prepared in line with the LBRT requirements for Flood Emergency Plans. There are two key requirements for access that are addressed in this Section:

- Emergency access during extreme floods
- Access during moderate flood events

The communications of warnings to residents will be undertaken by Site Management Staff, from the Management Office located on the ground floor of Block A. They will also manage the deployment of temporary protection measures, as outlined below and instruct the “on-call contractors” for deployment of the temporary access bridge to secure the safe access/egress from the site.

(a) Emergency access

It is a requirement that safe access be available from the site to areas that are wholly outside flood zone 3. Reference to flood zone maps (eg Figure 2-3) show that the site is surrounded by areas of flood zone 3. However, there are two routes available during flood conditions, via Broom Road and via the Teddington Lock footbridge.

Broom Road offers a safe and usable access route for the duration of many floods, initially with safe access for pedestrians. For higher flood levels, access will entail informal “shuttle” arrangements with the use of suitable vehicles along Broom Road (eg four wheel drive vehicles, tractors and trailers) to enable residents to access the safe areas on the Teddington bank directly.

However, for extreme floods the access/egress to and from the site will be via the Teddington Lock footbridge. All residential accommodation will benefit from “safe” access from the site to the opposite bank at Ham. The details of this route are presented in Section B.3.5 and it comprises the following elements:

- Paths internal to the site at a minimum of 6.8 mAOD
- Link to a telescopic bridge over the Angler’s Public House deployed during flood conditions with a connection to the Teddington Lock footbridge
- Teddington Lock footbridges
- Path through the riverside park towards Riverside Drive with dry access for the 1CC (Figure 2-3).

It is shown in Appendix B that, external to the site, the route is entirely above the 1% level, with allowance for climate change, and therefore dry, beyond the site boundary. Within the site boundary, all of the main Blocks (A, B, C, D and Affordable Housing) are accessible on paths set at a minimum 6.8 mAOD, as shown in Figure 4-2. Note that the stairwells that give out onto the garden areas do not form part of the emergency access/egress route. For a design flood level of 6.97 mAOD, this would imply a maximum depth of 0.17 m. DEFRA has issued guidance on the hazard rating of combinations of flow depth and velocity, part of which has been reproduced in Table 4-1. Use of the Hazard Equation shows that for internal access from the four blocks, the Hazard classification would be “Very Low” for velocities up to 0.97 m/s. Such a velocity is considered to be most unlikely on the walkways, given the protected nature of the site. This is for a debris factor of 0.5, which is also considered to be conservative, in view of the protected nature of the site.

It has been noted above that the floor level of the town houses in Block E will be at 6.2 mAOD. Emergency access from these properties will be via the rear of the properties into gardens that are behind flood walls. It is possible that the gardens will be subject to some flooding due to water passing through the ground. This will be mitigated by the installation of two sump-pump systems in this part of the site. The pumps will be actuated on an automated basis when water levels in the sumps exceed a threshold level. There will be a short walk of a maximum of 10 m for residents to reach the safe access of 6.8 mAOD.

Access from the Affordable Housing Units will be via a walkway at a minimum of 6.8 mAOD. This will lead up to Building C, from where access can be gained to the Piazza.

Access from the Cottage (Block F) will be via a dedicated walkway from the ground floor that will lead out onto the access route at 6.92 mAOD.

The LBRuT have commented that the proposed emergency access is of concern since residents are directed towards and ultimately over the river – which is the hazard. Whilst this is true, the route is safe, as judged by the DEFRA hazard rating. Whilst Broom Road will be used as fully as conditions permit, there will ultimately be a requirement fir an alternative route to avoid the hazard due to the fluvial flow paths under extreme conditions across Broom and Ferry Roads (Figure B-4).

Table 4-1 Hazard to People Classification using Hazard Rating

HR	Depth of flooding - d (m)												
	DF = 0.5				DF = 1								
Velocity v (m/s)	0.05	0.10	0.20	0.25	0.30	0.40	0.50	0.60	0.80	1.00	1.50	2.00	2.50
0.0	0.03 + 0.5 = 0.53	0.05 + 0.5 = 0.55	0.10 + 0.5 = 0.60	0.13 + 0.5 = 0.63	0.15 + 1.0 = 1.15	0.20 + 1.0 = 1.20	0.25 + 1.0 = 1.25	0.30 + 1.0 = 1.30	0.40 + 1.0 = 1.40	0.50 + 1.0 = 1.50	0.75 + 1.0 = 1.75	1.00 + 1.0 = 2.00	1.25 + 1.0 = 2.25
0.1	0.03 + 0.5 = 0.53	0.06 + 0.5 = 0.56	0.12 + 0.5 = 0.62	0.15 + 0.5 = 0.65	0.18 + 1.0 = 1.18	0.24 + 1.0 = 1.24	0.30 + 1.0 = 1.30	0.36 + 1.0 = 1.36	0.48 + 1.0 = 1.48	0.60 + 1.0 = 1.60	0.90 + 1.0 = 1.90	1.20 + 1.0 = 2.20	1.50 + 1.0 = 2.55
0.3	0.04 + 0.5 = 0.54	0.08 + 0.5 = 0.58	0.15 + 0.5 = 0.65	0.19 + 0.5 = 0.69	0.23 + 1.0 = 1.23	0.30 + 1.0 = 1.30	0.38 + 1.0 = 1.38	0.45 + 1.0 = 1.45	0.60 + 1.0 = 1.60	0.75 + 1.0 = 1.75	1.13 + 1.0 = 2.13	1.50 + 1.0 = 2.50	1.88 + 1.0 = 2.88
0.5	0.05 + 0.5 = 0.55	0.10 + 0.5 = 0.60	0.20 + 0.5 = 0.70	0.25 + 0.5 = 0.75	0.30 + 1.0 = 1.30	0.40 + 1.0 = 1.40	0.50 + 1.0 = 1.50	0.60 + 1.0 = 1.60	0.80 + 1.0 = 1.80	1.00 + 1.0 = 2.00	1.50 + 1.0 = 2.50	2.00 + 1.0 = 3.00	2.50 + 1.0 = 3.50
1.0	0.08 + 0.5 = 0.58	0.15 + 0.5 = 0.65	0.30 + 0.5 = 0.80	0.38 + 0.5 = 0.88	0.45 + 1.0 = 1.45	0.60 + 1.0 = 1.60	0.75 + 1.0 = 1.75	0.90 + 1.0 = 1.90	1.20 + 1.0 = 2.20	1.50 + 1.0 = 2.50	2.25 + 1.0 = 3.25	3.00 + 1.0 = 4.00	3.75 + 1.0 = 4.75

(b) Access for moderate floods

For moderate floods, and for the early stages of extreme floods, access will be available to the site via Broom Road. Although this will be affected to an increasing extent as flows increase in the Thames, it is expected that any change in depth and velocity along Broom Road would occur fairly slowly, due largely to the slow rate of change of water level in the river. This will give an opportunity for emergency services to react to changing conditions and manage access as required.

The Environment Agency has indicated that there "may" be a flow route around tidal defences, before they are overtopped. The maximum water level for such a mechanism would be 6.1 mAOD at the point where the defences were outflanked. The maximum level would then decrease as one moved away from the location of the outflanking. Furthermore, the duration of any such event, being tidal, would be of the order of tens of minutes.

This mechanism may lead to accumulation of water at the Broom Road/Ferry Road junction. However, Broom Road would likely remain passable, or at worst after a short delay. It is therefore not considered that this mechanism warrants specific inclusion in the Emergency Plan.

Figure 4-2 Emergency Access within the site

Table 4-2 Definition of Flood Hazards to People Classification

Flood Hazard Rating (HR)	Colour Code	Hazard to People Classification	Use of flood emergency plans to manage flood risk
Less than 0.75		Very low hazard – caution	Acceptable
0.75 to 1.25		Danger for some – includes children, the elderly and the infirm	Maybe acceptable
1.25 to 2.0		Danger for most – includes the general public	Unlikely to be acceptable
More than 2.0		Danger for all – includes the emergency services	Unacceptable

The mechanisms by which residents will be kept informed of flood risk conditions is explained in Appendix B . It is based on use of information screens supported by text/email messages, managed by Site Management Staff.

The slow rate of change of flows and levels also means that there is a relatively long lead time for flood warning. This will provide residents with opportunity to relocate vehicles, if required within the subterranean car park, or away from the site.

4.2.3 Car Parks

Car parking for residents is provided in either surface parking or in subterranean car parks. Surface parking will be at levels from 6.1 mAOD and is therefore at risk from flooding. The flood warning systems described in Appendix B will provide residents with warnings of when vehicles, parked at the surface, need to be relocated. Provision has been made for all cars parked in the surface car parks to be parked in the subterranean car park through “valet parking”.

The subterranean car parks will be accessed via down ramp (whose entrance is at a level of 6.3 mAOD) and up-ramp, whose entrance will be at 6.5 mAOD. The car parks will be protected from flooding by the use of a “flip-up” flood barrier (Figure 4-3), which will be flush with the road in its normal deployment. The barriers will provide protection to a level of 7.3 mAOD, requiring one barrier of height 0.8 m and one barrier of 1 m height. Provision will be made for any water that does enter the car parks such as from rain on the access ramps, to be removed by pumping. Barriers to be used would be in accordance with BSI PAS1188-2 - Temporary and demountable flood protection products. The Barriers will be subject to regular testing by the Site Management team.

Figure 4-3 Example of suitable “Flip-Up” Flood Barrier

http://www.floodcontrolinternational.com/PRODUCTS/FLOOD-BARRIERS/flip-up.html

4.2.4 Realignment of existing defences

The existing river frontage features a walkway at a level of around 5.1 to 5.2 mAOD. A small wall separates the walkway from the river as shown in Figure 4-4, with a crest at around 5.5 mAOD. The formal defence line is set back around 4 m from this small wall, with a crest at the nominal 6.1 mAOD. The alignment is broadly parallel to the river bank and is formed in part by buildings, as shown in the photograph.

Figure 4-4 Existing walkway

The proposed development, will involve refurbishment and realignment of the existing defences as shown in Figure 4-5; the proposed alignment being shown as the green dashed line. For the western part of the wall, it follows the existing alignment. In the centre, the alignment is set back whilst in the eastern part of the site, the alignment initially follows the river edge before reverting to the south of the riverside walkway. This alignment enables the building in the north east corner (Block C) to achieve a standoff of 16 m from the defences. The new wall will be designed in consultation with Environment Agency design team to ensure the integrity of the existing defences during construction and to ensure that the wall can be raised by 0.8 m at some stage in the future. The new alignment will be put in place before sections of the existing wall are removed. Furthermore, the wall will be keyed in to the existing defences along the eastern boundary of the site (Figure 4-6). The existing defences will be retained on the western boundary and river frontage as far as the wider part of the riverside walk (Figure 4-7). In structural terms, the future raising is considered to be a straightforward task requiring installation of columns within which some panels can be installed. In order to maintain access to the riverside walk, the three sets of steps can incorporate a flood-proof gate. In its normal position, this would allow access to the different sections of the riverside walk. A detail of the arrangement in the centre of the Riverside Walk is shown in Figure 4-6.

Figure 4-5 Proposed alignment of defences along river frontage

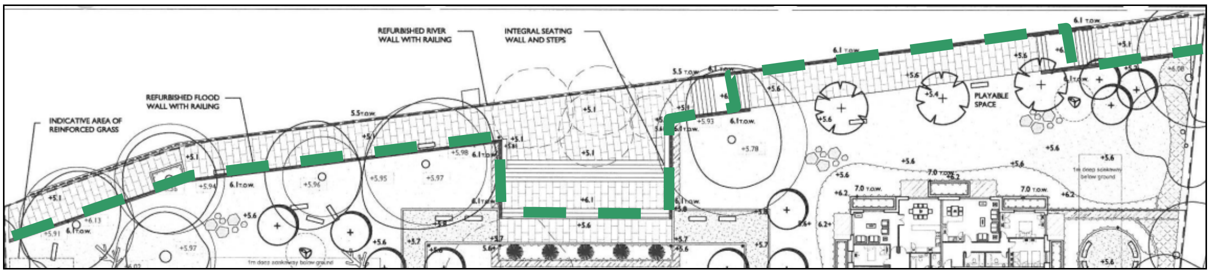
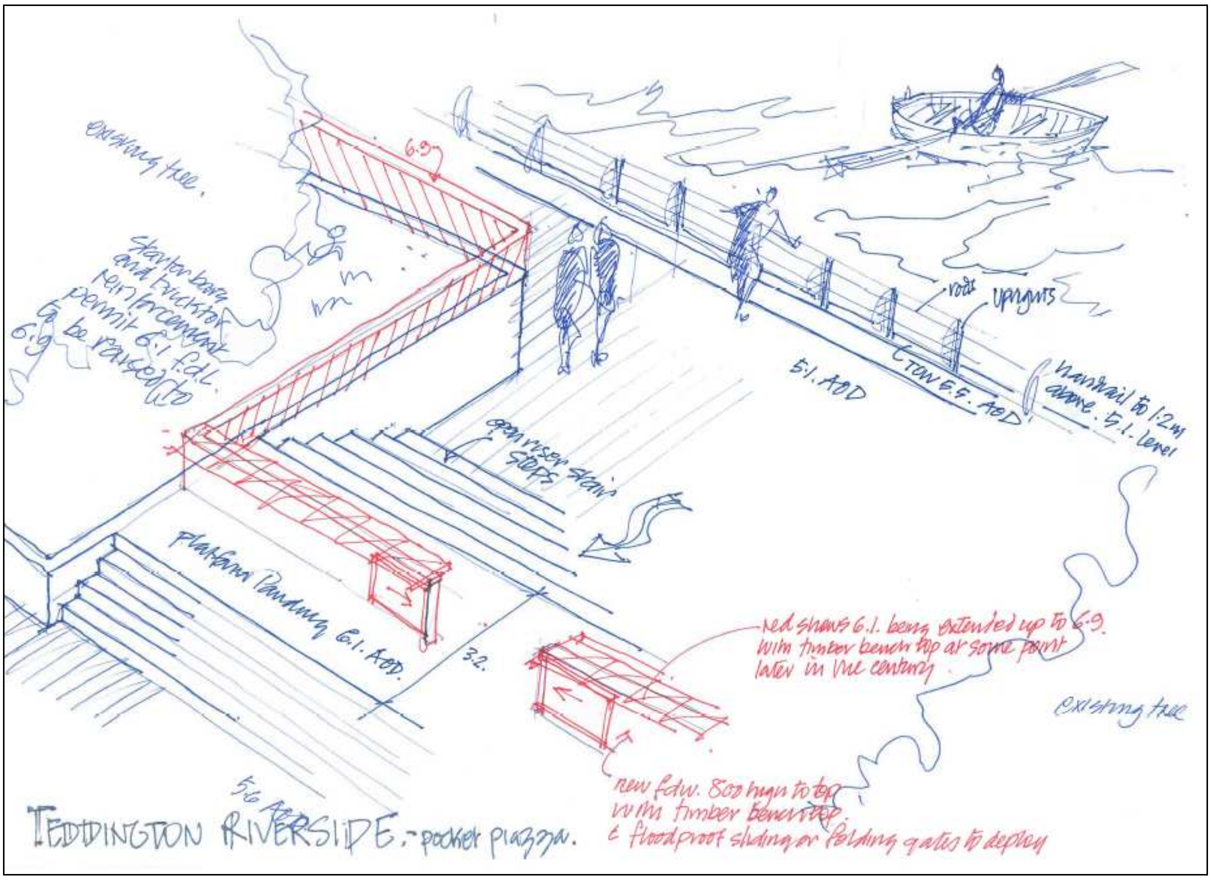


Figure 4-6 Location where realigned wall will key into existing defences: NE corner

Figure 4-7 Existing wall will be refurbished on part of river frontage and western boundary

a) River frontage *b) Western boundary*

Figure 4-8 Sketch detail to show raised defences to 6.9 mAOD in centre of Riverside Walk



4.2.5 Benefits to wider community

The Flood Emergency Plan provided in Appendix B provides wider opportunities for reducing flood risk to the wider community. Specifically, these include:

- Provision of emergency car parking;
- Allowing neighbours to use the proposed emergency access
- Allowing use of any emergency transport along Broom Road;
- Use of the site as a refuge
- Provision of access/egress route for the Lensbury Hotel

4.3 Off Site Impacts (B7a, B3d, B7b)

It is a fundamental requirement under NPPF that any proposed development should not have adverse impacts upon others. In this Section, the impacts are reviewed in terms of:

- Flow paths
- Flood plain storage
- Runoff

4.3.1 Flow paths

Model output from the 1%CC runs is presented in Figure 4-9 and Figure 4-10 for depths and velocities respectively. Note that these show the maxima in each case – which are not necessarily coincident. These figures show that the site is characterised by relatively shallow depths and low velocities compared to areas immediately around it.

Areas of particular note close to the site with deep and/or fast flowing water are as follows:

- Along Broom Road and in the adjacent Sports Ground, there are areas of deep flow and high velocity. This represents a significant flow path, with associated hazard. It does not affect the site directly, but does impact on the access along Broom Road.

- The grounds of the Lensbury are characterised by deep water (> 1.5 m). However, this is generally characterised by low velocity.

These confirm that the site is protected to some extent from flow paths. This is partly due to its elevation and partly due to the buildings on and adjacent to the site.

The modelled flood level data has shown that the maximum water levels in the river are slightly higher than those on the flood plain. At the 1%CC level, this is about 0.20 m from the river to the south of the site. This likely reflects a minor flow path from the Thames towards Broom Road.

The opportunity for flow in this direction on the existing site is limited. The only break in the buildings where this flow could occur is at the gatehouse (Figure 4-11). The ground level at this point is at around 6.41 mAOD and is a local high point. The width of the openings at this point is of the order of 7 m. Reference to Table 3-5 with design flood level data from the Environment Agency shows that the current probability for this level, in the river, is about 1%. Given that levels are lower in the vicinity of the Gatehouse, the probability of this flow path being active is small. Furthermore, for floods at this level, water levels will vary slowly over time by perhaps a few cm per day. Accordingly, this flow path will not be called on to rapidly convey water; it will rather provide a means for water to cross the site in a gradual way, in line with the progression of the flood. This means that hydraulic considerations of velocity and flow area are not limiting factors in its behaviour.

Figure 4-9 Maximum depths: 1% CC

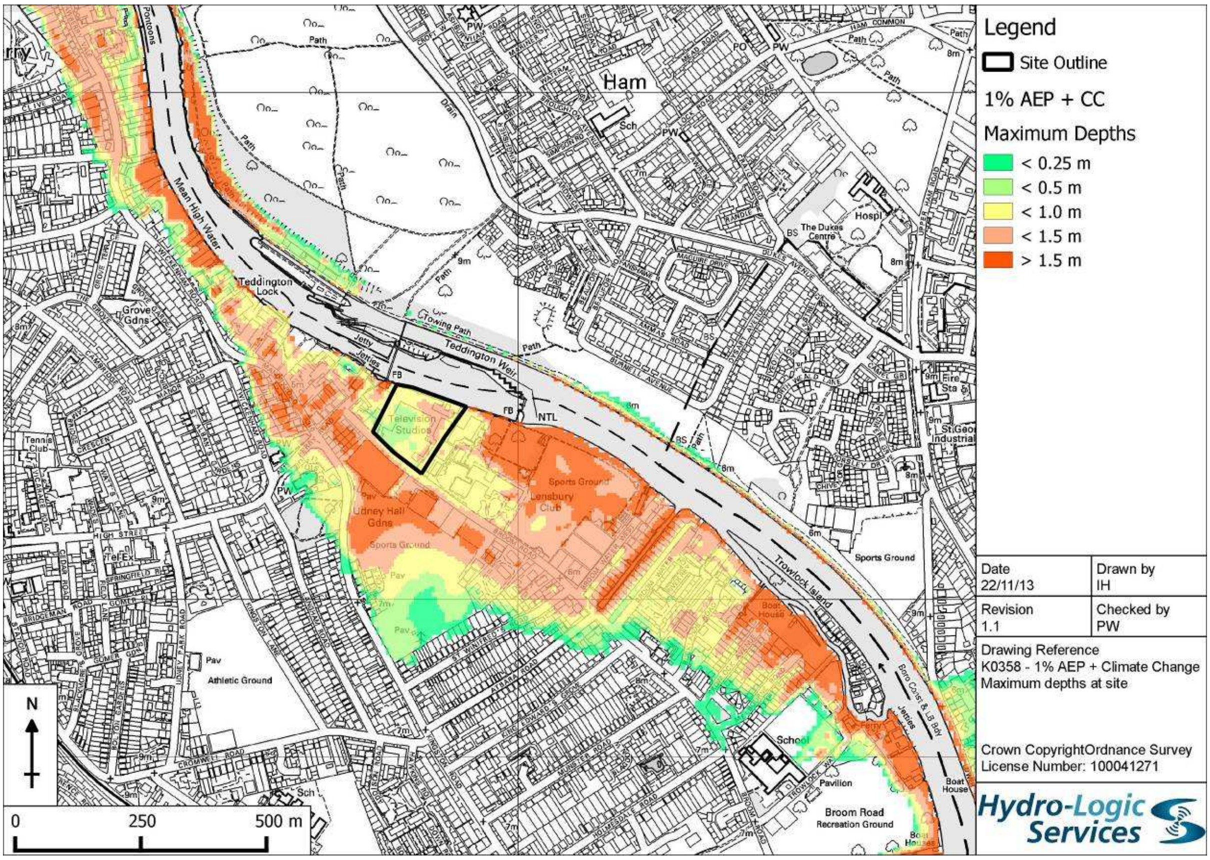
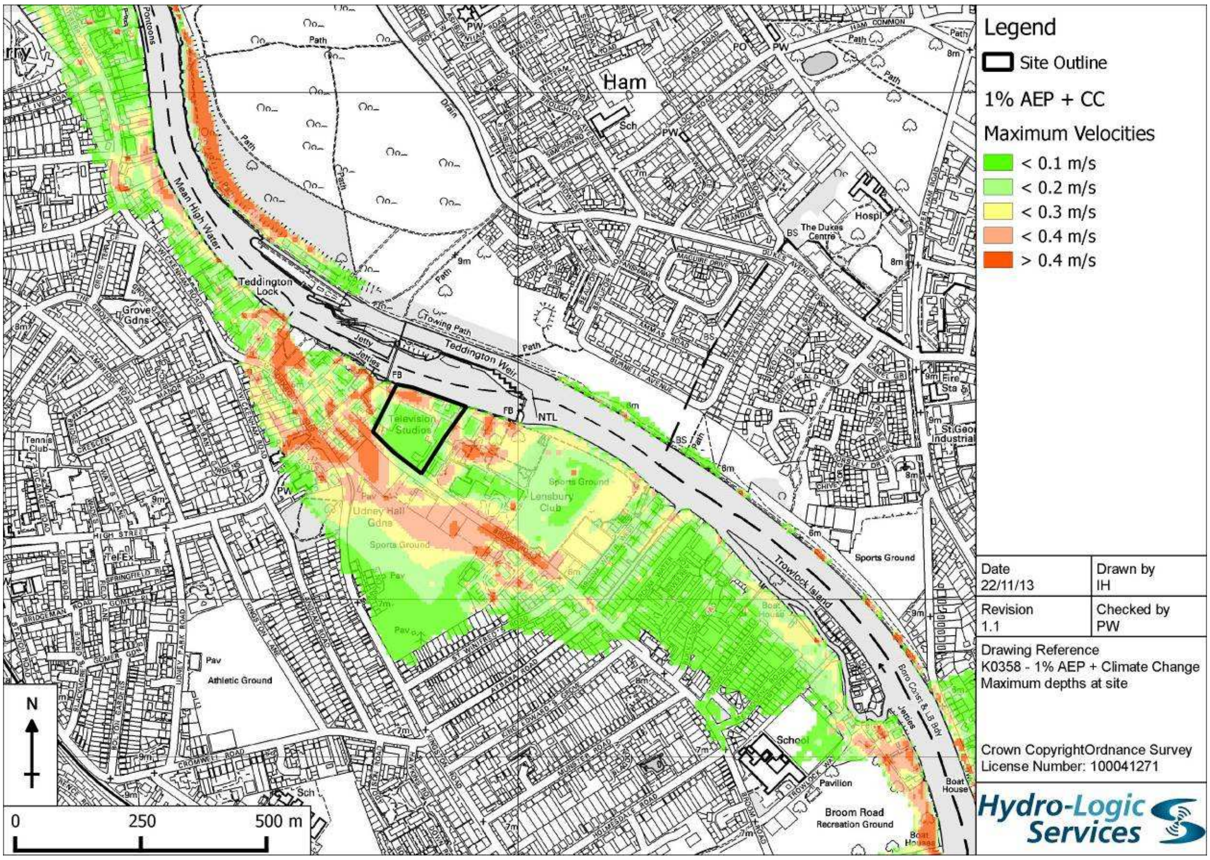


Figure 4-10 Maximum velocities: 1% CC



The proposed layout makes provision for an equivalent flow path as a culvert beneath the Piazza (Figure 4-12a). The inlet is adjacent to Block C and the outlet is below the entrance ramp for the car park. The long section of the culvert will feature a U-shape to enable it to fit between the top of the car park and the slab for the Piazza, with a height of 0.4 m. The inlet will comprise a horizontal grill set at 6.4 mAOD. Water in excess of this will flow through the grill and into the culvert. The outlet will also comprise a horizontal grill, set at 6.2 mAOD. The dimensions of the upstream grill will be about 7 m x 1 m whilst that at the downstream end will be approximately 4 m x 2m. For levels in excess of 6.8 mAOD, there is ample opportunity for water to flow through the site; this being the level of the principal access/egress route across the site and of the Piazza. It should be noted that the soffit level for that part of the culvert passing under the Piazza will be need to be around 6.3 mAOD, allowing a 0.5 m slab.

The culvert will therefore provide an equivalent flow width to that which currently exists at the Gatehouse. It will allow flow in both directions, should this be required and should water levels on the Broom Road side exceed those on the Thames side. It is therefore concluded that the proposed layout will not compromise the existing flow paths, these effectively being mimicked by the provision of the culvert. The grilles at both the inlet and outlet will be clearly visible and are located close to the Management office, making the risk of any blockage remote.

The proposed layout will also feature a further surface flow path as shown in Figure 4-12b. This has a width of around 1 m and a threshold of 6.3 mAOD.

Figure 4-11 The Gatehouse – a potential flow route across the site

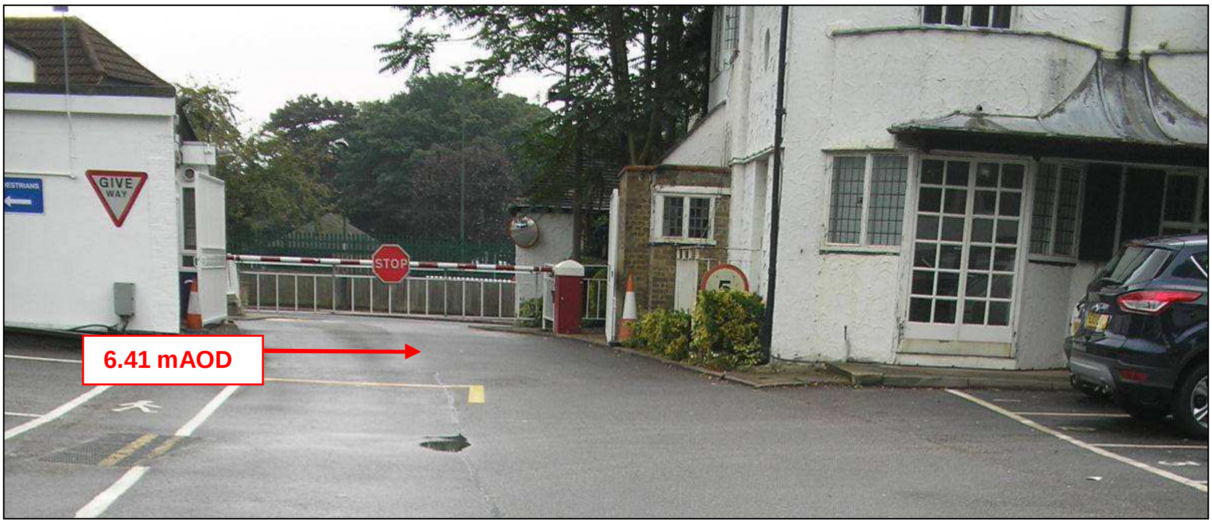
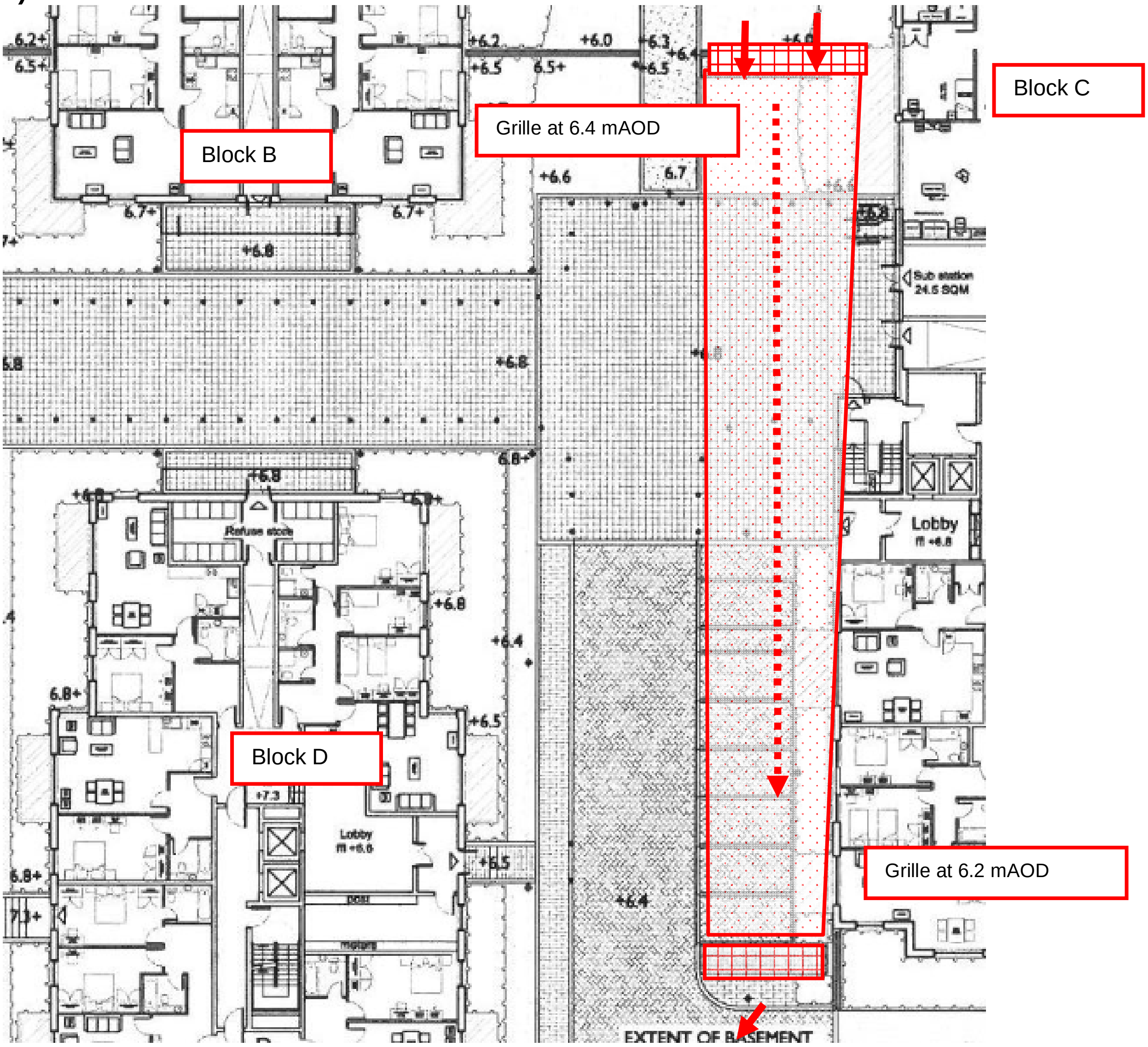
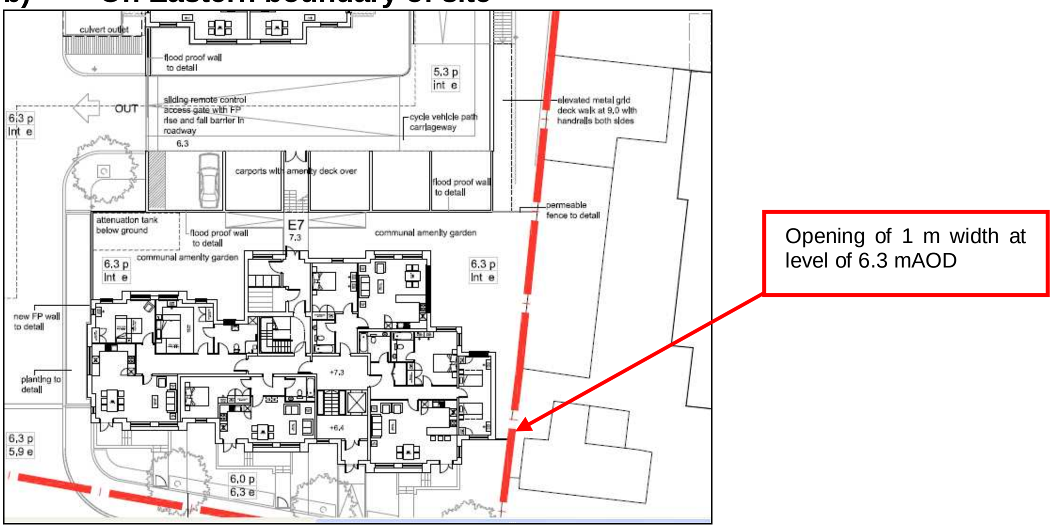


Figure 4-12 Proposed flow paths across the site

a) Culvert under Piazza



b) On Eastern boundary of site



4.3.2 Flood Plain storage

(a) General

It is a requirement under NPPF that there should be no loss of flood plain storage resulting from a development. The flood plain is defined by the 1% CC extent. The flood storage available on the site has been evaluated for the existing layout, by obtaining the floodable area at increments of 0.1 m up to 7.0 mAOD. This has then been compared with the floodable areas for the proposed development footprint. In general and in order to satisfy the "level-for-level" principle, the floodable area for the proposed development should exceed that for the existing layout for all level increments.

(b) Flood storage for existing site

The existing flood storage calculation has been based on the survey undertaken by Marchfield Surveys Ltd and shown on Drawing 2371 Rev A, dated April 2011 [sic]. On the plan, it is stated that the levels are related to EA BM (STN02) shown on survey value 5.238 m.

A site visit was undertaken on 3rd October 2013 to check if the buildings shown on the plan were likely to be able to resist water ingress. An extract from the survey plan is shown in Figure 4-13 along with photographs taken on that day. It was possible to confirm that the bold building boundary shown on the survey drawing is appropriate as a basis for flood storage computation as it demarcates the walls at **ground level**.

The visit also confirmed the extent of the multi-storey car park which would clearly be permeable and contribute to flood storage.

The doors and access points to all buildings were reviewed and a selection is shown in Figure 4-14 and Figure 4-15. Whilst some would not currently be classed as "flood resistant", they were all amenable to protection by the current occupiers, in order to exclude flood water.

The existing contours for the site are shown in Figure 4-16, along with the buildings that do not contribute to flood storage. Note that the multi-storey car park on the eastern boundary of the site is assumed to contribute fully to flood storage. These contours are based on the DTM; however, the DTM elevations were found to be unreliable along the boundary to the Thames. For this reason, the flood storage has been reviewed separately for the "riverside" and "development side" of the tidal defence.

The flood storage calculation for the "development side" is shown in Table 4-3, showing that there is 11,202 m^3 of storage on the site on the development side of the defences, of which **3,251 m^3** is below a level of 6.1 mAOD.

The storage on the riverside of the defences is topographically quite simple, being level and of reasonably uniform cross section. Given the unreliability of the DTM and the challenge of interpolating contours from limited spot elevation data from the topographic survey, a manual approach has been adopted for evaluating existing flood storage. The storage has been evaluated for three sections, A, B and C as shown in Figure 4-17. The resultant storage volumes are presented in Table 4-4 which shows that there is **498 m^3** of storage to a level of 6.1 mAOD on the "riverside" – giving a total flood storage volume of **3,749 m^3** (3,251 + 498) for the site as a whole to this elevation.

Figure 4-13 Review of buildings on eastern margin

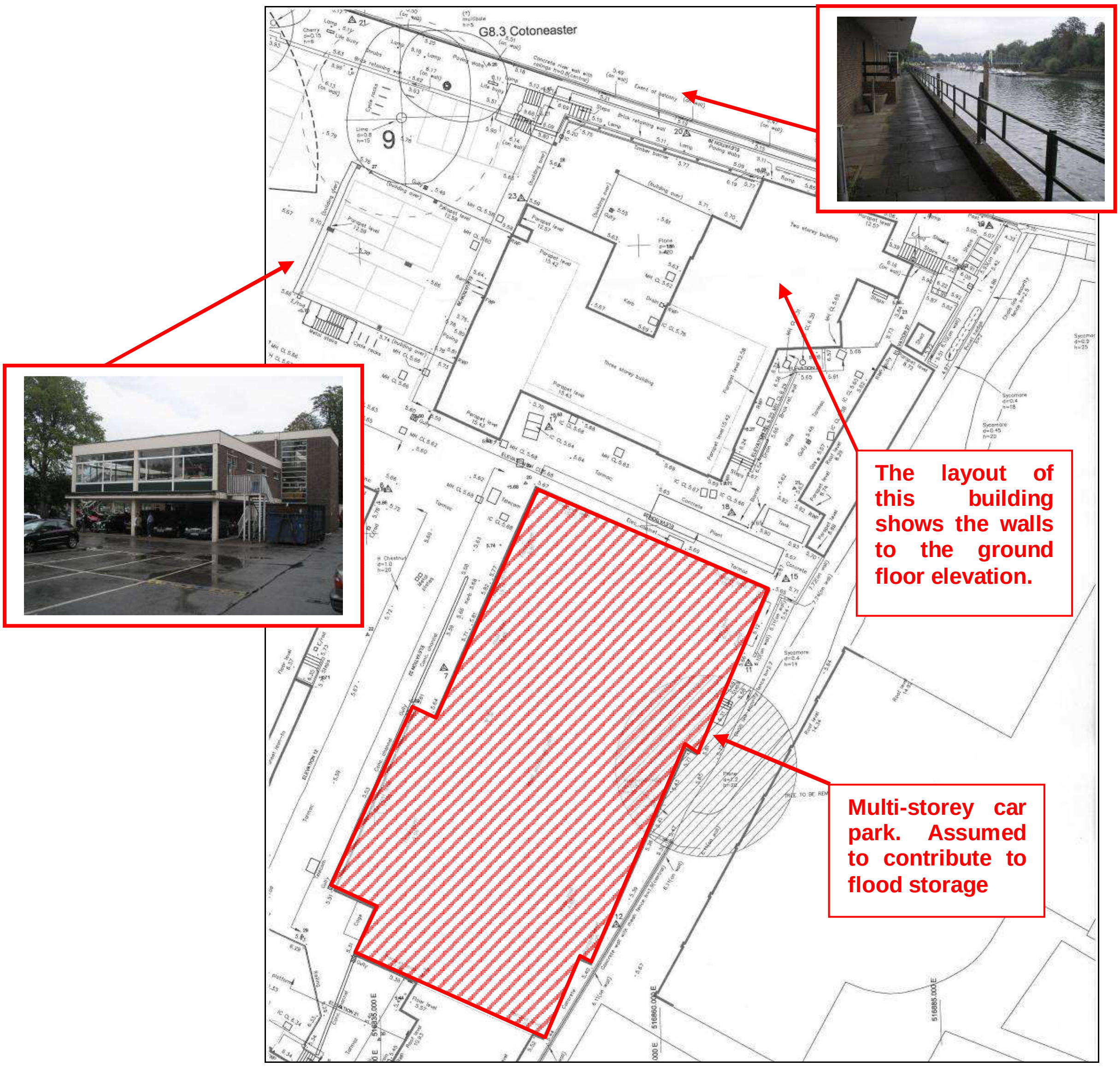


Figure 4-14 Selection of doorways and access points to buildings on the site

Figure 4-15 Selection of doorways and access points to buildings on the site

Table 4-3 Flood Storage for existing site: "Development side"

Lower (mAOD)	Upper (mAOD)	Depth (m)	Σ Area (m^2)	Area (m^2)	Σ Volume (m^3)
6.9	7	0.1	9,148	0	11,211
6.8	6.9	0.1	9,148	0	10,296
6.7	6.8	0.1	9,148	0	9,381
6.6	6.7	0.1	9,148	0	8,466
6.5	6.6	0.1	9,148	8	7,551
6.4	6.5	0.1	9,140	164	6,637
6.3	6.4	0.1	8,976	290	5,731
6.2	6.3	0.1	8,686	634	4,848
6.1	6.2	0.1	8,052	906	4,011
6	**6.1**	**0.1**	**7,146**	**804**	**3,251**
5.9	6	0.1	6,342	618	2,577
5.8	5.9	0.1	5,724	886	1,974
5.7	5.8	0.1	4,839	844	1,445
5.6	5.7	0.1	3,995	993	1,004
5.5	5.6	0.1	3,002	1,329	654
5.4	5.5	0.1	1,673	0	420
5.3	5.4	0.1	1,673	748	253
5.2	5.3	0.1	925	501	123
5.1	5.2	0.1	424	164	55
5	5.1	0.1	260	96	21
4.9	5.0	0.1	164	0	

Table 4-4 Flood Storage for existing site: "Riverside"

Lower (mAOD)	Upper (mAOD)	Depth (m)	Σ Area (m^2)	Area (m^2)	Σ Volume (m^3)	Comment
	To 7.0	0.1	544	0	987	
	To 6.1	**0.1**	**544**	**0**	**498**	
5.4	5.5	0.1	544	32	171	Soil c0.3 m high, 1 m wide
5.3	5.4	0.1	512	32	118	Soil c0.3 m high, 1 m wide
5.2	5.3	0.1	480	32	69	Soil c0.3 m high, 1 m wide
5.1	5.2	0.1	448	448	22	

Figure 4-16 Contours for existing site

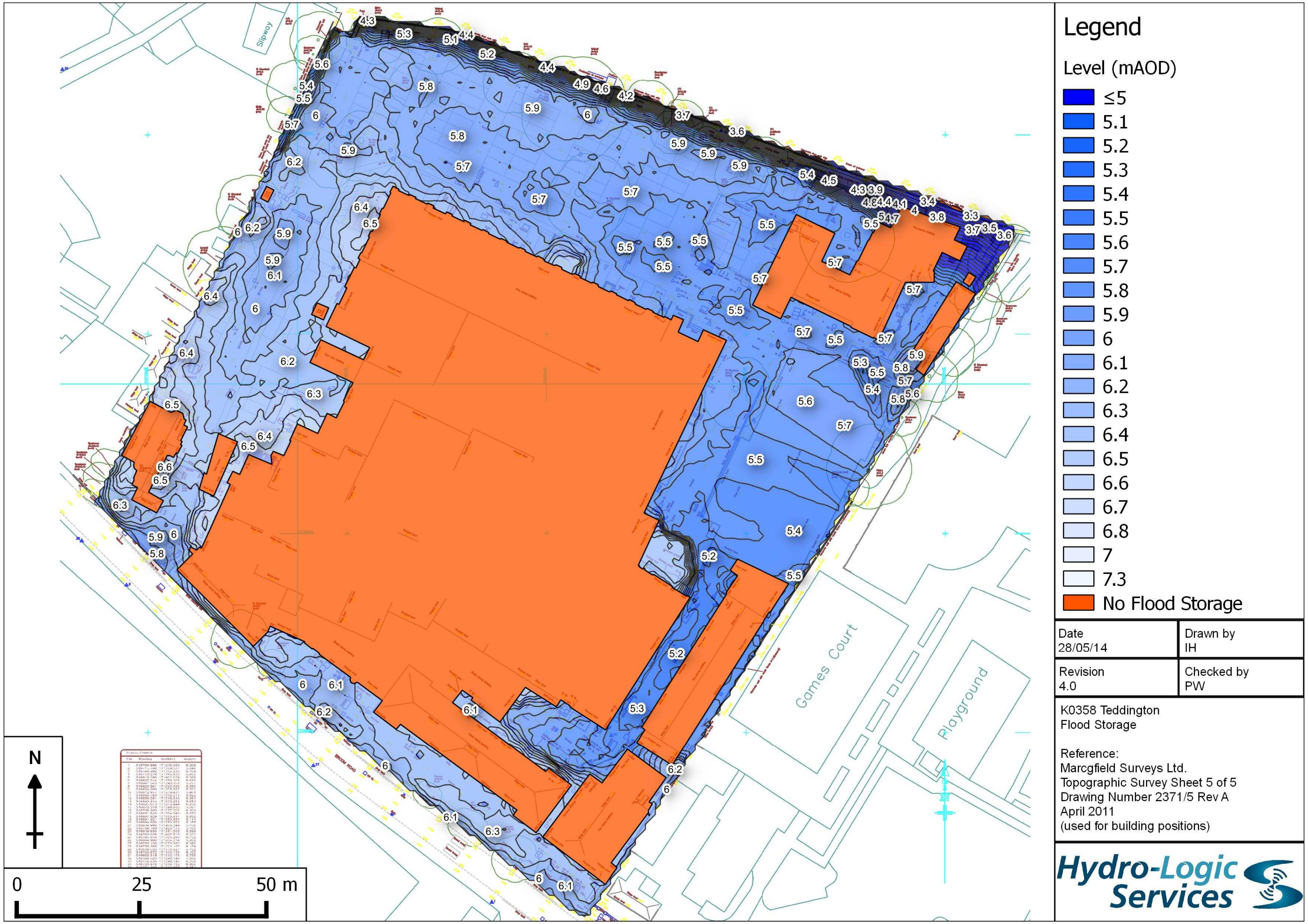
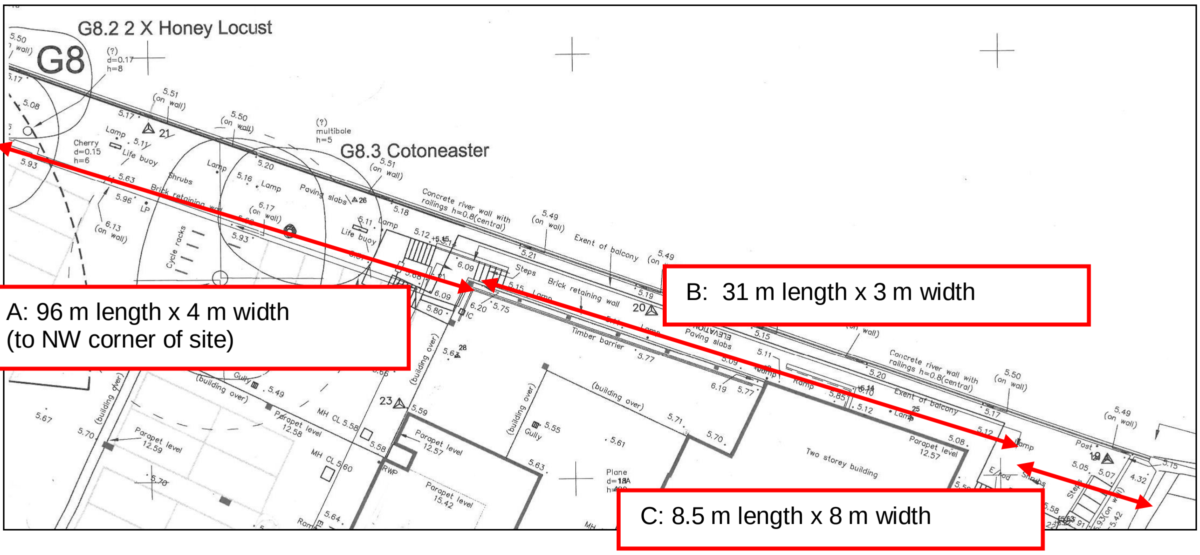


Figure 4-17 Flood storage: "Riverside" assumptions



(c) Flood storage for proposed development

The proposed levels for the development have resulted from iterative discussions between the principal architect, landscape architect and flood risk consultant. They are shown in Figure 4-18 (see also the landscape layout in Appendix F). The proposed layout has been developed in order to satisfy key storage requirements, namely:

- Preserving the existing flood plain storage volume up to the crest level of the existing defences (i.e. up to 6.1 mAOD) on both the "development" side and the "riverside".
- Preserving, on a level-for-level basis and volumetric basis, the flood plain storage above 6.1 mAOD;

For the development side of the defences, Table 4-5 demonstrates that the proposed layout satisfies the requirements of both volumetric and level-for-level. At the critical elevation of 6.1 mAOD, the table shows that there will be an increase in available flood storage of **329 m^3** (3,580 – 3,251).

For the riverside of the defences, the relative simple geometry makes it clear that with a base area of 558 m^2 for the riverside walkway, the volume is also increased as shown in Table 4-6. For the critical elevation of 6.1 mAOD, the volume increases by **72 m^3** (569 – 498). This gives an overall increase in flood storage at that elevation of **401 m^3**.

Recent revisions to the alignment of the defences have meant that it is necessary to make use of flood storage provision beneath Block C (Figure 4-18). An area of 300 m^2, will be utilised for this, with its base at 4.0 mAOD. This will be dedicated for flood storage, with access only for maintenance purposes. It will fill via openings at an elevation of 5.6 mAOD; which is the level of bounding garden, but lower than the level of the existing defences at 6.1 mAOD. It will drain via a flapped outfall to the Thames with invert at 3.8 mAOD.

Provision has been made for a further void with plan area of 250 m^2 beneath Block A (Figure 4-18). This will have a base level of 6.1 mAOD, extending to at least 6.5 mAOD and provides "fine tuning" to satisfy the specific requirements of level for level compensation at these elevations. The void will fill and drain via two openings, protected by grilles, of nominal width 1 m. In order to improve internal accessibility for maintenance, the soffit of the void may be increased to 6.8 mAOD; the 0.7 m depth providing a slightly more accessible space.

Table 4-5 Flood Storage for proposed site: "development side"

Level (mAOD)	Existing Area (m^2)	Existing Inc Area (m2)	Existing Vol (m3)	Proposed Total Area (m^2)	Proposed Inc Area (m2)	Inc. Area increase?	Proposed Volume (m^3)	Difference (m^3)	Volumetric increase?
7	9,148	0	11,211	10,803	15	Yes	12,084	874	Yes
6.9	9,148	0	10,296	10,788	0	Yes	11,005	709	Yes
6.8	9,148	0	9,381	10,788	1,078	Yes	9,926	545	Yes
6.7	9,148	0	8,466	9,710	227	Yes	8,901	435	Yes
6.6	9,148	8	7,551	9,483	137	Yes	7,941	390	Yes
6.5	9,140	164	6,637	9,346	189	Yes	7,000	363	Yes
6.4	8,976	290	5,731	9,157	440	Yes	6,075	344	Yes
6.3	8,686	634	4,848	8,717	646	Yes	5,181	333	Yes
6.2	8,052	906	4,011	8,071	916	Yes	4,342	330	Yes
6.1	**7,146**	**804**	**3,251**	**7,155**	**822**	**n/a**	**3,580**	**329**	**Yes**
6	6,342	618	2,577	6,333	906	n/a	2,906	329	n/a
5.9	5,724	886	1,974	5,427	19	n/a	2,318	344	n/a
5.8	4,839	844	1,445	5,408	306	n/a	1,776	331	n/a
5.7	3,995	993	1,004	5,102	78	n/a	1,251	247	n/a
5.6	3,002	1,329	654	5,024	4,723	n/a	744	90	n/a
5.5	1,673	0	420	301	0	n/a	478	58	n/a
5.4	1,673	748	253	301	0	n/a	448	195	n/a
5.3	925	501	123	301	1	n/a	418	295	n/a
5.2	424	164	55	300	0	n/a	388	332	n/a
5.1	260	96	21	300	0	n/a	358	337	n/a
5	164	0		300	0				

First 4 columns from Table 4-3

Table 4-6 Flood Storage for proposed site: "Riverside"

Level (mAOD)	Σ Area (m^2)	Σ Volume (m^3)	Proposed volume (m^3)	OK?	Comment
To 7.0	544	987	1,092	Yes	
To 6.1	544	498	569	Yes	Increase in area due to steps to 6.1
To 5.5	544	171	225	Yes	Base of walkway at 5.1 (area of 558 m^2)

First 3 columns from Table 4-4

The cross-sections that are shown in Figure 4-19 confirm that the gradation of levels within the site is such that all storage areas can fill and drain freely. The location of the cross sections is shown in Figure 4-18. Parts of the site adjacent to Broom Road will drain down towards the road whilst parts of the site adjacent to the river will drain through flap valves through the tidal defences.

The analysis presented above has demonstrated that the proposed development will lead to an increase in available both floodable area and flood storage over all elevations. However, there is further minor intervention into flood storage areas that needs to be reviewed. These are of such a small scale that it is not appropriate to consider them as part of the calculations already completed. They are therefore addressed separately below.

Firstly, the Landscape Plan on which Figure 4-18 has been based also shows some soil embankments adjacent to the walls of the principal Blocks where they project in into the gardens. These are purely for landscape purposes and serve no flood related purpose. These soil embankments will further reduce the available flood storage. A separate calculation has been made to show that the development still satisfies the flood storage requirements. The location of the soil embankments is shown in Figure 4-20 along with their base elevations. The embankments will have a width of 0.9 m, a slope of 1 in 3 and a height therefore of approximately 0.3 m.

A separate calculation has therefore been undertaken to compare the available flood area at each elevation, with the area taken up by the soil embankments. These are reviewed separately below, for embankments above and below the level of the existing defences at 6.1 mAOD in the penultimate column of Table 4-7.

- For the embankments with their base at 5.6 mAOD, all storage will be below 6.1 mAOD and there is only a need for a volumetric provision. The volume of the embankments is easily calculated from their combined length of 315 m and the cross-sectional area of 0.135 m^2. This gives a storage of 42.5 m^3 that can easily be accommodated with in the available storage provision up to 6.1 mAOD of 317 m^3.
- For other embankments, the demonstration of level-for-level compliance is demonstrated in Table 4-7 for all elevations above 6.1 mAOD.

The total volume of these soil embankments is given by the product of the combined length (484 m) and cross-sectional area (0.135 m^2). This volumetric loss of 65 m^3 is within the available storage from Table 4-5.

Figure 4-18 Proposed levels for flood storage calculation

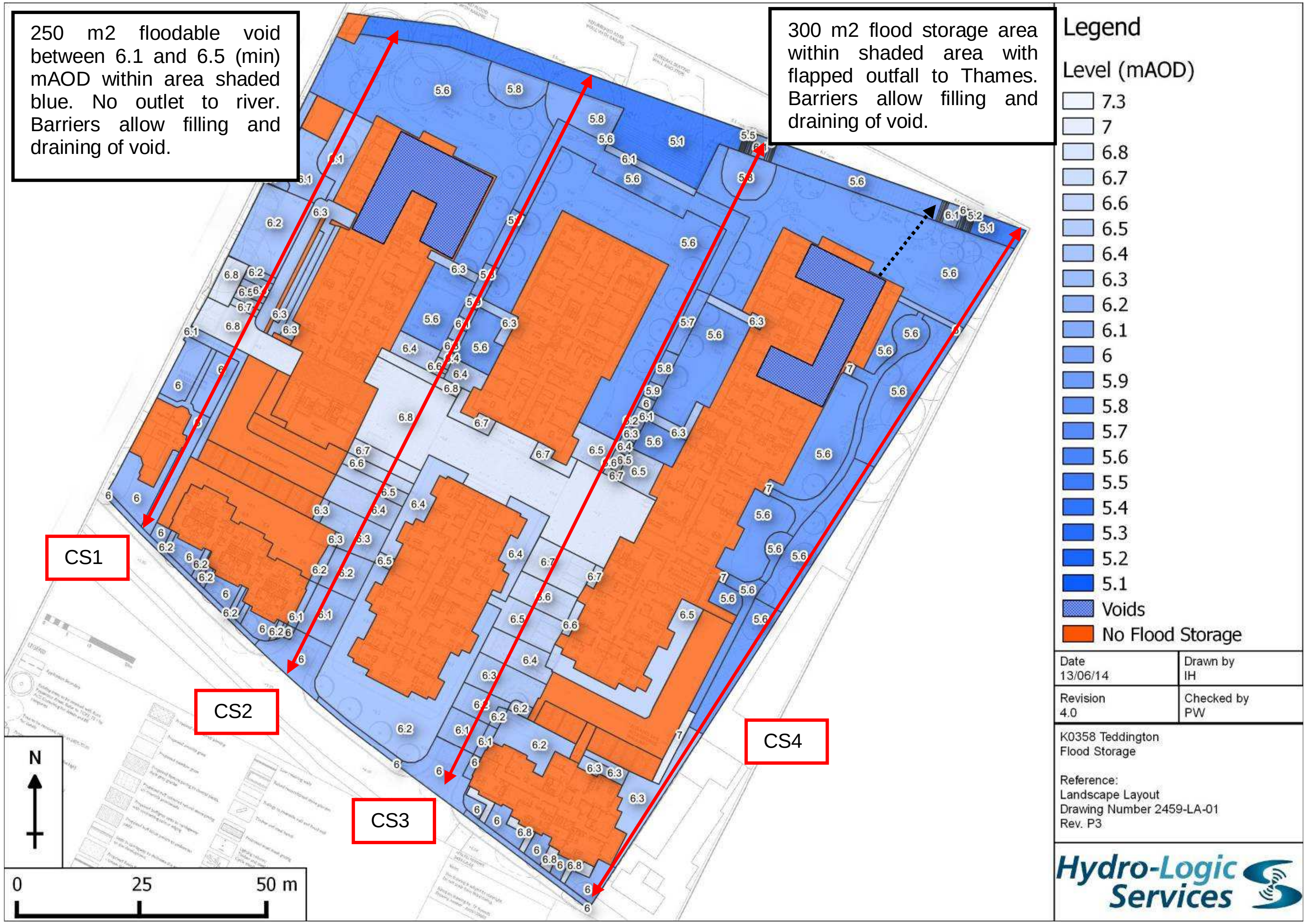


Figure 4-19 Cross sections through the site

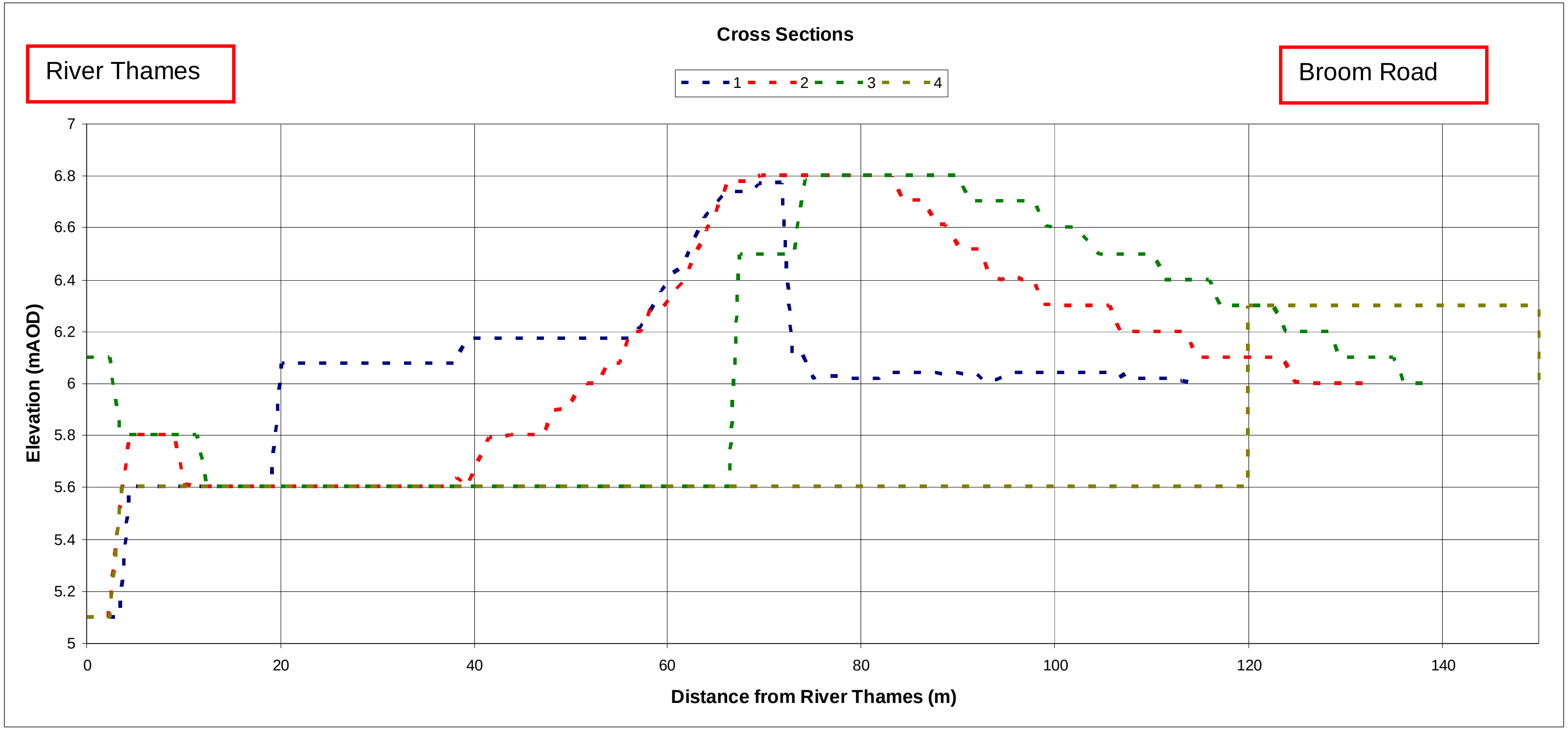


Figure 4-20 Soil embankments around main buildings

Reference	Level (mAOD)	Length (m)
A1	6.2	1.9
A2	6.1	15.7
A3	5.6	51.4
A4	5.6	15.4
B1	5.6	85.2
B2	5.6	15
C2	5.6	19.9
C3	5.6	51.7
C4	5.6	15.6
C5	5.6	33.3
C6	5.6	26
C7	5.6	10.8
D1	6.4	30.2
D2	6.2	81.1
D3	6.4	32.7

Table 4-7 Provision of flood storage for soil embankments

Level (mAOD)	Available Volume (m3)	Length at 5.6 mAOD (m)	Length at 6.2 mAOD (m)	Length at 6.4 mAOD (m)	Length at 6.5 mAOD (m)	Length at 6.7 mAOD (m)	Plan area of embankment (m2)	Volume of embankment (m3)	Level for Level satisfied?
Length of embankment (m)		315	83	63	13	11			
6.8	545					3.3	3.3	0.7	Yes
6.7	435				1.3	9.9	11.2	1.1	Yes
6.6	390			6.3	3.9		10.2	2.0	Yes
6.5	363			18.9	11.7		30.6	4.8	Yes
6.4	344		8.3	56.7			65	4.5	Yes
6.3	333		24.9				24.9	5.0	Yes
6.2	330		74.7				74.7	3.7	Yes

(d) Summary

It has been shown in this Section that the proposed development complies with the requirements of volumetric and level-for-level flood plain compensation, both in relation to the “riverside” and “development side” of the flood defences.

The analysis has also demonstrated that the volume of minor interventions, relating to soil embankments for landscape purposes (65 m^3) can be accommodated within the contingency.

There is in fact a net increase in flood storage across all elevations. After allowing for the two minor interventions, this is around 250 m^3 at 6.1 mAOD increasing to around 800 m^3 at 7.0 mAOD, providing contingency in the event of further landscape revisions.

4.3.3 Runoff

(a) General

It is a requirement under NPPF that there should be no increase in peak rates of runoff arising from the development. In the SFRA, there is a target that developers should achieve a 50% reduction of the pre-development rate of runoff for the 1 in 100 (1%) storm, whilst the London Plan seeks a reduction to Greenfield rates. Since the proposed development involves a substantial reduction of the impermeable area on the site, the development leads to a profound reduction in runoff.

In this Section, the existing rates of runoff are compared with post-development rates and scope for further reduction, using a SUDS methodology is discussed.

(b) Runoff from the existing site

The existing site is essentially 100% impermeable, comprising roofs, car parking and other hard standing. The 1% peak rate of runoff for the site has been evaluated using the Marshall & Bayliss method (Institute of Hydrology, 1994) and is 12.985 l/s/ha (Table 4-8) – equivalent to **24.0 l/s** for a site area of 1.86 ha. The mean greenfield rate of runoff has also been evaluated and is 1.522 l/s/ha (Table 4-9). The 1% greenfield rate of runoff is 4.854 l/s/ha – equivalent to **9.0 l/s** for the site. The 1% peak rate of runoff is thus almost 3 times the greenfield rate of runoff.

These calculations assume that the site lies in the WRAP (Winter Rain Acceptance Potential from the Flood Studies Report (1975)) class 2 which gives a SOIL index of 0.3 as shown in Table 4-9. This is somewhat higher than the SPRHOST value of 0.19 (19%) in Table 3-1.

In Section 3.4, it has been shown that the site drains either to sewers in Broom Road, operated by Thames Water, or discharges to the Thames at the north-west corner of the site. This stormwater tank may achieve some attenuation of runoff, though the size of the flapped outfall (Figure 3-13) would not appear to provide much hydraulic control.

Table 4-8 Evaluation of peak rate of runoff

Runoff estimation for site — Date: 15/11/2013

Methodology based on Marshall D.C.W. & Bayliss A.C., 1994. Flood estimation for small catchments, IH Report No. 124, Institute of Hydrology, Wallingford and Hall, Hockin & Ellis

AREA	0.0186
SAAR4170	600
SOIL	0.30
URBAN-pre	1
URBAN-post	0.22
CWI	95
REGION	Thames/Southern

	Runoff (l/s/ha)			**Runoff (l/s)**		
Return period (years)	**Greenfield**	**pre-devt**	**post-devt**	**Greenfield**	**pre-devt**	**post-devt**
QBAR	1.522	7.321	2.364	2.830	13.618	4.397
2		7.744	2.178		14.404	4.051
5		9.988	3.070		18.578	5.711
10		10.830	3.771		20.144	7.014
20		11.481	4.488		21.355	8.347
25		11.622	4.729		21.618	8.795
50		12.165	5.395		22.626	10.035
100		**12.895**	**6.325**		**23.985**	**11.765**
200		13.400	7.196		24.924	13.385
250		13.526	7.469		25.158	13.892
500		13.849	8.298		25.759	15.434
1000		14.415	9.303		26.812	17.303

Note: Post development runoff refers to the "critical" impermeable proportion of 22% to achieve a 50% reduction for the 1% peak rate of runoff.

Table 4-9 Evaluation of greenfield rate of runoff

QBAR estimation - generally used for small (>0.5km^2 <25km^2) rural catchments
Calculates mean annual flood for a rural catchment drained by well defined water course
Higher return periods can be calculated using the appropriate *flood studies report* regional growth curve

AREA	0.5	Catchment area in km^2
SAAR4170	600	Standard Average Annual Rainfall based on the period 1941 to 1970
S_1		Proportion of soil type within catchment (e.g. If 70% of catchment is Soil type 3 then S_3 = 0.7)
S_2	1	
S_3		
S_4		
S_5		
SOIL	0.30	SOIL = $S_1\,0.15 + S_2\,0.3 + S_3\,0.4 + S_4\,0.45 + S_5\,0.5$
QBAR-r	0.08	$QBAR_{rural} = 0.00108\ AREA^{0.89} SAAR^{1.17} SOIL^{2.17}$ = Cumecs
QBAR-r	1.52	l/s/ha

Marshall D.C.W. & Bayliss A.C., 1994. Flood estimation for small catchments, *IH Report No. 124*, Institute of Hydrology, Wallingford,

(c) Drainage strategy

The approximate breakdown of the site into impermeable and permeable areas is shown in Table 4-10, based on Figure 4-21 and the Design & Access Statement. This shows that 39% of the site area would be classed as impermeable. The analysis in Table 4-8 shows that in order to achieve a 50% reduction in peak runoff, the impermeable proportion would need to be below 22%. This indicates that some mitigation measures are required if the LBRT requirement is to be met and even moreso if peak rates of runoff are to be reduced to the greenfield rate.

Table 4-10 Surface cover for the developed site

Building	Area	Area	Soakaway	Main tank	Small tank
	(m^2)	(%)			
Block A: roof	1,002		1,002		
Block B: roof	825		825		
Block C: roof	1,665		1,000	665	
Block D: roof	739		175	564	
Block E7: roof	385				385
Town House (x6): roof	281		281		
F (weir Cottage):roof	118		118		
Sub-total	**5,015**	**27%**	**3,401**	**1,229**	**385**
Other imp. areas	2,172	12%		2,172	
Total imp. area	**7,187**	**39%**	**3,401**	**3,401**	**385**
Permeable area	11,413	61%			
Total site area	**18,600**	**100%**			

The review of SUDS selection is presented in Table 4-11 in relation to the developed site. This shows that there is limited potential for most of the measures due to limitations of area or compatibility with the development concept. However, the measures which may have some scope, shown in bold text in the Table, are Infiltration, Detention and Source Control.

Table 4-11 SUDS Selection Review

SUDS Group	Technique	Comment
Retention	Pond/Storage	Not compatible with development concept
Wetland	Pond/Channel	Not compatible with development concept
Infiltration	Trench/Basin/**Soakaway**	Subject to the results of Site Investigation, and exposure of natural geology, **soakaways appropriate for roof drainage**.
Filtration	Sand/vegetated strips	Insufficient area to accommodate these features
Detention	**Basin/Tanks**	**Tank for attenuation of roof drainage**
Open channels	Swales	Insufficient area to accommodate these features
Source control	**Permeable paving, green roof, rainwater harvesting**	**Scope for source control**

Based on Table 5.9 (CIRIA, 2007)

The strategy for dealing with stormwater on different parts of the site is shown in Figure 4-22 and uses the areas presented in Table 4-10. In broad terms, this will have the following components:

- A stormwater attenuation tank with an outfall to the River Thames for the balance of roof runoff on Buildings C and D plus other impermeable surfaces. ;
- A small stormwater attenuation tank beneath the Affordable Housing with outfall to the Thames Water sewer.
- Three large Soakaways for dealing with a portion (1,000 m^2 per soakaway) of the runoff from the Blocks A, B and C;
- A small soakaway for roof runoff from Weir Cottage and the Town Houses
- Although the use of green roofs may form part of the final design, all roofs have been treated as impermeable for the purposes of this modelling.

Whilst it is currently envisaged that the main tank could be built beneath Block B, the SI may reveal that the volume occupied by the existing tank in the north west corner of the site is suitable, in part, or in full, thereby reducing the volume of any tank under Block B.

The drainage strategy presented in this Section has been informed by output from the MicroDrainage software, in evaluation of critical storage requirements. The results from a series of simulation runs are shown in Table 4-12; supporting material is included in Appendix G . The key assumptions for these simulations are as follows:

- Point rainfalls have been obtained from the FEH CD-ROM v3 (CEH, 2009). These have been augmented by 30% to allow for climate change in line with the requirements of NPPF.
- Factor of safety of 1.5, in recognition of the minor consequences of any design exceedance.
- A runoff coefficient of 100% has been adopted for a nominal contributing area of 1,000 m^2.
- The infiltration coefficient of 0.05 m/h has been used, based on values for loam and sandy loam in Table 4.7 in CIRIA (2007).
- A porosity of 0.95 would be appropriate for a soakaway filled with crated modules.
- The peak outflow has been set as the 1 in 100 year peak greenfield runoff of 9 l/s.
- Hydraulic control is to be achieved using a hydrobrake.
- No green roofs have been assumed.

In broad terms, this shows that the proposed devices are able to attenuate storm runoff to the greenfield rate. The strategy and results are reviewed further in the next Section.

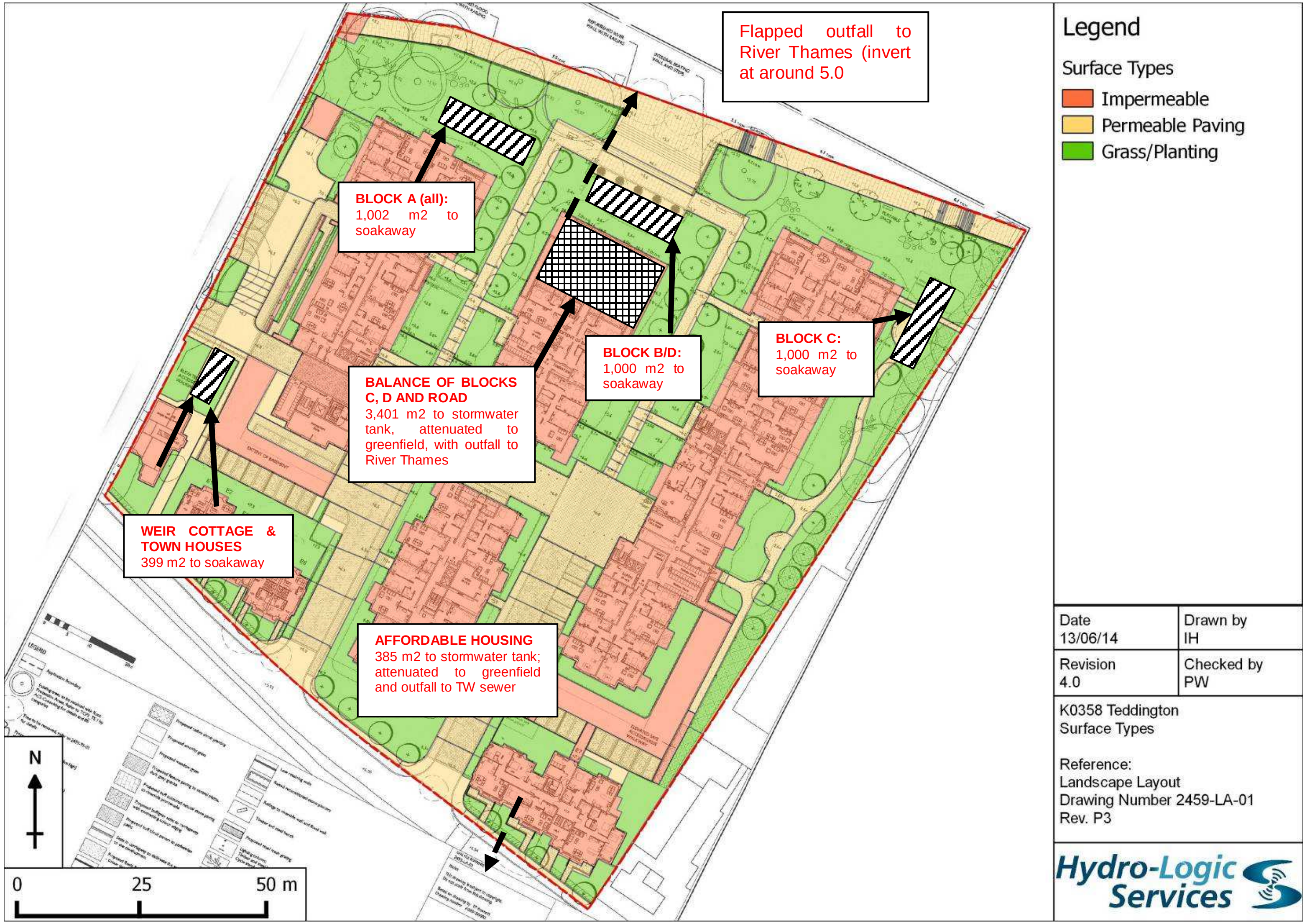
Table 4-12 Summary results of MicroDrainage simulation runs

Device	Impermeable Area (m^2)	Storage plan area (m^2)	Storage depth /max water depth (m)	Peak 1%CC outflow (l/s)	Required storage volume (m^3)
Main_tank	3,412	250	1/0.863	4.9	**205**
Secondary_tank	385	20	1/0.709	4	**13.5**
Main_soakaway	1,000	90	0.8/0.744	N/A	**63.6**
Small_soakaway	399	20	1.5/1.411	N/A	**26.8**

Results are presented in Appendix G to support these results

Figure 4-21 Surface cover for proposed development

Figure 4-22 Drainage Strategy



(d) Discussion – stormwater tanks

The drainage strategy has included simulation for a main tank beneath Block B with outfall to the River Thames and a secondary tank under the Affordable Housing Block with outfall to the Thames Water sewer. The tanks have been sized such that their combined peak outflow is less than the peak rate of greenfield runoff of 9 l/s. Since these peak outflows from each tank are unlikely to coincide precisely in time (due to different critical storm durations), there is a degree of conservatism in this analysis.

There is a residual risk, notably from storms in excess of the design capacity (1 in 100 years plus CC). Should the tanks surcharge, then there is ample storage with the lower garden area to accommodate any surplus. The available storage of over 3,000 m^3 up to the 6.1 mAOD defence level is equivalent to 161 mm of rainfall over the entire site – which is well in excess of the 1 in 100 year 24-hour rainfall.

It is proposed that the main tank outfall to the Thames via a flapped outfall. This introduces the possibility of tidelocking. For the normal tidal regime, this is unlikely to be a problem, as the mean high water springs (Section 3.3.2) is 4.3 mAOD for Richmond and slightly higher for Teddington. With the base of the tank at 5.6 mAOD, there would be a positive head under these conditions.

Under "extreme tidal conditions" with the 1% tidal level in excess of 6.1 mAOD (the crest level of the defences), there is greater probability of tidelocking. However, the duration is likely to be short (a few hours at most) because of these levels would only sustained around high water. Furthermore, any excess could be retained within an enlarged tank – by providing storage up to around 6.9 mAOD. This would reduce any impacts of tidelocking by retaining storage and increase the chances of a positive head.

Under "extreme fluvial conditions", high river levels may be sustained over a much longer period. However, under these conditions, the garden areas would be flooded in any event, so the practical consequences of tidelocking of the stormwater drainage system are limited.

In any event, it is recommended that the consequences of tidelocking be investigated more thoroughly during the detailed design phase.

There is an existing stormwater tank at the north western corner of the site and which outfalls to the River Thames via flapped gate. This tank does not form part of the drainage strategy as no information is available regarding its size and other features. Its potential can also be evaluated when the results of SI are available.

(e) Discussion - soakaways

The scope for soakaways is thought to be good on the basis that the underlying geology is likely to feature alluvium and river terrace deposits and which should be characterised by high rates of infiltration. Clearly, any made-ground would need to be excavated to expose and test the medium into which infiltration would take place. This would be an essential component of any site Investigation, following which the trial soakaway designs presented herein could be refined. These investigations will also clarify any requirement for separating the soakaway (eg using geotextile) from any residual man-made ground around it.

It is reported that the groundwater level on the site is around 2 mAOD and therefore similar to the normal level of the Thames downstream of the Teddington Weir, when not subject to high tides or high fluvial flow. The soakaways would require a nominal depth of 0.8 m and could be located in a range of about 4.2 to 5.0 mAOD, thereby providing around 0.6 m cover.

Table 4-13 Summary of Anticipated Geology (Campbell Reith, 2013)

Strata	Depth to Base (m bgl)	Depth to base (m AOD)	Thickness (m)	Typical Description
Made Ground	1 to 2b	4 to 5	1 to 2[b]	A mixture of cohesive and granular man-made soils associated with historic development of the site.
Alluvium[a]	2 to 3b	4 to 3	1 to 2[b]	Soft clay and silt, with bands of loose sand, gravel. Often contains bands of soft organic rich clay and peat.
River Terrace Deposits	5 to 6	1	3	Kempton Park Gravel (Medium dense gravel and sand. Can be clayey in part)
London Clay	65	-60	60	Stiff fissured grey clay, becoming very stiff at depth. Weathers near surface to an orange-brown colour and firm consistency.

a - where present
b - based on historic SI, held in CampbellReith GIS system, and located 300m to the north of the site. Actual values may vary.

On the basis of the soil information, a design value of 0.05 m/hr (1.39 x 10^{-5} m/s) has been adopted for infiltration. Since it has not been possible to conduct infiltration tests at the site, the simulation runs for the main stormwater tank have been extended by assuming that the roof area of 3,000 m^2 proposed to drain to soakaways, be directed into the stormwater tank. The resultant storage volume of 458 m^3 and design depth of 1.93 m are viable in the proposed location under Block B. This gives considerable flexibility to the strategy. Similarly, it may be possible to construct larger soakaways, subject to other site considerations and thereby reduce the size of the main stormwater tank.

The smaller soakaway that receives runoff from Weir Cottage and Town Houses may also be refined following Site Investigation.

(f) Summary

1. This Section has presented a drainage strategy for the proposed development. It incorporates the following components:

- 3 large soakaways and 1 small soakaway for dealing with roof runoff
- Large stormwater tank for attenuating runoff from roofs and the piazza, located at the northern edge of Block B and outfalling to the Thames;
- Small stormwater tank for attenuating runoff from the roof of the Affordable Housing Block

2. Simulation results from the MicroDrainage software show that this combination of devices can attenuate the 1 in 100 year CC storm to the 1 in 100 year **greenfield runoff of 9 l/**s. This is 38% of the pre-development rate of 24 l/s.

3. The strategy affords considerable flexibility. In the event that soakaways are found to be unsuitable, then simulation runs have shown that a single, large attenuation tank can attenuate runoff from the areas shown as draining to soakaways (i.e. 3,000 m^2). It is recommended that the balance between infiltration and attenuation measures be resolved during detailed design when the results of SI are available.

4. The SI will also reveal the extent to which the existing tank, or void in the north-west corner of the site can contribute to the drainage strategy.

5. Storms in excess of the design event may lead to surcharging; however, this can easily be accommodated in the flood storage area of the gardens.

6. The main stormwater attenuation tank may be subject to tidelocking. However, the practical consequences of this are small, due in part to the elevation of the tank and the flood storage provision. Further work may be carried out at the detailed design stage on tidelocking.

4.4 Residual Risks (B8a, B8b)

Residual risks are the risks remaining after applying the sequential approach and taking action to control risk. Residual risks need to be considered as part of all site specific flood risk assessments.

Flood risk to people and property associated with the development can be managed but it can never be completely removed; a residual risk will remain after flood management or mitigation measures have been put in place. Examples of residual flood risk from the PPS25 Practice Guide include:

- the failure of flood management infrastructure such as a breach of a raised flood defence, blockage of a surface water conveyance system, failure of a flap-valve, overtopping of an upstream storage area, or failure of a pumped drainage system; or
- a severe flood event that exceeds a flood management design standard, such as a flood that overtops a raised flood defence, or an intense rainfall event which the piped drainage cannot cope with.

These residual risks are reviewed in this Section.

4.4.1 Failure of flood management infrastructure

The most significant flood management infrastructure affecting the site is the Thames Barrier. Its importance underpins and has driven the TE2100 Management Strategy. Relevant issues pertaining to its operation and risk of failure are beyond the scope of this FRA and are the responsibility of the Environment Agency. The levels that may be consequent on any such failure are considered in Section 3.5.2 alongside general event exceedance.

The existing tidal defences have been described previously. The crest level of the defences is nominally at 6.1 mAOD which is well below the reference flood level of 7.0 mAOD and which has been used to inform the design and layout. Furthermore, the return period of any exceedance of the existing defences is approximately 5% (1 in 20). The consequence of failure of the defences within the site is thus likely to be similar to overtopping of the defences. The occurrence of overtopping events is included within the Emergency Plan (Appendix B). The consequences of breaching as opposed to overtopping are not considered to require special consideration.

The remaining features at risk are not specifically “flood management” infrastructure, but may be considered more appropriately as part of the drainage systems. These include flap valves from the (existing) storm water detention tank and (proposed) flap valve from the flood storage area behind and below the existing defences at 6.1 mAOD, soakaways, rainwater harvesting tank etc. The inspection of these features should form part of the regular and routine inspection of the site.

4.4.2 Event exceedance

As has been noted above, event exceedance, as defined by overtopping of existing tidal defences, is likely on several occasions during the lifetime of the development. It has accordingly been necessary to accommodate such exceedances in the Emergency Plan (Appendix B). Exceedance of the reference flood level (of 7.0 mAOD) has a low probability during the lifetime of the development, though the consequences are clearly serious. The principal residential accommodation in Blocks A, B, C, D plus the Affordable Housing has been designed with a 300 mm freeboard providing protection to a level of 7.3 mAOD. The same standard has been used for the subterranean car parks. The Townhouses (Block E) will be designed to be “flood resistant” to a level of 7.0 mAOD. For floods in excess of this level, water should be allowed to enter the property to avoid the risk of structural damage. Solid floors and flood resilient walls to the round floor are recommended in order to provide a resilient form of construction. All residents have access to areas on site that are “safe” as they have access to higher floors from within all properties.

The level of the emergency access/egress route has been set at 6.8 mAOD, with a maximum depth of 0.2 m. Under extreme flood conditions, the depth may be greater than this. However, the access route is through the raised Piazza in the centre of the site and subsequently along the western boundary. Flow velocities are likely to be low along this entire route and so the hazard classification is likely to remain in the “Low Hazard” or “Danger for Some” categories (Table 4-1 and Table 4-2).

Event exceedance may also result from severe storms on the site that lead to surcharge of the storm drainage system. Given the elevated nature of the proposed development and that it has been designed to cope with a reference flood level of 7.0 mAOD, the consequences of extreme storms are unlikely to have any impact upon the residential property. Surcharged stormwater is likely to flow across the site and may be stored temporarily in the flood storage area, prior to draining under gravity to the Thames through the flap valve. This may cause some inconvenience but is unlikely to pose any significant hazard.

4.4.3 Maintenance

The key requirement in order to minimise residual risk is to ensure that regular inspection and maintenance takes place of drainage systems and infrastructure. This includes the following:

- Main stormwater attenuation tank, including the flap valve.
- Flood storage area beneath Block C, including the flap valve
- Soakaways
- Secondary stormwater tank for Affordable Housing Block
- Permeable paving to be regularly swept to maintain infiltration characteristics.
- Storm drainage system in general
- The FAV incorporating the telescopic bridge
- Flood protection systems, including demountable barriers, flood proof doors, car park barriers, non return valves etc.

4.5 Risks During Construction

The construction activities will involve demolition of existing buildings (excluding the Cottage), construction of new dwellings and associated landscaping. These will involve storage of waste materials, prior to being transferred off-site and storage of building materials and plant. Such storage may impact on flow paths across the site and flood storage, in the event of extreme flooding. The magnitude of these impacts cannot be ascertained at this stage as the construction schedule is not available. However, given the extent of buildings on the site and the likely requirement for reasonably low levels of material storage on site, it is most unlikely that there will be an adverse impact during the construction period. Construction activity may lead to wash off of silt and pollutants to the surface drainage system.

In order to ensure that there are no adverse effects from the storage of materials during the construction phase, it should be confirmed that the flood storage areas and volumetric requirements identified in the FRA are satisfied for all stages of construction. As stated above, given the current extent of buildings on site, satisfying this condition should not be onerous.

The potential for impacts to occur as a result of storage of materials will be minimised by the following measures:

- Storage compounds (for the storage of construction materials or temporary stockpiling of material from demolished buildings) will be located away from the Thames and drains;
- Drums and barrel will be stored in a designated bunded safe area within a site compound; and
- All drums and barrels will be fitted with flow control taps and will be properly labelled.

The Construction Site Manager should also be in receipt of flood warnings for the Thames from the Environment Agency. This will allow removal of plant from the site or its relocation to areas outside those liable to flooding. Whilst flooding will be unhelpful to the construction process, the consequences may be managed by preparation and controlled dewatering following the flood.

The proposed development will also involve realignment of the existing defences. All such work would be undertaken in conjunction with the Environment Agency to ensure necessary approvals for design and constructional sequence. In particular, it will be necessary to ensure the integrity of the existing tidal defences throughout the period of construction. This will be achieved by maintaining the existing defences until any replacements are in place. Should there be any requirement for tying in new defences to existing alignments, this will be undertaken at times when there is essentially no risk of fluvial or tidal flooding. Engagement with Environment Agency staff will also be required to ensure that the new defences are compatible with the Environment Agency plans for possible raising by up to 0.8 m at some stage in the future.

4.6 Climate Change (C4a)

The general impacts of climate change on flood behaviour in England and Wales remain unclear. The FEH (Institute of Hydrology, 1999) describes a review of flood peak data to investigate possible trends. The analyses do not show that climate change has affected UK flood behaviour, but neither do they prove that it has not affected it. NPPF requires a consideration of the impacts of climate change on the flood risk for any proposed development. The suggested mechanism for this is to allow for increases of 10% in peak flows by 2025 and increases of 20% from 2025 to 2115. For precipitation, NPPF recommends a progressive increase reaching 30% by 2115. Climate change has been accounted for in accordance with these requirements by the Environment Agency by:

- Increasing river flows by 20%;
- Increasing rainfall depths by 30%;
- Use of appropriate tidal projections to inform model boundary conditions for combined model runs.

The climate change allowance that need to be used in FRAs are shown in Appendix C .

5. Summary and Recommendations

This Report presents an FRA for the proposed Teddington Riverside development on the site of the existing Teddington Studios. It has been informed by exchanges with the LBRT, The Environment Agency and Thames Water, with officials from each organisation providing valuable input, relevant data and feedback. The main findings are as follows, with cross referencing to the appropriate Section of the FRA shown in square brackets. By way of a summary, the LBRT requirements are presented in Table 5-1 with further cross-referencing to the FRA.

1. The proposed development is for a residential scheme which mapping provided by LBRT has confirmed is in **flood zone 3a** [Section 3.5]. Residential use has a vulnerability classification of "More Vulnerable". Accordingly, it is only acceptable in flood zone 3a if both the Sequential Test and the Exception Test have been satisfied.

2. **The Sequential Test** has been undertaken by CgMs Consulting, the findings of which have been discussed with staff from LBRT. The Sequential Test has shown that there are no other equivalent sites available for development. Subject to review by the Environment Agency, the Sequential Test is deemed to have been satisfied. [Section 2.3]

3. **The Exception Test** involves two components based on the sustainability credentials of the development and an acceptable FRA. Subject to this FRA being acceptable, the Exception Test is deemed to have been passed. [Section 2.3].

4. **Flood levels** at the site result from a complex interaction of fluvial and tidal factors and are subject to the operation of the Thames Barrier. The Environment Agency has provided the results of detailed hydraulic modelling which has provided the basis for adopting the reference flood level for the site. Whilst moderate floods have a large tidal component, the truly extreme floods are dominated by fluvial factors. The flood level for the site is 6.97 mAOD (nominally 7.0 mAOD) which corresponds to the 1% (1 in 100) fluvial extreme. [Section 3.3 and 3.5]. The Environment Agency has provided revised flood levels arising from the TE2100 modelling. These extreme levels are higher than the reference flood level for the early years of the development. These levels have not been used in this FRA for reasons that are outlined in Section 3.5.2.

5. **Other sources of flooding** have been reviewed in the FRA. The Environment Agency has indicated that the risk of groundwater flooding is unlikely. The elevated position of the site relative to the surrounding area means that it is not at risk from surface water flooding, nor sewer flooding. It is clear that the main risks are from some combination of fluvial and tidal flooding.[Section 3.3]

6. **Finished floor levels** for the main residential blocks plus the Affordable Housing have been set at 7.3 mAOD, which includes a 300 mm contingency, as recommended in the LBRT SFRA. Floor levels for the Townhouses are set at 6.2 mAOD but flood resistance and resilience measures will be provided to a level of 7.1 mAOD. This is 300 mm above the flood levels provided for the flood plain at this location, namely 6.8 mAOD. Flood resistance and resilience measures are also recommended for Weir Cottage to at least this level. [Section 4.2.1].

7. **The Basement** is not for habitation, but is solely for car parking. The entry to and exit from the car park will be equipped with a removable flood barrier providing

protection to a flood level of 7.3 mAOD. Furthermore, the car park will be provided with drainage to deal with storm water or flood water that may enter the car park. There will be internal access via lifts and steps to the residential blocks. The basement car park will have sufficient space for all cars that use the surface car park; this to be achieved by valet parking. There should be no cars in the surface car parks during major flood events. [Section 4.2.3]

8. **Flow routes** through the site have been maintained at existing levels by the provision of a culvert that passes under the Piazza. This replicates the existing flow path in the vicinity of the Gatehouse. In practice, this flow route is likely to be active very infrequently, currently for levels higher than the 1% level. At such a level, the water level changes only slowly over time, so the hydraulics of the culvert are not considered to be limiting factors. Additional flow will be able to cross the site through a 1 m wide gap at a level of 6.3 mAOD on the eastern boundary of the site. [Section 4.3.1]

9. **Flood Storage** calculations have shown that the proposed layout satisfies the flood storage requirements on a level-for-level and volumetric basis above the existing tidal defences of 6.1 mAOD – for both the “riverside” and “development side” of the tidal defences. For levels behind and below the defences, the volumetric storage requirements are satisfied, including a provision for soil embankments adjacent to the main Buildings for landscaping purposes. The proposal makes use of flood storage beneath Block C, which is able to drain via a flapped outlet to the Thames. There is a further flood storage provision under Block A, specifically to “fine tune” the level for level storage compensation. As a consequence, there is in fact a small gain in flood plain storage of around 250 m^3 at 6.1 mAOD and 800 m^3 at 7.0 mAOD; after allowance for some contingency for soil embankments. [Section 4.3.2]

10. **Runoff rates** are substantially reduced from the existing levels as a result of the development, thereby reducing flood risk for surrounding areas. This is due to the replacement of the largely impermeable site with a mixture of roofs, permeable paving, grass and borders. The drainage strategy has been developed using the simulation mode, MicroDrainage. This has demonstrated that a combination of soakaways and stormwater attenuation tanks can be used to attenuate peak runoff for the 1%CC storm to the greenfield rate, which is 38% of the pre-development rate. This satisfies the LBRT condition of reductions of at least 50% from current levels and the London Plan to achieve greenfield rates of runoff. [Section 4.3.3c]

11. The drainage strategy has demonstrated the storage volumes required to achieve **Surface Water attenuation** in both soakaways and attenuation tanks. There is considerable flood storage available on site which can provide contingency in the event of failure of any drainage component or storms in excess of the design storm [Section . 4.3.3e].

12. Following removal of surface cover, but prior to any construction, **Site Investigations** should seek to establish the dimensions and the condition of the existing stormwater tank in the north-west corner of the site, with a view to it being used as part of the stormwater management infrastructure. The Site Investigation should seek to establish the nature and infiltration characteristics of the soil that underlies the impermeable surfaces and buildings. This will help to refine the surface water management strategy. Given that it was not possible to undertake field infiltration tests, the drainage strategy has demonstrated that the main soakaways can be replaced with an enlarged attenuation tank and still achieve the target reductions in runoff. It is thus clear that the drainage strategy is very flexible.

13. **Safe access** and egress is provided via Broom Road for moderate floods initially on foot and for deeper floods using suitable vehicles. For extreme floods, safe access and egress is to be provided to land wholly outside flood zone 3 via raised walkways within the site at an elevation of 6.8 mAOD and a telescopic bridge across the Anglers' Public House that will link to the Teddington Lock footbridge. The ground levels on the Ham Bank are above the 1% climate change fluvial event and thus "dry". [Section 4.2.2 and Appendix B]

14. An **Emergency Plan** has been prepared in line with the LBRT requirements. This is included as Appendix B and describes the procedures for warning and evacuation of the site at times of imminent flooding. It is recommended that an annual drill be undertaken, ideally in association with the Environment Agency and LBRT.

15. The Emergency Plan provides benefits to the wider community including the Provision of emergency car parking; use of the proposed emergency access, use of the site as a refuge and provision of an access/egress route for the Lensbury Hotel [4.2.5]

16. The **Residual Risks** have been assessed and are considered to be minor. [Section 4.4] A maintenance programme of key drainage infrastructure should be put in place to ensure that residual risks are minimised. [Section 4.4.3]

17. There is a **16 m standoff** from the River Thames as required by the Environment Agency. This is achieved in part by realignment of the existing defences [Section 4.2.4]. Provision has been made in the design layout to satisfy the possible future need for **raising the existing defences** to a level of 6.9 mAOD, as indicated by the Environment Agency. This has ensured that there is relatively easy access to the bank and there are no pinch points that may restrict the ability of plant to access the river.

18. Flood risks during the **period of construction** have been assessed and, with the adoption of standard site management practice, they should be of no practical consequence. [Section 4.5]

19. A **statement of flood risk** should be provided to all residents that they can provide to their Insurance Company (or other organisations).

20. In summary, the proposed development will lead to an increase in flood storage on the site and la reduction in peak rates of runoff. The provision of elevated living accommodation with a range of access/egress routes will provide benefits to the local residents under flood conditions, as well as a refuge for future residents of the site.

Table 5-1 LBRT: Planning & Development Control Recommendations

Spatial planning recommendations		***Response in FRA and reference***
Important Considerations	Future development within Zone 3a High Probability can only be considered following application of the Sequential Test	*Section 2.3. Given that no equivalent and available sites were identified at lower risk of flooding, the Test is deemed to have been passed.*
Land Use (refer PPS25 Table D2)	Land use should be restricted to Water Compatible or Less Vulnerable development. More Vulnerable development may only be considered if Exception Test can be passed.	*Section 2.3. Subject to acceptance of the FRA, the Test is deemed to have been passed.*
Development control recommendations		
Detailed Flood Risk Assessment (FRA)	Required	*This Report.*
Floor level	Floor levels are to be situated a minimum of 300mm above the Q100 fluvial or Q200 tidal (whichever is greater) flood level, including climate change, assuming a breach of the river defences.	*Section 4.2.1. Most floor levels set at 7.3 mAOD, 300 mm above 1%CC fluvial extreme. Flood resistance and resilience provided where floor levels are lower (Town Houses and Weir Cottage).*
Site access & egress	Refer SFRA Appendix E. For residential property, dry access is to be provided above the Q100 fluvial or Q200 tidal (whichever is greater) flood level, including climate change, assuming a breach of the defences.	*Safe access routes presented in Section 4.2.2 and Appendix B . Agreed level of 6.8 mAOD in consultation with EA & LBRT.*
Basements	Self-contained residential basements and bedrooms at basement level should not be permitted. All basements, basement extensions and basement conversions should have internal access to higher floors.	*Basement car park is protected by "flip-up" flood barriers. The car park has internal pedestrian access to higher floors (Section 4.2.3).*
Site runoff	Implement SuDS to ensure that runoff from the site (post redevelopment), as a minimum, is not increased. A reduction in site runoff should be sought, aiming to achieve greenfield run-off rates, or reduce run-off rates by at least 50% over current levels.	*Reduction to greenfield (38%) of pre-development rate based on reduction of impermeable area, provision of permeable pavements, soakaways and attenuation tanks.*
Buffer Zone	A minimum buffer zone must be provided to 'top of bank' within sites immediately adjoining the River Thames. A 16m buffer will be sought along the River Thames. Advice must be sought from the Environment Agency at an early stage.	*16m buffer zone provided along with provision for raising defences.*
Other	Ensure that the proposed development does not result in an increase in the risk of flooding (from all sources) within adjoining properties. This may be achieved by ensuring (for example) that the existing building footprint is not increased, that overland flow routes are not truncated by buildings and/or infrastructure, or hydraulically linked compensatory flood storage is provided within the site (or upstream)	*Reduction in built footprint means that the proposed redevelopment results in increase in flood plain storage and reduction in runoff rates (Section 4.3.3). Demonstrated in Figure 4-19 that flood storage is hydraulically linked.*

Extract for "Zone 3a, Defended, Richmond"

6. References

Author	Date	Title/Description
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Centre for Ecology and Hydrology.	2009	The Flood Estimation Handbook CD-ROM 3. Centre for Ecology & Hydrology, Wallingford, Oxon, UK.
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Cundall	2013	Teddington: Servicing Strategy – Teddington Riverside. For the Haymarket Media Group.
DCLG	Mar 2012	National Planning Policy Framework.
DCLG	Mar 2012(b)	Technical Guidance to the National Planning Policy Framework.
DCLG	Mar 2010	Planning Policy Statement 25: Development and Flood Risk.
DCLG	Dec 2009	Planning Policy Statement 25: Development and Flood Risk Practice Guide (Updated).
Institute of Hydrology	1988	Maidenhead, Windsor and Eton Flood Study. Stage 2 Hydrology Report. M.A. Beran and E.K. Field, April, 1988.
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Kjeldsen, T.R.	2007	ReFH, The revitalised FRS/FEH rainfall-runoff method. FEH Supplementary Report No. 1.
LBRT	2010	Strategic Flood Risk Assessment (SFRA) Level 1 Update, August 2010.
LBRT	2011	Guidance on Producing a Flood Emergency Plan. Planning Advice Note. LBRT, November 2011.
Marsh, T. J., Greenfield, B. J. and Hannaford, J.	2005	The River Thames flood of November 1894 – a reappraisal of the maximum flow. ICE Water Management. 158, 103-110.
Natural Environmental Research Council	1975	The Flood Studies Report (5 volumes).

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Haymarket Media

Teddington Riverside

Flood Risk Assessment
(Appendices)

Report K0358/1

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Appendix A Pro-Forma for Undertaking a Flood Risk Assessment (Appendix B of Practice Guide (CLG, 2009))

This proforma has been completed in such a way as to identify the sections in the accompanying report where the relevant issues are addressed.

1 Development description and location
1a. What type of development is proposed and where will it be located? • A location plan at an appropriate scale should be provided with the FRA, or cross referenced to the main application when it is submitted.
Section 2.1
1b. What is its vulnerability classification? • Vulnerability classifications are provided in Table D.2, Annex D of PPS25
Section 2.3
1c. Is the proposed development consistent with the Local Development Documents?
?
1d. Please provide evidence that the Sequential Test or Exception Test has been applied in the selection of this site for this development type? • Evidence is required that the Sequential Test has been used in allocating the proposed land use proposed for the site and that reference has been made to the relevant Strategic Flood Risk Assessment (SFRA) in selecting development type and design (See paragraphs 16-20 and Annex D of PPS25). Your Local Planning Authority planning officer should be able to provide site-specific guidance on this issue. • Where use of the Exception Test is required, evidence should be provided that all three elements of this test have been passed (see paragraphs 20 and Annex D of PPS25). Your Local Planning Authority planning officer should be able to provide site-specific guidance on this issue.
Section 2.3
1e. *[Particularly relevant to minor developments (alterations & extensions) & changes of use]* Will your proposal increase overall the number of occupants and/or users of the building/land; or the nature or times of occupation or use, such that it may affect the degree of flood risk to these people?
2. Definition of the flood hazard
2a. What sources of flooding could affect the site? (see Annex C PPS25). • This may include hazards such as the sea, reservoirs or canals, which are remote from the site itself, but which have the potential to affect flood risk (see Chapter 3 of the Practice Guide).
Section 3.2
2b. For each identified source, describe how flooding would occur, with reference to any historic records wherever these are available. • An appraisal of each identified source, the mechanisms that could lead to a flood occurring and the pathways that flood water would take to, and across, the site. • Inundation plans, and textural commentary, for historic flood events showing any information available on the mechanisms responsible for flooding, the depth to which the site was inundated, the velocity of the flood water, the routes taken by the flood water and the rate at which flooding occurred.
Section 3.3
2c. What are the existing surface water drainage arrangements for the site? • Details of any existing surface water management measures already in place, such as sewers and drains and their capacity.
Section 3.4
3. Probability
3a Which flood zone is the site within? • The flood zones are defined in Table D.1 of Annex D PPS25.
Sections 2.2

3b If there is a Strategic Flood Risk Assessment covering this site, what does it show? • The planning authority can advise on the existence and status of the SFRA.
Section 2.3
3c What is the probability of the site flooding taking account of the contents of the SFRA and of any further site-specific assessment? This may need to include • a description of how any existing flood risk management measures affect the probability of a flood occurring at the site FRA Pro-forma • supporting evidence and calculations for the derivation of flood levels for events with a range of annual probability • inundation plans of, and cross sections through, the existing site showing flood extents and levels associated with events with a range of annual probability • a plan and description of any structures which may influence the probability of a flood occurring at the site. This may include bridges, pipes/ducts crossing a watercourse, culverts, screens, embankments or walls, overgrown or collapsing channels and their likelihood to choke with debris. • details of any modelling studies completed to define the exiting degree of flood risk (Ref Chapter 3 of the PG)
Section 3.5
3d What are the existing rates and volumes of run-off generated by the site? • This should generally be accompanied by calculations of run-off rates and volumes from the existing site for a range of annual probability events (see Chapter 4 of the Practice Guide).
Section 4.3
4. Climate change
4a How is flood risk at the site likely to be affected by climate change? • Annex B of PPS25 and Chapters 3 and 5 of the Practice Guide provide guidance on how to assess the impacts of climate change.
Section 4.6
5. Detailed development proposals
Where appropriate, are you able to demonstrate how land uses most sensitive to flood damage have been placed in areas within the site that are at least risk of flooding, including providing details of the development layout? • Reference should be made to Table D.2 of PPS25. • Chapter 4 of the Practice Guide provide guidance on how the sequential approach can be used to inform the lay-out of new development sites.
Section 4.1
6. Flood risk management measures
How will the site be protected from flooding, including the potential impacts of climate change, over the development's lifetime? • This should show that the flood risk management hierarchy has been followed and that flood defences are a necessary solution. This should include details of any proposed flood defences, access/egress arrangements, site drainage systems (including what consideration has been given to the use of sustainable drainage systems) and how these will be accessed, inspected, operated and maintained over the lifetime of the development. This may need to include details of any modelling work undertaken in order to derive design flood levels for the development, taking into account the presence of any new infrastructure proposed.
Section 4.2
7. Off site impacts
7a How will you ensure that your proposed development and the measures to protect your site from flooding will not increase flood risk elsewhere? This should be over the lifetime of the development taking climate change into account. The assessment may need to include: • Details of the design basis for any mitigation measures (for example trash screens, compensatory flood storage works and measures to improve flood conveyance). A description of how the design quality of these measures will be assured and of how the access, operation, inspection and maintenance issues will be managed over the lifetime of the development. • Evidence that the mitigation measures will work, generally in the form of a hydrological and hydraulic modelling report. • An assessment of the potential impact of the development on the river, estuary or sea environment and fluvial/coastal geomorphology. A description of how any impacts will be mitigated and of the likely

longer-term sustainability of the proposals.
Section 4.3
7b How will you prevent run-off from the completed development causing an impact elsewhere? • Evidence should be provided that drainage of the site will not result in an increase in the peak rate or in the volumes of run-off generated by the site prior to the development proceeding.
Section 4.3
8. Residual risks
8a What flood-related risks will remain after you have implemented the measures to protect the site from flooding? • Designing for event exceedence on site drainage systems is covered in Chapter 5 of the Practice Guide. Guidance on other residual risks is provided in Chapter 7.
Section 4.4
8b How, and by whom, will these risks be managed over the lifetime of the development? • Reference should be made to flood warning and evacuation procedures, where appropriate, and to likely above ground flow routes should sewers or other conveyance systems become blocked or overloaded. This may need to include a description of the potential economic, social and environmental consequences of a flood event occurring which exceeds the design standard of the flood risk management infrastructure proposed and of how the design has sought to minimize these – including an appraisal of health and safety issues.
Section 4.4

Appendix B Flood Emergency Plan

B.1 Introduction

This is the Flood Emergency Plan for the Teddington Riverside development. It has been prepared with help and guidance from the Environment Agency and LBRT and informed by the Planning Advice Note for Guidance on Producing a Flood Emergency Plan (LBRT, 2011).

B.2 General

B.2.1 Scope, Objectives and Background

The purpose of this document is to present the flood emergency plan for the proposed Teddington Riverside development. Its content is relevant to residents in order that they understand both the risks of flooding and the actions that they will need to take to prepare for and to respond to flooding. The document is also relevant to the emergency services and LBRT officials who will be required to manage the emergency response during flooding.

The objectives are:

- To inform residents of the risks of flooding.
- To outline proper and safe procedures to be followed before and during flooding.
- To explain the meanings of flood warnings and what action will be required and by whom.
- To provide clear advice on emergency procedures to be followed before and during a flood event.

The important aspects of this plan include:

- The different types of flooding that may affect the area, principally tidal and fluvial.
- The process and evolution of flooding in the area.
- The emergency access and egress routes to be followed at different stages of a flood
- Risks and hazards posed to people and property.
- The emergency contacts.

B.2.2 Location and Proposal

The Teddington Riverside site is currently a commercial site, for the Teddington Studios and The Haymarket Group. The proposed development involves demolition of existing buildings and replacement with residential accommodation, mostly provided in four blocks.

The accompanying FRA has shown that the residential accommodation will be protected from flooding by setting the finished floor level for the majority of properties above existing ground level. The design flood level has been agreed with the Environment Agency and the LBRT and is at 6.97 mAOD and corresponds with the 1 in 100 (1%) probability with allowance for climate change. The majority of residential accommodation has been set a minimum of 0.3 m above the design flood level (nominally at 7.30 mAOD), and so is at an acceptably low risk of flooding. The exceptions to this are the 6 Town Houses and Weir Cottage for which flood resistance and resilience measures form part of the design.

The FRA has also noted that the development proposal will lead to a slight reduction in the flood risk to surrounding properties. This is due to two factors:

- A reduction in the impermeable area on the site from virtually 100% to around 40%, leading to a reduced peak rate of runoff;
- An increase in flood storage resulting from there being a smaller area of buildings in the area liable to flooding.

The most important flood risk issue for the proposed development is that of access and egress which is the main focus of this Appendix.

The flood risk to the site and its residents depends strongly on the flooding processes. The highest threat in terms of flood levels and the duration of flooding is from *fluvial flooding*. However, the site may be affected by *tidal flooding* and access routes around the site may be affected by *surface water flooding*.

It is of the utmost importance that residents are made aware of the flooding mechanisms and that they follow emergency procedures appropriate to that mechanism. Although the mechanisms may interact, the overwhelming expectation is that one mechanism is dominant during a particular extreme event.

The characteristics of the different types of flooding are reviewed briefly.

Fluvial flooding

- This results from prolonged heavy rainfall in the Thames catchment which includes parts of Gloucestershire, Oxfordshire and Berkshire.
- It is likely to be in the winter months and when the catchment is saturated due to several months of above average rainfall.
- Snowmelt has contributed to earlier flood events (eg 1947) and freezing of the ground surface in the catchment may make flooding more severe.
- Flooding at the site will be preceded by flooding at major towns along the Thames, including Oxford and Reading.
- With the flood forecasting technology available to the Environment Agency, it will be possible to forecast the flooding with a lead time of several days.
- Flood events may last for several days, or even weeks, based on observations of historic Thames floods, such as that in 1947.
- Roads such as Broom Road and Ferry Road may be closed for long periods during the flooding. The depth of “fluvial flooding” along Broom Road is illustrated in Figure B-1.

Tidal flooding

- The Thames is tidal as far as the Teddington Locks. Tidal flooding may result from high astronomical tides, particularly during “spring tides”. This is not a reference to the season of spring, but to more extreme range of tidal water levels that occur in response to planetary movements with a frequency of about 2 weeks.
- The tidal flooding may also be made worse by *storm surge* conditions in the North Sea. These result in elevated water levels due to reduced atmospheric pressure and wind.
- With the storm surge forecasting capability of the Meteorological Office and the Environment Agency, it should be possible to forecast tidal flooding with a lead time of 12 hours.
- Tidal flooding can interact with fluvial flooding. Results from combined modelling provided by the Environment Agency are shown in Figure B-2 and compared with fluvial flood levels.
- Flood events will last for up to a few hours, essentially at the peak of the tidal cycle, though this will be affected by the fluvial flows and operation of the Thames Barrier.

Figure B-1 Fluvial flood levels

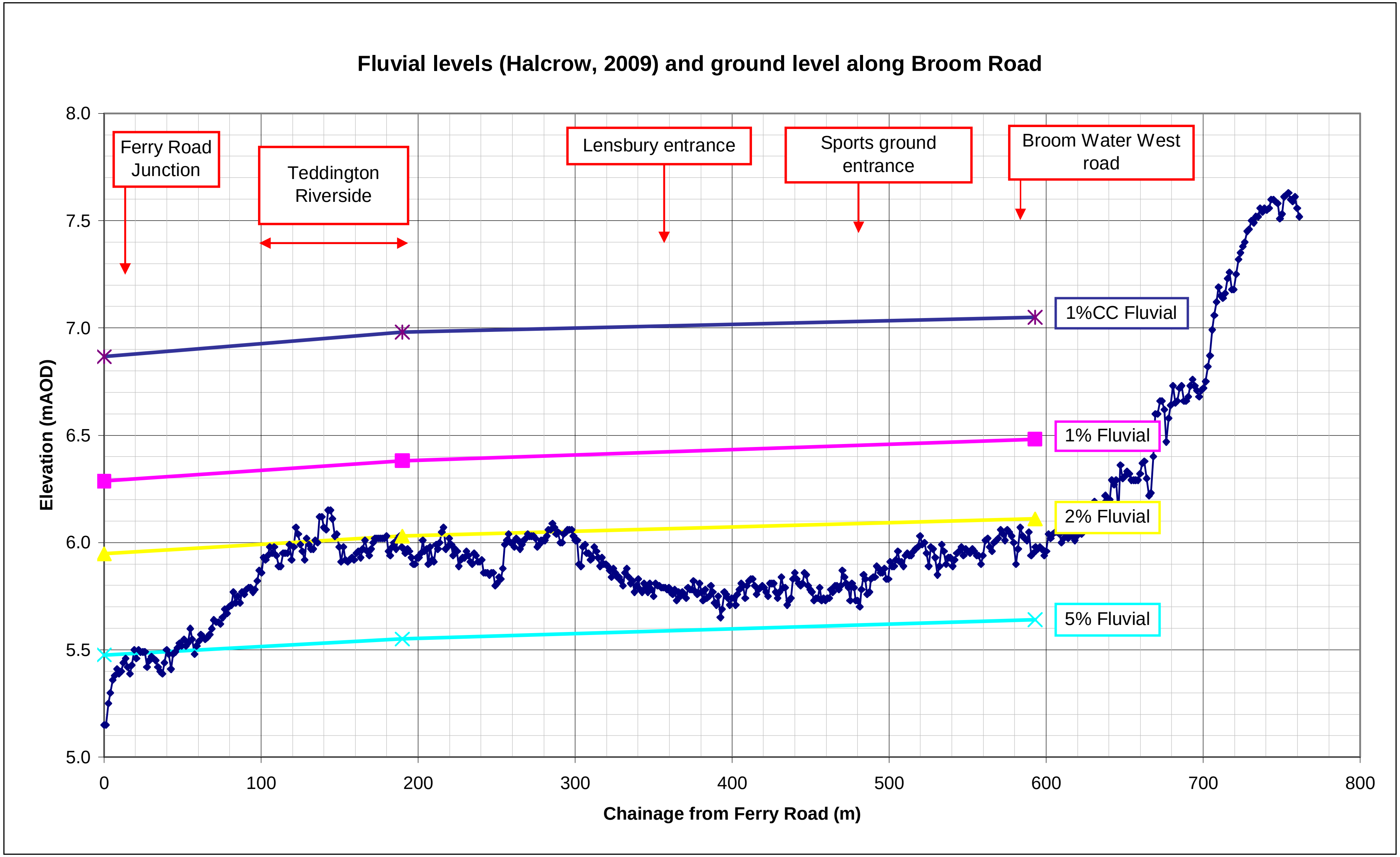
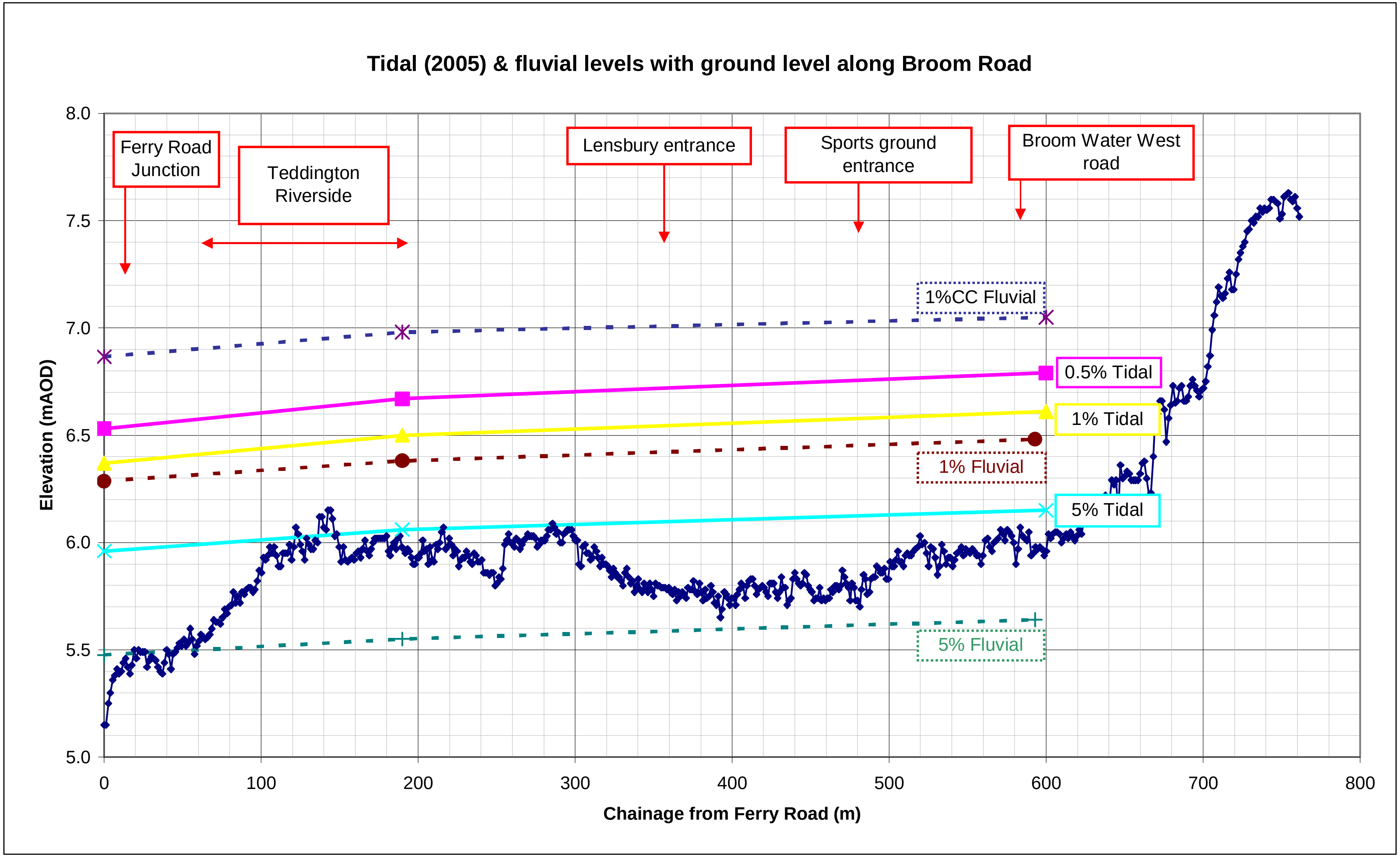


Figure B-2 Comparison of tidal and fluvial flood levels



- Local roads such as Ferry Road may be closed during tidal flooding events.
- There may be sequences of tidal flooding at intervals of around 12 hours associated with the natural tidal cycle.

For most frequencies (or return periods), the tidal flooding provides the highest flood levels. However, the most extreme flooding is fluvial in origin. This is why the finished floor levels for the site have been set by reference to the 1% **fluvial** flood, with allowance for climate change.

Surface water flooding

- Surface water flooding occurs due to intense local rainfall that is too heavy for the drains to handle.
- It typically occurs in the summer months, often associated with intense thunder storms, but surface water flooding can also occur in autumn and winter, for example when leaves can block the inlets to drains.
- The duration of flooding is typically short, lasting only a few hours, or less. This is because the surface water is usually able to dissipate through the drainage system, following the end of the storm.
- The Teddington site is elevated above the surrounding land and so will be unaffected by surface water flooding. However, low lying access roads such as Ferry Road may be affected.
- Roads such as Ferry Road may be closed for a few hours during surface water flooding events.

The impact of the flood mechanism on flood extents and flood hazard is presented in Section B.2.3 along with a detailed review of access/egress arrangements. For extreme flooding, when road closures are fully in place, raised walkways within the site will provide a "safe" route to the north-west corner of the site. A dedicated telescopic bridge will provide a link to the Teddington Lock footbridge, allowing "dry" access to the Ham Bank. These arrangements are described in more detail in the following Section.

The site will remain fully operational during a flood event, and it is not envisaged that there will be any need for evacuation. The design team for the scheme have been aware of the risks of flooding from the outset. Mitigation measures have been put in place to ensure maintenance of key infrastructure for the duration of any flooding. Specific measures are discussed in the Servicing Strategy by Cundall (2013) and include provision of dedicated back up generator and online UPS systems and on site water tank of 25 m^3 volume, plus rainwater harvesting tank (225 m^3).

It is likely that Broom Road will continue to constitute the main access route to the site for emergency vehicles and *in extremis* small boats. The design layout incorporates ramps up from Broom Road to the site that can serve as a safe point of entry under these extreme conditions.

There are subterranean car parks on the site. These will be equipped with flood barriers to prevent entry of water. These will be closed in accordance with the site management plan and following due warnings to residents. Once the barriers have been closed, no vehicular exit will be possible for the duration of the flood event. Since no residents should have cause to enter the car park during a flood emergency, they can be secured. The car parks have sufficient space through "valet parking" (ie minimising the space between vehicles) to accommodate all vehicles from the surface car parks. The surface car parks are thus expected to be free of cars in advance of flooding. There may also be space for cars of local residents by prior arrangement.

B.2.3 Risk Assessment Summary

(a) General statement of risk

As indicated in the previous Section, all residential accommodation will be at a safe level, excluding the Town Houses and Weir Cottage. This safe level is defined as the 1% (1 in 100) flood level with allowance for climate change plus a contingency of 300 mm. For the Town Houses and Weir Cottage, flood resistance and resilience measures will be provided. All property will therefore be at an acceptably low level of flood risk. As indicated above, precautionary measures have been included in the design to ensure that the site can remain operational and inhabitable during extended flood periods. The most important issue in relation to the flooding is that of access and egress for residents.

(b) Sequence of fluvial flooding

This FRA and emergency plan are able to benefit from the long history of detailed computational modelling of the Thames at Teddington by the Environment Agency and its consultants. The outputs from these models provide a clear picture of the flood extent for floods with different levels of severity. They also provide information on the depth of floodwater and the velocity – both of which are important in establishing the hazard to people.

The results of model runs for **fluvial flooding** are presented in Figure B-1 for different frequencies of flooding:

- 1 in 20 (5%)
- 1 in 50 (2%)
- 1 in 100 (1%)
- 1 in 100 with allowance for climate change (1%CC) – this is the reference or design flood

The four images illustrate how a (fluvial) flood would spread across the site and the surrounding area. The extent is represented by the flood hazard which is described in Table B-1. Note that the maps have used a blue shading to reflect the “Very low hazard” classification, rather than the white shown in the table.

Table B-1 Hazard to People Classification System

Flood Hazard Rating (HR)	Colour Code	Hazard to People Classification	Use of flood emergency plans to manage flood risk
Less than 0.75		Very low hazard – caution	Acceptable
0.75 to 1.25		Danger for some – includes children, the elderly and the infirm	Maybe acceptable
1.25 to 2.0		Danger for most – includes the general public	Unlikely to be acceptable
More than 2.0		Danger for all – includes the emergency services	Unacceptable

The results in Figure B-1 show that for the 5% (1 in 20) fluvial flood, the site is fully accessible via Broom Road and Ferry Road. However, there is a marked change for the 2% (1 in 50) fluvial flood with Broom Road classed as “Low Hazard” and “Danger for Some”.

Ferry Road is affected to a greater extent and is classed as “Danger for Most”. The main reason for this marked change is that the Thames spills out of bank, upstream of the site. The path taken by the flow is across the playing fields to the south-west of Broom Road. This low lying area is subsequently filled to a depth of up to 1.5 m and contributes to the high hazard rating. More extreme floods see an expansion of areas of “Danger for most” and “Danger for all”.

(c) Sequence of tidal flooding

As indicated above, there is a low risk of the site being affected by tidal flooding in isolation. There may be some localised impacts on access (eg on Ferry Road), but there will always be an alternative access route via Broom Road.

The major impact of tidal flooding is when it occurs in combination with fluvial flooding. This combined occurrence has been investigated in detail by Halcrow (2009) on behalf of the Environment Agency. Many computer model runs have been undertaken to establish flood levels for a wide range of fluvial and tidal combinations and these are available for the Thames both upstream and downstream of the site. For the reference flood, the combined levels are lower than those for the “fluvial extremes” that are described above. Accordingly, this FRA has based the design and access/egress issues entirely on the fluvial extreme levels. This is not to suggest that tidal effects are unimportant, but that they do not contribute to the design levels.

The existing tidal defences are at a level of 6.1 mAOD. They afford sufficient protection to the site such that it is in flood zone 3a, with an annual probability of flooding of 5% (1 in 20) for the current conditions. Several instances of overtopping of these defences may therefore be expected during the lifetime of the development. Moderate overtopping will lead to flooding of the garden area between Blocks A/B/C and the Thames. The duration of overtopping may last from a few minutes to a few hours. However, since overtopping will occur for the full river frontage, it is likely that the gardens will fill to a level in excess of 6.1 mAOD. Flood water may be present for several days afterwards as water drains back to the Thames and infiltrates to the ground. Demountable barriers will prevent water from entering the stairwell/liftwells at the base of Blocks A, B and C.

The Environment Agency has indicated that there “may” be a flow route around tidal defences, before they are overtopped. The maximum water level for such a mechanism would be 6.1 mAOD at the point where the defences were outflanked. The maximum level would then decrease as one moved away from the location of the outflanking. Furthermore, the duration of any such event, being tidal, would be of the order of tens of minutes.

The practical consequences of such a mechanism may lead to accumulation of water at the Broom Road/Ferry Road junction. However, Broom Road would likely remain passable, or at worst after a short delay. It is therefore not considered that this mechanism warrants specific inclusion in the Emergency Plan.

(d) Surface Water Flooding

Surface water flooding will not affect the site directly as it is raised above the surrounding ground; this is clear from the 2% fluvial flood map (Figure B-4). Surface water flooding will affect low lying streets around the site such as Ferry Road. The indirect effect of the surface water flooding will therefore be to restrict normal access via this road, which is likely to be impassable for severe events. Broom Road, being elevated above the surrounding land will not be affected and is likely to remain open.

(e) Emergency Access and Egress routes

The progressive closure of Broom Road is a crucial event for residents and will entail the following stages:

- Normal access
- Flooded, but very low hazard
- Flooded, but hazard classed as “danger for some”
- Flooded and unsuitable for pedestrians, but passable in suitable vehicles
- Flooded and unsuitable for all but specialist emergency vehicles

Broom Road may thus continue to offer a safe and usable access route for the duration of many floods. This will entail informal “shuttle” arrangements with the use of suitable vehicles along Broom Road (eg four wheel drive vehicles, tractors and trailers) to enable residents to access the safe areas on the Teddington bank directly.

However, for extreme floods the access/egress to and from the site will be via the Teddington Lock footbridge. All residential accommodation will benefit from “safe” access from the site to the opposite bank at Ham. The details of this route are presented in Section B.3.5.

(f) Practicalities of Emergency Access and Egress

The practicalities of the emergency access routes depend greatly upon the flooding mechanism. For **purely tidal flooding** and **surface water flooding**, flood durations and associated closures will be of the order of a few hours at most. This will pose considerable short term disruption and inconvenience to daily routines of residents. This will be most pronounced for those with time commitments (eg collecting children from schools, carers etc). It is the expectation that the quality of tidal forecasting will be good and that, provided that this can be communicated to residents, appropriate alternative plans may be made.

Under the Site Management Plan, staff will be on stand-by and provision should be made for dealing with elderly or infirmed – even given the short duration of flooding. This will require appropriate rostering of staff at such times. As indicated above, this will benefit from the likely quality of forecasts of tidal flooding.

The practicalities for **fluvial** and **combined fluvial/tidal flooding** will, by contrast require special consideration. This is because of the likely duration of fluvial flooding and the additional hazards posed by the extent of flooding. The depth and velocity of flood water will also contribute to the overall hazard.

An indication of the flood extents is provided in Figure B-4. The durations of flooding and associated hazards are available from the results of detailed simulations provided by the Environment Agency. The durations for which the critical section of Broom Road will be subject to different levels of hazard to pedestrians is summarised in Table B-2. This shows that Broom Road would be rated as “No Hazard” for the 5% flood and “Danger for Some” for the 2% flood. The general suburban situation of Broom Road is such that the boundary garden walls at the front of each property will provide assistance to those needing to use the road. There are no special hazards (eg falls or open sections) that would cause particular concern. There is a risk of manhole covers becoming displaced and posing a hazard, though this is thought to be small on account of the low rate of rise of the Thames. Further, this is not the designated emergency access route – it is a route that is likely to be closely monitored by the police and warnings provided in the event of specific hazards such as exposed manholes or deep and/or fast flowing water.

For the 1% flood, the rating is “danger for most” and pedestrian access would be suspended under these conditions. With a maximum depth of around 0.7 m, access by emergency vehicles would be possible under these conditions. Furthermore, certain 4-wheel drive vehicles could safely use this route; Land/Range Rovers for example have a wading depth of 0.5 to 0.7 m depending on the model (http://www.roverguide.com/8167/driving-land-rover-through-flood-water/).

For the 1%CC, the rating is “Danger for all” and with flood depths of over 1 m, access by standard emergency vehicles would also likely be restricted.

Table B-2 Durations of Hazards to People on Broom Road in hours (fluvial)

Probability	Low hazard	Danger for some	Danger for most	Danger for all
1%CC	303	260	232	84
1%	258	164	128	0
2%	222	78	0	0
5%	0	0	0	0

The full suspension of Broom Road for access/egress would then require the emergency access via the Teddington Lock footbridge to be used. It is clear from Table B-2 that the durations over which this access would need to be used are of the order of 5 days for the 1% flood and 10 days for the 1%CC flood. Whilst this will have a significant impact upon the lives of the residents, there will be major disruption to the lives of many people along the Thames and risk to life. The associated load on the emergency authorities is likely to be great. Accordingly, Site Management arrangements should seek to make as small a load as possible on the emergency services. It is proposed to do this by the following:

- Prompt provision of instructions to residents of imminent flooding by warnings and communications systems
- Deployment of the proposed telescopic bridge and managing the flow of people across this route.
- Arrangements for vehicles for transporting people along Broom Road to safe areas on Teddington bank, subject to emergency services approval.
- Arrangements for possible increased use of roads, parking and bus services on Ham bank.
- Special provision for the elderly/infirmed residents to enable provision of food and access. Such residents would be known to Site Management staff, whose responsibility would include checking that they were provided for and if necessary ensuring delivery of food.
- Enabling residents and businesses in the immediate area that are affected by flooding to benefit from these arrangements.
- An annual drill comprising deployment of the “drawbridge” and other measures and a “walk-through” of the access/egress route

More details of the emergency arrangements are provided in Section B.3.5.

Figure B-3 Ham Lands showing possible area for rendezvous

The design of the site is such that all access routes internal to the site are at a minimum of 6.8 mAOD and residential floor levels are predominantly at 7.3 mAOD. However, much of the site will be affected by flooding and the indicative durations for different probabilities of flooding are shown in Table B-3. These likely overstate the duration as they do not make allowance for draining of water from the site (e.g. the flood storage area) back into the Thames once river levels have fallen (eg via flap valves or by infiltration). The presence of water on the site poses a hazard due to its depth. It is largely “standing water” in view of the protected and elevated position of the site.

Figure B-4 Hazard maps for 5%, 2%, 1% and 1%CC fluvial flood events