Resilience and Flood Risk

Russell and Strathmore Schools, Richmond

FLOOD RISK ASSESSMENT

09th February 2015
Final Version 3.0
RAB: 916B

London Borough of Richmond upon Thames
Environment Directorate
Civic Centre
44 York Street
Twickenham
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Resilience and Flood Risk

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Executive Summary

RAB Consultants was appointed by the London Borough of Richmond upon Thames to undertake this flood risk assessment (FRA) in support of a proposed development at:

- Russell School, Petersham Road, Richmond, Surrey, TW10 7AH; and
- Strathmore School, Meadlands Drive, Petersham, Richmond, TW10 7ED.

The two schools share a boundary.

The proposed development is partly for the expansion of the Russell Primary School from one form of entry to one form of entry plus four classes. As part of the proposals, the Strathmore School will be co-located to the site.

The existing Strathmore School site is located entirely within the Environment Agency's Flood Zone 1 with a risk of flooding from tidal and fluvial sources less than 0.1% (1 in 1,000 year). However, a large part of Russell School is located within Flood Zone 2; which has a risk of tidal flooding from the adjacent River Thames between 1% and 0.1% annual probability (1 in 100 to 1 in 1,000 year). This does not take defences into account that offer protection from flooding up to and including a 0.1% annual probability flood event. There is no residual risk of flooding to the site associated with these defences.

The site is at low risk of flooding from all other sources.

The site is within an Environment Agency Flood Warning Area meaning occupants will have access to flood warnings of up to two hours before onset.

Any increase in hard-standing could affect surface water runoff rates and volumes leaving the site. The use of SuDS techniques should be used to limit post-development surface water runoff to the pre-development greenfield runoff rate. Regardless of whether there will be an increase in hardstanding or not, in line with Policy 13 of the London Plan and Policy 4.32 of the London Borough of Richmond upon Thames LDF Core Strategy, suitable SuDS should be incorporated where possible as part of the development to provide a betterment to the existing situation. The conceptual drainage strategy identified that the site presents potential for the installation of SuDS features such as green roofs, infiltration trenches, porous pavement, and an attenuation pond to discharge at a pre-development rate. The pond in this report is sized for the worst case scenario (no infiltration SuDS present) and for the critical 1 in 100 plus 30% climate change storm.

Initial permeability tests conducted by Risk Management for the Phase 1 and Phase 2 of the Site Investigation indicate that shallow infiltration SuDS are likely to be successful. This can be confirmed by full permeability tests that meet BRE Digest 365.

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Resilience and Flood Risk

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Abbreviations

Abbreviation	Definition
EA	Environment Agency
FRA	Flood Risk Assessment
LLFA	Lead Local Flood Authority
NPPF	National Planning Policy Framework
SFRA	Strategic Flood Risk Assessment
PFRA	Preliminary Flood Risk Assessment
SuDS	Sustainable Drainage Systems
SWMP	Surface Water Management Plan

1.0 Introduction

1.1. Terms of Reference

RAB Consultants was appointed by the London Borough of Richmond upon Thames to undertake this flood risk assessment (FRA) for:

- Russell School, Petersham Road, Richmond, Surrey, TW10 7AH; and
- Strathmore School, Meadlands Drive, Petersham, Richmond, TW10 7ED.

The two schools share a boundary.

The National Planning Policy Framework requires a FRA to be carried out to ensure flood risk to the site is considered as well as the impact the development will have elsewhere on people and property.

This FRA has been prepared in accordance with the Environment Agency's Flood Risk Assessment (FRA) Guidance Note 3 (All development in Flood Zones 2 and 3 where standing advice does not apply).

1.2. FRA Requirements

It is a requirement for development applications to consider the potential risk of flooding to a proposed development over its expected lifetime and any possible impacts on flood risk elsewhere, in terms of its effects on flood flows and runoff.

Where appropriate, the following aspects of flood risk should be addressed in all planning applications in flood risk areas:

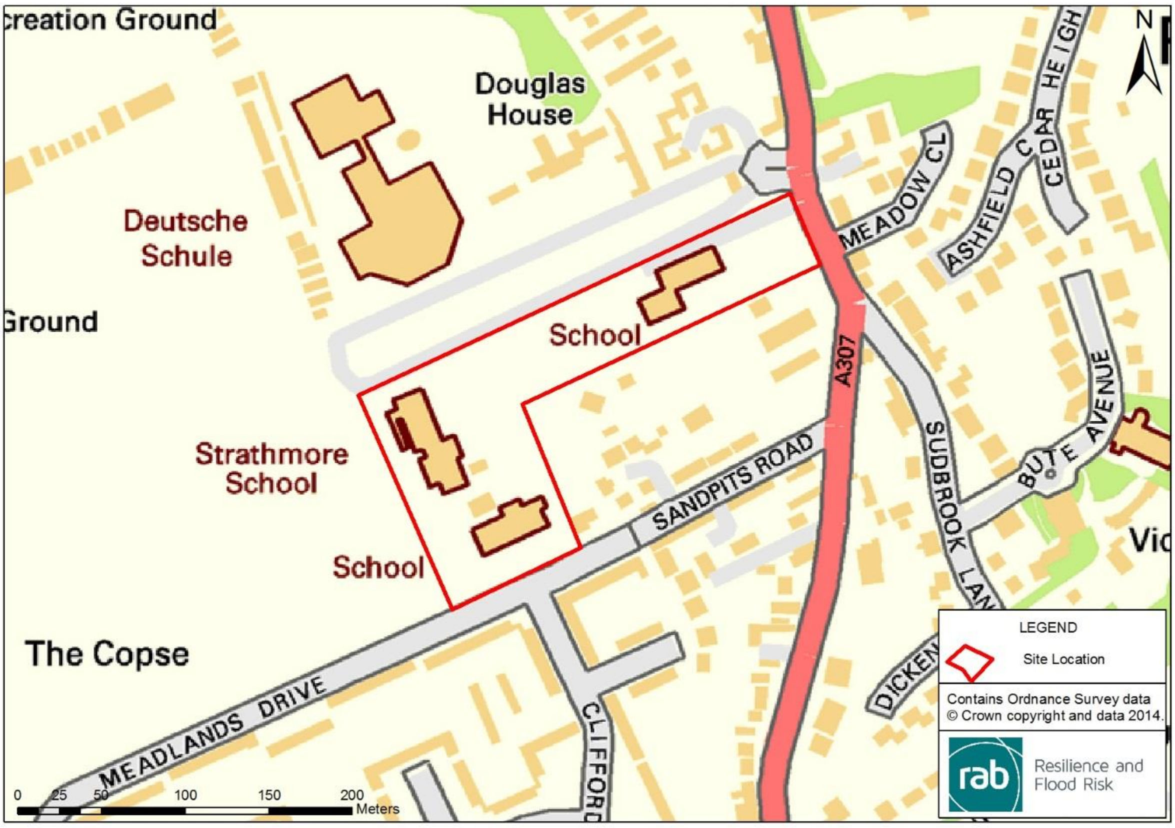
- The area liable to flooding.
- The probability of flooding occurring now and over time.
- The extent and standard of existing flood defences and their effectiveness over time.
- The likely depth of flooding.
- The rates of flow likely to be involved.
- The likelihood of impacts to other areas, properties and habitats.
- The effects of climate change.
- The nature and currently expected lifetime of the development proposed and the extent to which it is designed to deal with flood risk.

This FRA follows government guidance on development and flood risk (National Planning Policy Framework).

1.3. Site Details

Figure 1 - Summary of site details

Site name	Russell School, Petersham Road, Richmond, Surrey, TW10 7AH & Strathmore School, Meadlands Drive, Petersham, Richmond, Surrey, TW10 7ED
Site footprint	2.12ha
Existing land-use	Educational Facility
Purpose of development	Education
Estimated lifespan	100 years
OS NGR	517862 173014
Country	England (NPPF applies)
Local planning authority	London Borough of Richmond upon Thames
Other authorities	Environment Agency Kent and South London Area



1.4. Site Description

The Russell and Strathmore Schools are located in the London Borough of Richmond upon Thames. The schools are bounded by Petersham Road to the east and the copse parkland to the west. Meadlands Drive and the rear of properties on Sandpits Road are the sites southern boundary, whilst to the north is The German School. Notable features in the surrounding landscape include Ham House and Gardens to the west, the River Thames to the north and Richmond Golf Club to the south east.

The site currently comprises of a numbers of buildings, all serving an educational purpose spread out across the site. Strathmore School is comprised of one large building in the sites north western corner, the remaining buildings form part of The Russell School.

There are limited areas of hard-standing ground on site, with the majority being composed of grassed areas that make up playing fields and soft landscaping.

Vehicular access to the site is afforded to Strathmore School via a short driveway off Meadlands Drive and The Russell School via a long driveway off Petersham Road. Pedestrian access to the site is afforded to via the same roads.

1.5. Site History and Development Proposals

The proposed development is for the expansion of Russell School to provide additional places to meet forecasted demands across the borough and to re-provide the school on three new sites and the co-location of the Strathmore School.

Figure 2 - Existing Impermeable Footprint

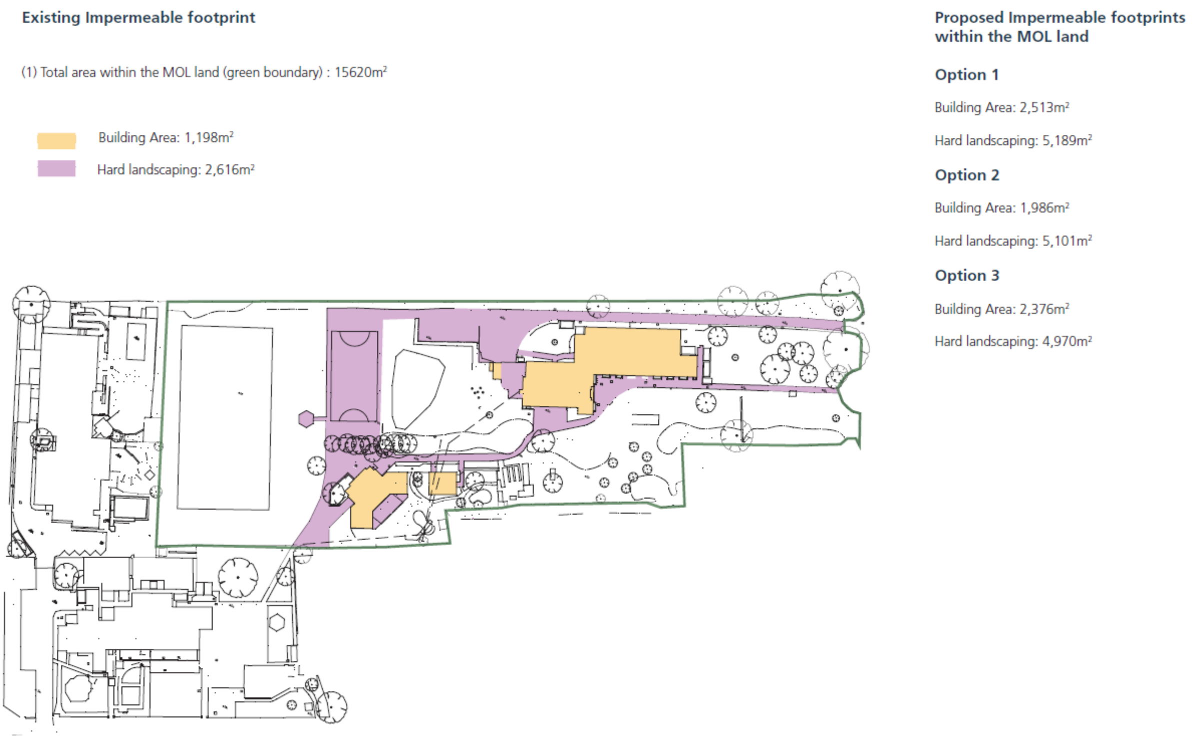


Figure 2 shows the existing impermeable areas at the site. In detail the existing impermeable area at the site is 3,814m^2. The proposed increase (Option 2) in impermeable area is 3,273m^2.

1.6. Existing Drainage Network

The existing site is formally drained through rainwater pipes and gutters leading to the public sewer. Thames Water has provided an asset location plan centred on the site (Appendix C). This shows that there is a well-established surface water and foul sewer network running along all the surrounding roads, including Petersham Road.

2.0 Site Visit – 13th August 2014

2.1. Observations

The site visit was undertaken by RAB Consultants on a dry sunny day. RAB Consultants undertook a photographic survey and visual assessment of the existing site.

The main entrance to Russell School was accessed directly off Petersham Road (A307). The road, which forms the sites eastern boundary was observed to be well served by roadside gullies (Figure 3; Figure 4). These were largely free and clear of debris, although there was some leaf debris observed within one. This is not thought to impede function of the drain in question.

The main entrance road provides vehicular and pedestrian access to the site (Figure 5). The road was observed to be well served by gullies, although some were silted and in need of maintenance (Figure 6). On either side of the road, large areas of natural ground were observed (Figure 7). There were no obvious signs of infiltration issues here, although the preceding weather had been largely dry and warm, meaning this observation is possibly not a reliable indicator of the soils infiltration capability.

The main entrance road led directly to a hard-standing car park area and to the main school building (Figure 8). The entrance to the school office was set slightly above the surrounding ground level. Next to the main school building a number of storage buildings were noted, these were at the bottom of a slight slope and the entrances were not raised above ground (Figure 9). The south east of the main building has numerous entrances (Figure 10). These were set at varying levels above the immediately surrounding ground (65-110mm). Further west along the outside of the school building on its south east face, the school hall doors are set at ground level (Figure 11). Despite this, there is a gentle slope away from the building at this location. A basement level was visible from a lightwell next to the school hall (Figure 12). Access was not afforded but it appeared to contain a boiler.

To the west of the main school building, the land opens into a hard-standing and a natural playground which leads west to the fenced boundary with Strathmore School (Figure 13). The hard-standing playground was served by an aco drain which had been recently desilted (Figure 14).

South of the hard-standing playground, two buildings were observed; an outbuilding and the Hawthorn building (Figure 15; Figure 16). The outbuilding was raised approximately 515mm above the ground on wooden foundations, which would not impede flow, making this area essentially natural ground. The Hawthorn building was raised above ground at its eastern entrance but at the bottom of a slope at the western entrance which could make it vulnerable to surface water runoff or drainage failure (Figure 16; Figure 17).

The south west of the site houses a hard-standing play area and large building to the west of that (Figure 18), a junior school building (Figure 19), and a small cabin building at the schools northern boundary with Strathmore School (Figure 20). The junior school building was partially constructed with UPVC and timber panels below windows.

Strathmore School was accessed directly off Meadlands Drive. Surface water gullies on Meadlands Drive were well maintained. The access road leads directly into a hard-standing car park area. This area was served by gullies but these were so heavily vegetated and silted that they are essentially defunct in terms of their intended function (Figure 21).

The buildings main entrance was to the north west of the car park area (Figure 22). Further along the western boundary of the site, access points were observed to a kitchen area and a boiler room. Access to the eastern face of the school building was not afforded due to an ongoing class at the time of the site visit.

Figure 3 – North facing view of Petersham Road

Figure 4 – Gully observed on Petersham Road

Figure 5 – Main entrance road into Russell School

Figure 6 – Silted gulley on Russell School entrance road

Figure 7 – Natural ground to the south of Russell School main entrance road

Figure 8 – Main building at entrance to Russell School office

Figure 9 – Storage buildings near to school office

Figure 10 – View along the western face of the main school building

Figure 11 – School hall doors

Figure 12 – Basement lightwell

Figure 13 – View from Russell School main building to Strathmore School

Figure 14 – Recently cleared drains serving the hard-standing Russell School playground

Figure 15 – Wooden building observed to be raised above ground on site

Figure 16 – Hawthorn Building eastern entrance

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Figure 18 – View across playground to a school building in the south western corner of the site

Figure 19 –Junior school building entrance

Figure 20 – Cabin building at northern boundary of Russell School

Figure 21 – Vegetated drain in Strathmore School car park

Figure 22 – Main entrance to Strathmore School building

3.0 Development and Flood Risk Policy

3.1. Planning Context

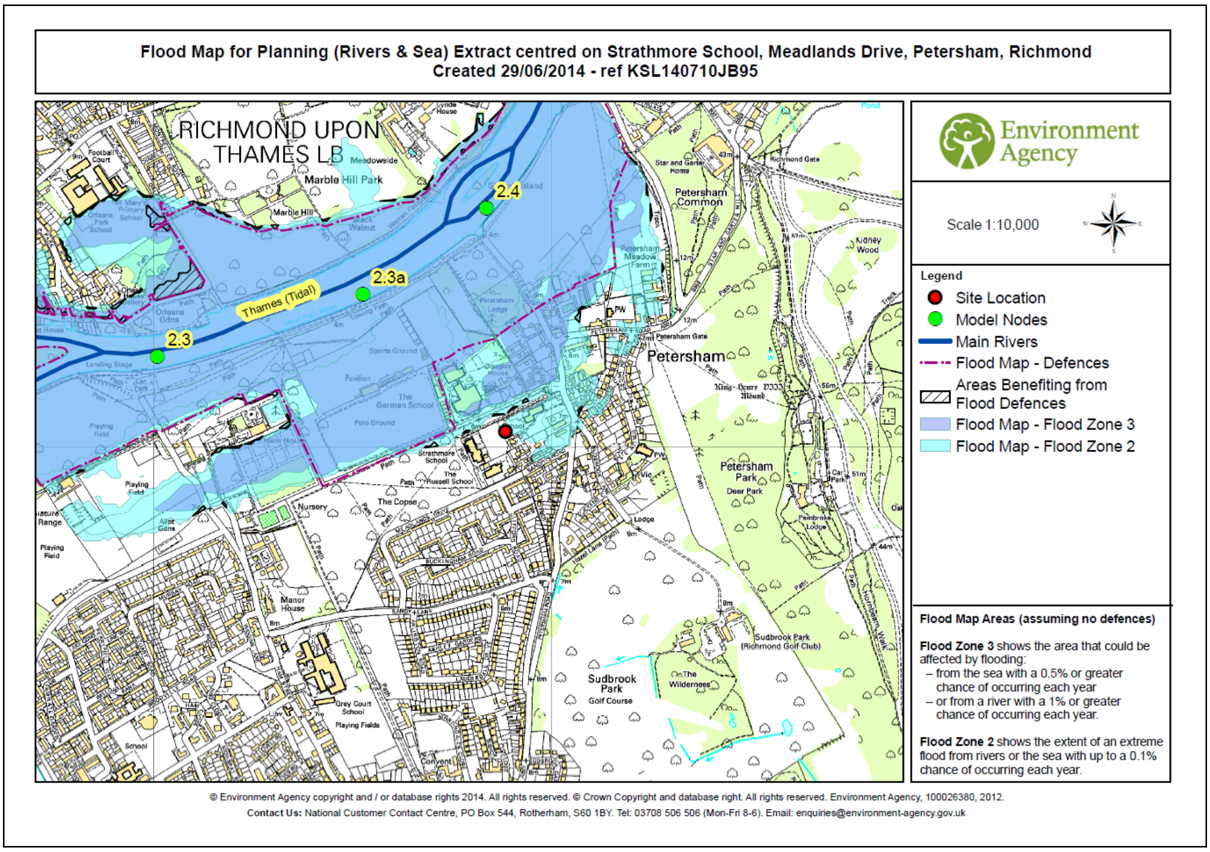
3.1.1. Applicable Planning Policy

National Planning Policy Framework (NPPF) was issued by the Department for Communities and Local Government in March 2012. NPPF deals specifically with development planning and flood risk using a sequential characterisation of risk based on planning zones and the Environment Agency Flood Map. The main study requirement is to identify the Flood Zones and vulnerability classification relevant to the site, based on an assessment of current and future conditions.

3.1.2. Flood Zones

The Environment Agency has developed a Flood Map that shows the risk of flooding in England and Wales for different return period events. It should be noted that the Environment Agency's Flood Map is based on broad scale hydraulic modelling and is an indication of the potential flood risk to a site and the actual risk may differ. The Flood Zone Maps (without climate change) provide the information required by NPPF for planning purposes, as described in Section 3.2. The Flood Zones do not take account of the effect of flood defences. The Environment Agency Flood Map has been provided for the site and is shown below in Figure 23.

Figure 23 - Environment Agency Flood Map



The eastern half of the site lies within Flood Zone 2 as described in Table 1 of the Technical Guidance to the National Planning Policy Framework, with annual probability of fluvial and tidal flooding between 1% (1 in 100 year) and 0.1% (1 in 1,000 year) while the western half of the site is in Flood Zone 1; at low risk of tidal and fluvial flooding, with an annual probability of less than 0.1%. Any proposed educational development would be categorised as a 'more vulnerable' development in accordance with Table 2 of the Technical Guidance to the National Planning Policy Framework.

3.1.3. Sequential and Exception Tests

The Sequential and Exception Tests should be applied when choosing the location of new development and the layout of the development site. The Sequential Test aims to promote development in areas with low flood risk. The Exception Test is used where no suitable development areas can be found in low risk areas, the risk of flooding is clearly outweighed by other sustainability factors, and the development will be safe for its lifetime, taking climate change into account.

The proposed educational building is located in Flood Zone 1. The area of the site in Flood Zone 2 will be used for green space and an access road. These uses are considered less vulnerable in accordance with the National Planning Policy Framework and consequently are appropriate for the Flood Zone. There is no need for either the Sequential Test or the Exception Test to be carried out for the site.

3.2. NPPF Flood Zones

Table 1 shows how the Flood Zones relate to a sequential planning process.

Table 1 - NPPF Flood Zones and Requirements

Zone 1: Low Probability	
Land assessed as having a less than 1 in 1,000 annual probability of river or sea flooding in any year (<0.1%).	**Appropriate uses** All uses of land are appropriate in this zone. **FRA requirements** For development proposals on sites comprising one hectare or above the vulnerability to flooding from other sources as well as from river and sea flooding, and the potential to increase flood risk elsewhere through the addition of hard surfaces and the effect of the new development on surface water run-off, should be incorporated in a FRA. **Policy aims** Developers and local authorities should seek opportunities to reduce the overall level of flood risk through the layout and form of the development, and the appropriate application of sustainable drainage techniques.
Zone 2: Medium Probability	
Land assessed as having between a 1 in 100 and 1 in 1,000 annual probability of river flooding (1% - 0.1%) or between a 1 in 200 and 1 in 1,000 annual probability of sea flooding (0.5% - 0.1%) in any year.	**Appropriate uses** The water-compatible, less vulnerable and more vulnerable uses of land and essential infrastructure in Table2-2 are appropriate in this zone. Highly vulnerable uses in Table 2-2 are only appropriate in this zone if the Exception Test is passed. **FRA requirements** All proposals in this zone should be accompanied by a FRA. **Policy aims** Developers and local authorities should seek opportunities to reduce the overall level of flood risk through the layout and form of the development, and the appropriate application of sustainable drainage techniques.
Zone 3a: High Probability	
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.	**Appropriate uses** The water-compatible and less vulnerable uses of land in Table 2-2 are appropriate in this zone. The highly vulnerable uses (Table 2-2) should not be permitted in this zone.

	The more vulnerable and essential infrastructure uses in Table 2-2 should only be permitted in this zone if the Exception Test is passed. **FRA requirements** All proposals in this zone should be accompanied by a FRA. **Policy aims** Developers and local authorities should seek opportunities to: • reduce the overall level of flood risk through the layout and form of the development and the appropriate application of sustainable drainage techniques; • relocate existing development to land with a lower probability of flooding; • create space for flooding to occur by allocating and safeguarding open space for flood storage.
Zone 3b: Functional Floodplain	
Land where water has to flow or be stored in times of flood. (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 local planning authority and the Environment Agency, including water conveyance routes).	**Appropriate uses** Only the water-compatible uses and the essential infrastructure listed in Table 2-2 that has to be there should be permitted. It should be designed and constructed to: • remain operational and safe for users in times of flood; • result in no net loss of floodplain storage; • not impede water flows; • not increase flood risk elsewhere. **FRA requirements** All proposals in this zone should be accompanied by a FRA. **Policy aims** In this zone, developers and local authorities should seek opportunities to: • reduce the overall level of flood risk through the layout and form of the development and the appropriate application of sustainable drainage techniques; • relocate existing development to land with a lower probability of flooding.

Source: NPPF Technical Guidance Table 1

Table 2 - Flood Risk Vulnerability Classification

Essential Infrastructure	Essential transport infrastructure and strategic utility infrastructure, including electricity generating power stations and grid and primary substations.
Highly Vulnerable	Police stations, Ambulance stations and Fire stations and Command Centres and telecommunications installations and emergency dispersal points. Basement dwellings, caravans, mobile homes and park homes intended for permanent residential use. Installations requiring hazardous substances consent.
More Vulnerable	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, hotels and sites used for holiday or short-let caravans and camping. Non–residential uses for health services, nurseries and education. Landfill and waste management facilities for hazardous waste.
Less Vulnerable	Buildings used for shops, financial, professional and other services, restaurants and cafes, offices, industry, storage and distribution, 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). Water treatment plants and sewage treatment plants (if adequate pollution control measures are in place).
Water-compatible Development	Flood control infrastructure, water transmission infrastructure and pumping stations. Sewage transmission infrastructure and pumping stations. Sand and gravel workings. Docks, marinas and wharves, navigation facilities. MOD defence installations. Ship building, repairing and dismantling, dockside fish processing and refrigeration and compatible activities requiring a waterside location Water-based recreation (excluding sleeping accommodation). Lifeguard and coastguard stations. Amenity open space, nature conservation and biodiversity, outdoor sports and recreation. Essential sleeping or residential accommodation for staff required by uses in this category, subject to a warning and evacuation plan.

Source: NPPF Technical Guidance Table 2

Table 3 - Flood Risk Vulnerability and Flood Zone 'compatibility'

Vulnerability Classification (Table 3)		Essential Infrastructure	Water Compatible	Highly Vulnerable	More Vulnerable	Less Vulnerable
Flood Zone (Table 2)	Zone 1	✓	✓	✓	✓	✓
	Zone 2	✓	✓	Exception Test	✓	✓
	Zone 3a	Exception Test	✓	×	Exception Test	✓
	Zone 3b	Exception Test	✓	×	×	×

Source: NPPF Technical Guidance Table 3

Key:

✓ Development is appropriate

× Development should not be permitted

3.3. Critical Drainage Areas

Critical Drainage Areas are areas of significant flood risk, characterised by the amount of surface runoff that drains into the area, the topography and hydraulic conditions of the pathway and the receptors (people, properties and infrastructure) that may be affected by surface water flooding.

The National Planning Policy Framework defines “areas at risk of flooding” as land within Flood Zones 2 and 3; or land within Flood Zone 1 which has critical drainage problems and which has been notified to the local planning authority by the Environment Agency.

The 2011 London Borough of Richmond upon Thames Council Surface Water Management Plan (SWMP) defined 7 Critical Drainage Areas within the Borough. These were derived by assessing areas of significant interaction between the 100yr mapped depth and hazard outputs with critical infrastructure and property (EA National Receptor Data). Where areas of significant surface water flooding was shown to be affecting property and/or critical infrastructure a CDA was drawn using the underlying topography and the drainage network.

The site is not located within a Critical Drainage Area.

3.4. Policy 5.13 of the London Plan (2011)

The drainage strategy for any proposed development at the site should follow the drainage hierarchy of Policy 5.13 of The London Plan (2011).

The London Plan Policy states:

A) Development should utilise sustainable urban drainage systems(SuDS) unless there are practical reasons for not doing so, and should aim to achieve greenfield run-off rates and ensure that surface water run-off is managed as close to its source as possible in line with the following drainage hierarchy:

1. *store rainwater for later use;*
2. *use infiltration techniques, such as; Porous surfaces in non-clay areas;*
3. *attenuate rainwater in ponds or open water features for gradual release;*
4. *attenuate rainwater by storing in tanks or sealed water features for gradual release;*
5. *discharge rainwater direct to a watercourse;*
6. *discharge rainwater to a surface water sewer/drain;*
7. *discharge rainwater to the combined sewer.*

Drainage should be designed and implemented in ways that deliver other policy objectives of this Plan, including water use efficiency and quality, biodiversity, amenity and recreation.

3.4.1. Policy 4.32 of the London Borough of Richmond upon Thames LDF Core Strategy

The requirement for a drainage strategy for any proposed development at the site to follow the drainage hierarchy of Policy 5.13 of The London Plan (2011) is reinforced by Policy 4.4.2 ENV34 and ENV35 of the SFRA.

Policy ENV34 (Protection of the Floodplain and Urban Washlands) states:

"5.123 Within the area liable to flood, as shown on the proposals map, development, including land raising, will not be permitted unless it can be demonstrated to the satisfaction of the Council that the proposal would not of itself, or cumulatively in conjunction with other development:

i. increase impedance to the flow of floodwater;

ii. reduce the site's contribution to the capacity of the floodplain to store water (ideally a scheme should enhance its capacity);

iii. increase the number of people or properties at risk from significant adverse effects of flooding;

iv. obstruct land adjacent to water courses required for access and or maintenance purposes;

v. adversely affect flood defence structures or other features with the same role."

Policy ENV35 (Surface Water Runoff) states:

"5.127 Planning permission will not normally be granted for new development or redevelopment if such development would result in an increased flood risk in areas downstream due to additional surface water run-off. Where development is permitted which is likely to increase the risk of flooding, it must include appropriate attenuation measures for the disposal of surface water, defined by the Council in consultation with the Environment Agency."

4.0 Assessment of Flood Risk

4.1. Previous Flood History

The 2010 London Borough of Richmond upon Thames Council Level 1 Strategic Flood Risk Assessment (SFRA) has collated observed incidents of flooding in the borough. These incidents have primarily been fluvial and surface water flooding. It is documented that property flooding from the River Thames has occurred nine times within the past 100 years. However, these flood events are not shown to have affected the site.

The 2011 London Borough of Richmond upon Thames Council Preliminary Flood Risk Assessment (PFRA) has collated all readily available historic flood data from key stakeholders within the London Borough of Richmond upon Thames, including the Richmond council and the Environment Agency. This allowed for the identification of significant historic flood events within the borough. There is no evidence provided within the PFRA to suggest that the site has been impacted by historical flooding from any source.

4.2. Fluvial Flood Risk

River levels in the Thames at this location are dominated by the tides. Fluvial risk on its own does not present a risk to the site, but fluvial risk must be taken into account when considering the combined risk of tidal and fluvial flood risk which is discussed below.

4.3. Tidal Flood Risk

The proposed development site is shown to be partially within the Environment Agency Flood Zone 2; at risk of tidal flooding with an annual probability between 1% and 0.1% (1 in 100 year and 1 in 1,000 year). This flood risk is attributed to the adjacent River Thames.

The tidal flood zones do not take account of the River Thames tidal defences in the area which are estimated to protect the site up to and including a 0.1% (1 in 1,000 year) tidal flood event (Appendix B). The defences only protect against extreme tidal levels and not the combined effect of high fluvial and high tides. This is discussed below.

4.4. Joint Probability Tidal and Fluvial Flood Risk

The Environment Agency has provided in-channel flood levels for the tidal River Thames. These have been taken from the Thames Estuary 2100 (TE2100) study completed by HR Wallingford in 2008. The TE2100 study has only recently become live and within it are a set of levels on which the TE2100 strategy is based. The plan is the overarching flood management strategy for the Thames Estuary and therefore any development planning should be based on the same underlying data.

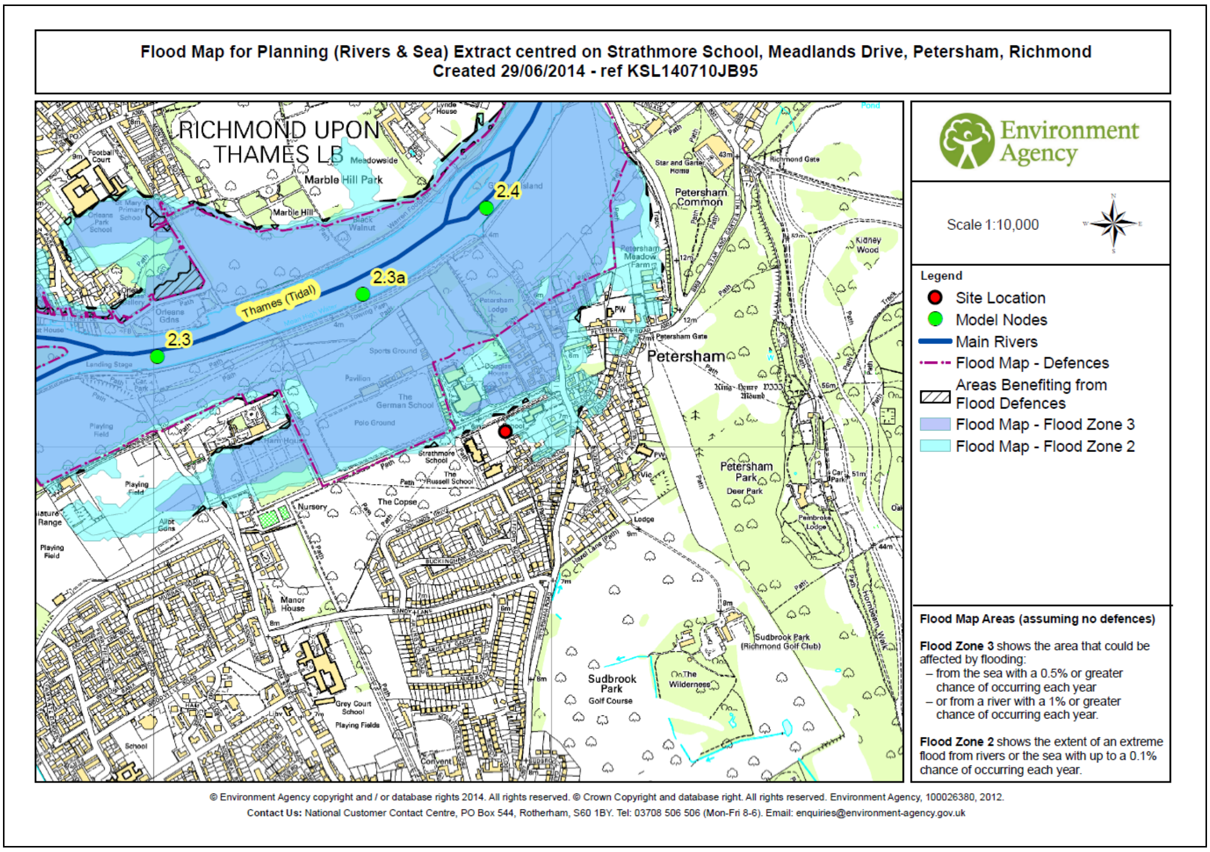
The TE2100 study takes into account operation of the Thames Barrier when considering future levels. The Thames Barrier requires regular maintenance and with additional closures the opportunity for maintenance will be reduced. When this happens, river levels for which the Environment Agency would normally shut the barrier will have to be allowed through to ensure that the barrier is not shut too often. For this reason, levels upstream of the barrier will increase and the tidal walls will need to be heightened to match.

4.4.1. TE2100 Present Day Levels

The levels upstream of the Thames 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 1,000 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.

Modelled flood levels have been provided for in channel Node 2.3a; closest to the proposed development site (Figure 24).

Figure 24 - Environment Agency Flood Map displaying in-channel nodes



The data provided in Table 4 below shows the current and future water levels at Node 2.3a permitted by the Barrier.

Table 4 - Environment Agency modelled River Thames present extreme water levels

Node	Easting	Northing	Present Day Water Level	Future 2065-2100 Water Level	Future 2100 Water Level
2.3a	517525	173383	5.77	5.95	6.40

The Environment Agency note that defence levels on both banks of the River Thames will rise to 6.9m AOD by 2100 which is 0.5m above the future 2100 water level (Appendix B).

There is therefore no risk of overtopping from a tidal flood event up to 2100 due to the proposed increases in defence level on both banks.

4.5. Flood Defence Breach

The Environment Agency data states that all defences along the Tidal Thames in this area are all raised, man-made and privately owned (Appendix B). Defences are inspected twice a year to ensure that they remain fit for purpose. They are maintained by their owners to a crest level of 6.10m AOD; the statutory Flood Defence Level in this reach of the Thames (Appendix B).

Defence condition is rated based on the National Flood and Coastal Defence Database categories (Table 5). The overall condition grade for defences in the area is 2 (Good) (Appendix B).

Table 5 - Flood Defence Condition Descriptions

Condition Rating	Condition	Condition Description
1	Very Good	Fully serviceable
2	Good	Minor defects
3	Fair	Some cause for concern. Requires careful monitoring
4	Poor	Structurally unsound now or in the future
5	Very Poor	Completely failed and derelict

The site is outside the 1 in 200 year flood zone and consequently is not at risk from the modelled 1 in 200 year breach event. It is understood that no maps have been provided within the Environment Agency data for this reason (Appendix B).

4.6. Canal Flood Risk

There are no canals in Richmond and the immediately surrounding area; consequently there is no risk from this source.

4.7. Reservoir Flood Risk

The site is identified as being at risk of reservoir flooding from three reservoirs on the EA reservoir flood map, this is shown in Table 6.

Table 6 - Reservoirs identified as posing a risk to the proposed development site

Name	Owner	Grid Reference	EA Area	Local Authority
Queen Elizabeth II	Thames Water Ltd	512410 167770	Kent & South London	Surrey County
Queen Mary	Thames Water Ltd	508310 169750	Hertfordshire and North London	Surrey County
Queen Mother	Thames Water Ltd	501297 177727	West Thames	Windsor and Maidenhead

The reservoir flood map provided by the Environment Agency is a worst case scenario and in reality reservoir flooding is extremely unlikely with no loss of life attributed to dam failure in the UK since 1925 which was prior to reservoir safety legislation being introduced to ensure high standards in reservoir maintenance.

4.8. Surface Water Flood Risk

When the infiltration capacity of land or the drainage capacity of a local sewer network is exceeded, excess rainwater flows overland; this water will collect in topographic depressions and at obstructions, and can inundate development downslope. The severity of the rainfall event, the degree of saturation of the soil before the event, the permeability of soils and geology, hill slope steepness and the intensity of land use all contribute to and affect the severity of overland flow.

The Environment Agency most recent flood map for surface water published in December 2013 is freely available online at their website and can be used to see the approximate areas that would experience surface water flooding from a variety of rainfall return periods. The risk is categorised based on annual probability of occurrence. The different risk categories are displayed below in Table 7.

Table 7 - Environment Agency Surface Water Risk Categories

Environment Agency Surface Water Risk Category	Surface water flooding annual probability of occurrence
Very Low	Less than 0.1% (1 in 1,000 years)
Low	Between 1% and 0.1% (1 in 100 years and 1 in 1,000 years)
Medium	Between 1% and 3.3% (1 in 100 years and 1 in 30 years)
High	Greater than 3.3% (1 in 30 years)

The surface water map identify that the majority of the site itself has a very low risk of surface water flooding. There are some small scattered areas of low risk but these are not thought to pose a threat to the overall site. This type of flooding can be difficult to predict as it is hard to forecast where or how much rain will fall in any storm. The Environment Agency's flood map is based on the best information available to them, such as ground levels and drainage assumptions.

The site has not been impacted by any historical flooding associated with this source in accordance with the 2010 SFRA and 2011 PFRA. This supports the Environment Agency classification of very low risk associated with surface water flooding.

4.9. Drainage and Sewage Infrastructure

Sewer flooding is often caused by excess surface water entering the drainage network causing sewers to surcharge. Thames Water, are responsible for the management of urban drainage and sewerage within the Borough.

The 2010 SFRA consulted Thames Water to discuss the risk of localised flooding; however feedback provided was general in nature providing a simple summary of the number of incidents per postcode. This was summarised within the report and associated maps. The results indicate that the site has not been affected by flooding from this source within the ten years prior to production of the 2010 SFRA. It is important to note that previous sewer flood incidents do not indicate the current or future risk to the site as upgrade work could have been carried out to alleviate any issues or conversely in areas that have not experienced sewer flooding incidents the local drainage infrastructure could deteriorate leading to future flooding.

4.10. Groundwater/Geology

British Geological Survey records indicate that the sites underlying bedrock is composed of London Clay formation Clay and Silt. Clay is characteristically an aquitard, known to preclude groundwater rise. This is overlain by superficial deposits composed of Kempton Park Gravel Formation Sand and Gravel. This, unlike the London Clay, is likely to be highly permeable and to allow surface water to freely infiltrate into the soil. In a geological setting such as this one, surface water can form a perched water table as it travels through the superficial deposits before meeting the impermeable London Clay bedrock. In saturated conditions this can make the site susceptible to groundwater flooding.

Despite this, there is no history of flooding from this source in either the 2011 SFRA or the 2011 PFRA. Consequently, it is thought that there is a low risk of flooding to the site from this source. Ultimately, ground investigation would be required to accurately determine the sites groundwater regime.

The Phase 1 and Phase 2 Site Investigation Report conducted by Risk Management has found that Kempton Park Gravel sits beneath the site to between 6.7m and 8.0m depth, overlying London Clay. Groundwater was encountered across the site in the Kempton Park Gravel at 3.5 to 4.0m depth.

4.11. Climate Change

There is clear scientific evidence that global climate change is happening now. Over the past century around the UK sea levels have risen and more of our winter rain has fallen in intense wet spells like that seen as recently as the 2013/14 winter.

In assessing the impacts of climate change on flood risk emanating from the land, rivers, and the sea, sensitivity ranges in Table 4 and Table 5 of the Technical Guidance to the National Planning Policy Framework may provide an appropriate precautionary response to uncertainty about climate change impacts on peak rainfall intensity and peak river flow. These tables are reproduced below as Table 8 and Table 9 respectively.

Table 8 - NPPF Technical Guidance recommended national precautionary sensitivity ranges for peak rainfall intensities and peak river flows

Parameter	1990 to 2025	2025 to 2055	2055 to 2085	2085 to 2115
Peak Rainfall Intensity	+5%	+10%	+20%	+30%
Peak River Flow	+10%	+20%		

Table 9 - NPPF Technical Guidance recommended national precautionary sensitivity ranges for net sea level rises

	Net sea level rise (mm per year) relative to 1990			
	1990 to 2025	2025 to 2055	2055 to 2085	2085 to 2115
East of England, east midlands, London, south-east England (south of Flamborough Head)	4.0	8.5	12.0	15.0
South-west England	3.5	8.0	11.5	14.5
North-west England, north-east England (north of Flamborough Head)	2.5	7.0	10.0	13.0

Climate changes can affect local flood risk in several ways. Impacts will depend on a local conditions and vulnerability. More intense rainfall causes more surface runoff, increasing localised flooding and erosion. In turn, this may increase pressure on drains, sewers and water quality. Storm intensity in summer could increase even in drier summers, so there is a need to be prepared for the unexpected. Rising sea or river levels may also increase local flood risk inland or away from major rivers because of interactions with drains, sewers and smaller watercourses.

5.0 Mitigation Measures

5.1. Recommended Finished Floor Levels

In order to afford a level of protection against flooding it is normally recommended that finished floor levels are set a nominal 300mm above either the 1% (1 in 100 year) fluvial flood or the 0.5% (1 in 200 year) tidal flood (including an allowance for climate change) depending which is higher. This measure is not necessary at the proposed development site as there is no risk of flooding from the River Thames directly or indirectly as a result of breach or overtopping of the defences.

5.2. Flood Warning and Evacuation

5.2.1. Flood Warnings Direct

The Environment Agency operates a free flood warning service called Floodline Warnings Direct (FWD) which can give advance notice of when tidal flooding is likely to happen and time to prepare for a flood event. Property owners on the proposed development site will be able to sign up to FWD online using the following channels:

Channel	Details
Online	https://fwd.environment-agency.gov.uk/app/olr/register
Telephone	0845 988 1188
Typetalk	0845 602 6340

5.2.2. Flood Warning Service

The Environment Agency provides a Flood Warning Service throughout England and Wales in areas at risk of flooding from rivers or the sea. This is provided using up to date rainfall, river level and sea condition monitoring 24 hours a day to forecast the possibility of flooding. If flooding is forecast, the Environment Agency will issue warnings using a set of three different warning types (Table 10). Many areas of England are covered by the full four stages of the Environment Agency Flood Warning Service, including Richmond. The Environment Agency Flood Warning target lead time; the time between a flood warning being issued and the onset of flooding is approximately two hours. Providing the Environment Agency can meet their target Flood Warning lead time, the occupants of the proposed development will have two hours to ensure that property is relocated to minimise risk and evacuation to safe locations can be carried out.

Table 10 - Environment Agency Flood Warning Codes

Flood Warning Code	What it Means	What To Do
	Flooding is possible. Be prepared.	Be prepared to act on your flood plan. Prepare a flood kit of essential items. Monitor local water levels and the flood forecast on our website.
	Flooding is expected. Immediate action required.	Move family, pets and valuables to a safe place. Turn off gas, electricity and water supplies if safe to do so. Put flood protection equipment in place.
	Severe flooding. Danger to life.	Stay in a safe place with a means of escape. Be ready should you need to evacuate from your home. Co-operate with the emergency services. Call 999 if you are in immediate danger.
Warnings no longer in force	No further flooding is currently expected in your area.	Be careful. Flood water may still be around for several days. If you've been flooded, ring your insurance company as soon as possible.

5.2.3. Richmond Flood Warning Service

The site lies within a flood warning area serving the site as follows:

Table 11 – Tidal Thames from Richmond Bridge to Teddington Weir flood warning area

Location	River Thames from Richmond Bridge to Teddington Weir including West Petersham and Ham Lands
Area	Kent and South London Area
Floodline	Call Floodline on 0345 988 1188 or 0845 988 1188, select option 1 and enter Quickdial number 174103 to get more information

5.3. Safe Access and Exit

A flood warning will allow safe access and exit from the site in advance of flooding occurring in the event of an extreme 1% (1 in 1,000 year) flood. Safe pedestrian access to and from the site will be provided via Meadlands Drive, leading south from the existing Strathmore School entrance. This entrance area is in Flood Zone 1 and leads out away from the River Thames.

6.0 Surface water runoff pre-development condition

The current site area has areas of impermeable hard-standing ground. Despite this, there are significant areas of natural ground on site to the south and east.

6.1. Pre-development runoff rate per ha

Using the IH124 method for determining greenfield runoff built into Microdrainage WinDes 2013.1 (including the modification given in Interim Code of Practice for SUDS, Chapter 6):

- AREA = 1ha.
- SAAR = 600mm
- SOIL = 0.3
- **Pre-development QBAR = 1.5 l/s.**
- **Pre-development peak flow with 1 year return period = 1.3 l/s.**
- **Pre-development peak flow with 30 year return period = 3.4 l/s.**
- **Pre-development peak flow with 100 year return period = 4.9 l/s.**
- **Pre-development peak flow with 100 year return period plus 30% climate change = 6.37 l/s.**

6.2. Pre-development runoff volume per ha

Using FSR method to determine rainfall and FSSR 16 fixed percentage runoff model for volume (Greenfield runoff volume analysis module built into Microdrainage WinDes 2013.1):

- M5_60 = 20.000mm
- Ratio R = 0.409
- Areal reduction factor = 1.00 (for small site)
- Return period = 100 year
- Storm duration = 360 minutes
- Area = 1ha
- SAAR = 600mm (obtained from WinDes 2013.1 built in FSR map)
- CWI = 87.000
- Urban = 0.000
- SPR = 30.000
- PR% = 24.41
- Pre-development Greenfield runoff volume = 151.265m^3

7.0 Development Impacts

7.1. Post development surface water runoff

Any increase in the site's hard-standing area will increase surface water runoff rates and volumes and could alter flow paths which may put areas of the existing site and neighbouring properties at risk for this increased rate and volume. In the event of any part of the site being developed, it is therefore necessary for post-development surface water runoff to be controlled to the same level as the existing greenfield runoff rate (1.5 l/s per ha) for a range of annual flow rate probabilities, up to and including the 1% annual probability (1 in 100 year) return period storm, including the effects of climate change to ensure that flood risk is no greater to the surrounding area as a result of the development. This is in line with CIRIA C697 SuDS Manual which states the following:

The regulatory authorities will normally require the developed rate of runoff to be no greater than the greenfield runoff rate for a range of annual flow rate probabilities, up and including the 1 per cent annual probability (1 in 100 year return period). Volumes or runoff should also be reduced where possible. These criteria can be relaxed by regulators where appropriate, or where it is impractical to meet these requirements.

The use of suitable SuDS is a sustainable method of achieving this level of surface water runoff control.

7.2. SuDS

Paragraph 1.3.2 from the SuDS Manual (C697) discusses the SuDS 'management train' which is intended to mimic the natural catchment process as closely as possible. The hierarchy of techniques used to achieve the management train are shown below in Table 12.

Table 12 - Hierarchy of SuDS techniques

Technique	Description
Prevention	The use of good site design and housekeeping measures to prevent runoff and pollution (e.g. rainwater harvesting/reuse).
Source control	Control of runoff at or very near its source (e.g. soakaways, porous and pervious surfaces, green roofs).
Site control	Management of water in a local area or site (e.g. routing water to large soakaways, infiltration or detention basins)
Regional control	Management of runoff from a site or several sites (e.g. balancing ponds, wetlands).

The following SuDS techniques could be used in conjunction with each other or in isolation to help manage the surface water runoff from a development at the site.

7.3. Prevention

The use of good housekeeping measures such as rainwater harvesting can reduce the sites surface water runoff and put the rainwater collected to good use, such as watering plants, and flushing toilets. This should be considered throughout any proposed development site.

7.4. Source Control

Current indications of site permeability have been obtained from 1:50,000 scale British Geological Survey records. The British Geological Survey records indicate that the site has a high permeability but also has the potential for an elevated groundwater table. It is therefore possible that infiltration SuDS (soakaways, infiltration ponds etc) will be ineffective at the site. There are however, alternative SuDS techniques that could be considered.

The Phase 1 and Phase 2 Site Investigation Report conducted by Risk Management indicate that infiltration SuDS are likely to be successful at the site. The Falling Head Tests undertaken into the underlying Kempton Park Gravel gave permeability (k) values of between 1.57×10^{-5} and 6.59×10^{-6}. However, it should be noted that the test water ran away too quickly to raise the water to the surface in each case.

7.5. Site Control

If infiltration SuDS are not preferred, the use of storage SuDS such as an attenuation pond or tank with outlet control is an option that could be considered.

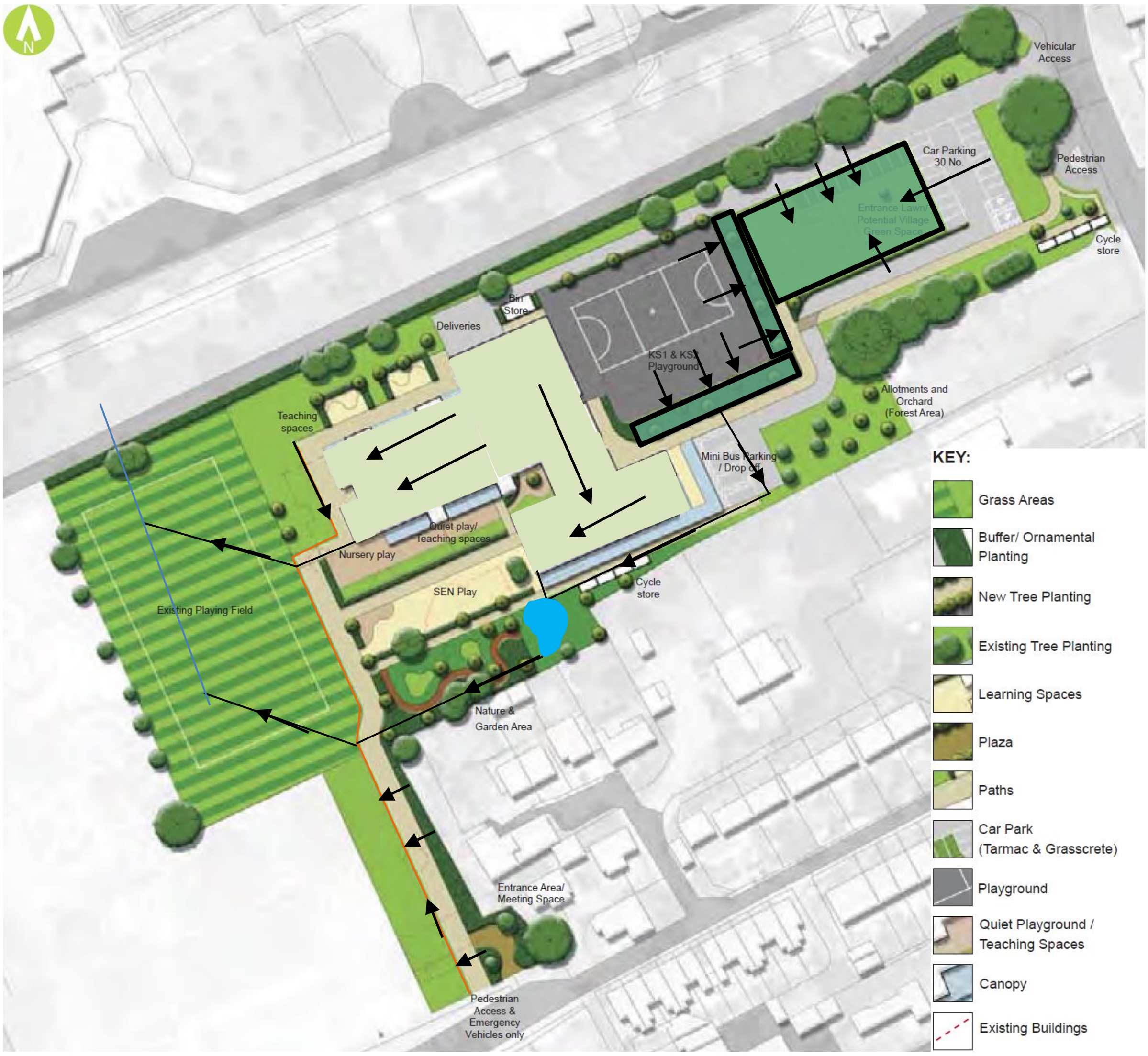
The site is sufficiently sized to accommodate the use of an attenuation pond or storage tank to ensure that any increased volume as a result of the development will be discharged at QBAR for the 1 in 100 year rainfall event. The transfer of surface water runoff (conveyance) across the site, between components is essential for this approach. There are a variety of approaches that can be used; underground through pipes with little control or water quality treatment, or through vegetated channels on the surface providing some treatment and attenuation and through more engineered canals or rills. The preference in terms of delivering sustainable drainage objectives is the conveyance of water through vegetated channels or swales. Uncontrolled conveyance to a point of discharge into the environment is discouraged.

The use of conveyance at the site is thought to be appropriate given the availability of natural ground available to use. Such areas comprise the natural ground in the south east corner of the site.

Figure 25 shows a conceptual drainage strategy which employs the use of various SuDS features and an attenuation pond which will control the outflow at a pre-development rate by using a hydro-brake. The outflow will be connected to the Thames Water surface water network (se Appendix C) located in the existing playing field. Note that the pond has been sized without taking into account the presence of other SuDS features. In other words, its size and depth can be reduced.

The pavement/tarmac should ideally be permeable. The conceptual drainage design also incorporates the use of infiltration trenches, green roofs, and bio-retention areas for storage and conveyance at site level. The features are interconnected with underground pipes but this could be changed to over-ground SuDS features if preferable.

Figure 25 - Conceptual Drainage Strategy



Key:

- Infiltration trench
- Attenuation Pond
- Green roof
- Bio-retention area/rain garden
- Underground pipe
- Thames Water existing pipe
- Flow path

7.6. Conceptual Drainage Design

The Hydro-brake delivers water more efficiently across the full range of water heads than other outlet controls such as an orifice. Because of this, the Hydro-Brake controls to a low rate whilst maintaining a suitably sized orifice diameter which helps mitigate against blockage.

The effectiveness of this conceptual drainage option has been tested using Microdrainage WinDes 2013.1 Source Control module, under the following conditions. The area relates to the increased impermeable area as a result of the development.

Table 13 – Drainage Design Conditions

Win Des Parameter	Value used
Global Variables	
Inflow	Rainfall Data
Additional inflow	None
Storage structure	Tank or Pond
Outflow control	Hydro-brake
Overflow control	None
Climate change (%)	30
Rainfall details	
Return period (years)	100
Region	England and Wales
M5-60 (mm)	20.000
Ratio R	0.409
Storms	Summer and Winter
Cv	0.750 (summer) 0.840 (winter)
Shortest storm duration (mins)	15
Longest storm duration (mins)	10080
Network storage volume (m3)	0
Time area diagram	
0 – 4 minutes	0.129 ha
8 - 12 minutes	0.129 ha
12 - 16 minutes	0.129 ha
16 minutes onwards	0 ha
Pond Structure	
Cover level (m)	100.000
Invert Level (m)	98.800
Storage (online/offline)	Online
Depth (m) - Area (m^2)	1.2 - 250
Hydro-Brake Outflow Control	
Invert Level (m)	98.800
Design Head (m)	1.20
Design Flow (l/s)	5
Hydro-Brake Type	MD-SCE-0105-5000-1000-5000

The critical storm had 360 minute duration.

The final outflow results for the critical storm are:

- Post-development peak flow with 1 year return period = 2.2l/s.
- Post-development peak flow with 30 year return period = 3.2l/s.
- Post-development peak flow with 100 year return period = 3.7l/s.
- Post-development peak flow with 100 year return period (+CC) = 4.3l/s.

Post-development discharge volume for a 360 minute, 100 year storm from proposed impermeable area = 271.9m^3.

The discharge rates are limited to the pre-development QBAR without a risk of flooding during the 100 year return period rainfall event including climate change. Please note that ideally the minimum discharge rate is 5l/s so that potential blockages are avoided. The pond outflow must be inspected and cleared at least once every two months.

The attenuation pond will have a size of approximately 250m^2. This, however, does not take into account the presence of swales or any other SuDS features. In other words the pond could be much smaller or shallower depending the developers' preference.

8.0 Conclusion

This FRA has been prepared to meet National Planning Policy Framework guidelines for a proposed expansion of the Russell and Strathmore Schools in the London Borough of Richmond.

Half of the existing site of Russell and Strathmore Schools, within the Russell School boundary is within Flood Zone 2, with an annual probability of tidal flooding between 1% and 0.1% (1 in 100 year and 1 in 1,000 year) from the River Thames. The flood zones do not take into account the effect of the River Thames tidal defences which deem the site as an 'Area Benefitting from Defences'.

The defences are in good condition and are shown to prevent overtopping from a tidal flood event up to and including a 0.1% (1 in 1,000 year) flood including the effects of climate change. There is no residual risk of flooding as there is no risk of a breach affecting the site.

The site is at low risk from other sources of flooding including surface water, groundwater and canals.

An asset location search provided by Thames Water has determined that the area of the School is well served by public surface water and foul sewers.

The greenfield runoff rate for the site has been estimated using the IH124 method for determining greenfield runoff rate revealing a surface water runoff rate of 1.5 l/s per ha. The greenfield runoff volume was also calculated, revealing a value of 151.265m^3 per ha during a 1 in 100 year 6 hour duration storm event.

There will be an increase in hard-standing as a result of the development. This means that the use of suitable SuDS techniques must be used to ensure that the development has no effect on surface water runoff in accordance with Policy 5.13 of the London Plan. Permeability tests carried out by Risk Management for the Phase 1 and Phase 2 Site Investigation indicate that infiltration SuDS such as soakaways, infiltration ponds and porous surfaces are likely to be suitable. This can be confirmed by formal percolation tests that conform to BRE Digest 365.

A conceptual drainage strategy has been drafted as part of this flood risk assessment in order to ensure that the increase in impermeable area will not impact the volume of flow downstream. An attenuation pond along with other infiltration SuDS (infiltration trenches, bio-retention areas, etc.) are to manage storm-water by discharging it to the public sewer at a pre-development rate.

The site is within an Environment Agency Flood Warning Area meaning occupants will have access to flood warnings of up to two hours before onset.

It can be concluded therefore that the proposed development is appropriate for the flood risk and is not expected to increase the risk of flooding elsewhere.

9.0 Recommendations

- The development's final occupants should sign up to the Environment Agency's flood warning service in operation in the local area. Details of how to do this are provided in Chapter 5.2.2.
- A surface water drainage strategy must accompany this flood risk assessment to ensure that post-development surface water runoff from any additional hard-standing created as a result of the development during a 100 year return period storm event including the effects of climate change is controlled to 1.5l/s to ensure that flood risk is no greater to the surrounding area as a result of the development.
- The surface water drainage strategy should incorporate SuDS, that meets the requirements of Policy 5.13 of the London Plan should be developed to limit the rate of surface water run-off to the greenfield rate of 1.5 l/s per ha and improve the quality of the run-off.
- A SuDS maintenance plan and schedule should be written to ensure efficient operation of the SuDS at all times.
- Regular maintenance of existing drainage infrastructure at the site should be carried out including desilting and unblocking of drains.
- Whilst Falling Head Tests show that infiltration SuDS are favourable, full infiltration tests must be carried out in accordance with BRE Digest 365 to confirm the permeability of the soil if infiltration SuDS are to be considered.

Appendix A Development Proposals

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Appendix B Environment Agency Data

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Appendix C Thames Water Asset Data

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