COOMBE HILL INFANT SCHOOL

FLOOD RISK INVESTIGATION

PREPARED FOR THE ROYAL BOROUGH OF KINGSTON UPON THAMES

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EXECUTIVE SUMMARY

This flood risk investigation for Coombe Hill Infant School was triggered due to multiple reports of flooding at the site. The first report was received in 2007, and the second in February 2019. The February 2019 report stated that the school had been experiencing a flooding problem over a period of several months.

The data collection and investigation exercises established that the site is potentially at risk of groundwater influenced flooding via throughflow and flooding from artificial sources. A catchment analysis provided hydrological catchment outputs for the site. The defined catchment shows that Coombe Hill Infant School falls within the same catchment as the superficial and bedrock aquifers to the north of the site.

The flood risk at the site is exacerbated due to several factors, including changes in topography and geology between the aquifers upstream of the site and the site itself. Building work carried out at the site may have also altered sub-surface flows associated with the Coombe Conduit (a historical pipe system which runs beneath the school).

The Risk Management Authority (RMA) who is responsible for managing the potential risks posed by flooding to the Coombe Hill Infant School site is the Royal Borough of Kingston upon Thames (Kingston, the landowner). To date, Kingston have carried out investigative work with regards to the flood incidents and carried out two site visits to the school. The actions carried out by Kingston align with their roles and responsibilities. Recommendations for further actions have been outlined below:

- The LLFA should continue to work with the school to better understand the extent of the flooding incident, the actions they have taken since the incident, and the site's private surface water drainage network.
- The LLFA should find out whether the recommended land and structural survey at the site was carried out, and what the results of this were.
- The LLFA should investigate mitigation measures such as SuDS which can be incorporated on the site to reduce the risk of flooding.
- The LLFA should investigate who the owner of the Coombe Conduit is and who maintains it. They should also arrange for a survey of the Coombe Conduit to be conducted and determine what impact this has on sub surface flows on the school site.
- For any future development at the school, Kingston's Planning team should work with Kingston's Education team to ensure that developers undertake any necessary investigations

to understand the relationship between sub surface flows and potential flooding at the site. If necessary, these investigations should include mitigation measures to reduce the risk of further groundwater influenced flooding to the site.

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ACRONYMS AND ABBREVIATIONS

Abbreviation	Definition
EA	Environment Agency
FWMA	Flood and Water Management Act 2010
Kingston	Royal Borough of Kingston upon Thames
LLFA	Lead Local Flood Authority
LiDAR	Light Detection and Ranging
RMA	Risk Management Authority
RoFSW	Risk of Flooding from Surface Water
SuDS	Sustainable Drainage Systems
TBR	Tipping Bucket Raingauge
TfL	Transport for London
TWUL	Thames Water Utilities Limited

1 INTRODUCTION

1.1 Background Policy and Information

As a unitary authority, the Royal Borough of Kingston upon Thames (Kingston) is a Lead Local Flood Authority (LLFA). LLFAs are defined as a Risk Management Authority (RMA) under Section 6, Part 1 of the Flood and Water Management Act (FWMA) 2010. They are one of several parties who are responsible for managing the risks posed by flooding. Other RMAs as defined by the FWMA 2010 are:

- the Environment Agency (EA)
- a district council for an area for which there is no unitary authority
- an internal drainage board
- a water company, and
- a highway authority.

RMAs relevant within Kingston are found in *Chapter 4.* There are no district councils or internal drainage boards within Kingston.

As part of their role as an LLFA and an RMA under Section 19, Part 1 of the Act, Kingston is required to act when they become aware of flooding in the area. The FWMA 2010 states that:

> *A lead local flood authority must, to the extent that it considers it necessary or appropriate, investigate –*
>
> *a. which risk management authorities have relevant flood risk management functions, and*
>
> b. *whether each of those risk management authorities has exercised, or is proposing to exercise, those functions in response to the flood.*

For all flood investigations carried out under Section 19 of the FWMA 2010, Kingston must:

a. publish the results of its investigation, and

b. notify any relevant risk management authorities

Kingston received a report of surface water flooding at Coombe Hill Infant School in 2007. Since then, a further report in early 2019 stated that the school had been experiencing a flooding problem within the school grounds over a period of several weeks. There are certain threshold criteria defined in the Local Flood Risk Management Strategy which if met, trigger Kingston to conduct a Section 19 investigation. These are:

- If internal flooding of one building has been experienced on more than one occasion
- Where internal flooding of five or more properties has been experienced during a single flood incident
- Where critical infrastructure (e.g. roads impassable to traffic) has been affected by flooding more than once within a 12 month period

Kingston can also investigate other flood incidents which do not meet these criteria if it is deemed necessary. The multiple reports of flooding at Coombe Hill Infant School triggered Kingston to conduct a Section 19 investigation.

1.2 Location

Coombe Hill Infant School is located in Coombe, an area in the north east of the borough (see *Figure 1.1*). Further information on the flooding reported at the site can be found in *Chapter 2*.

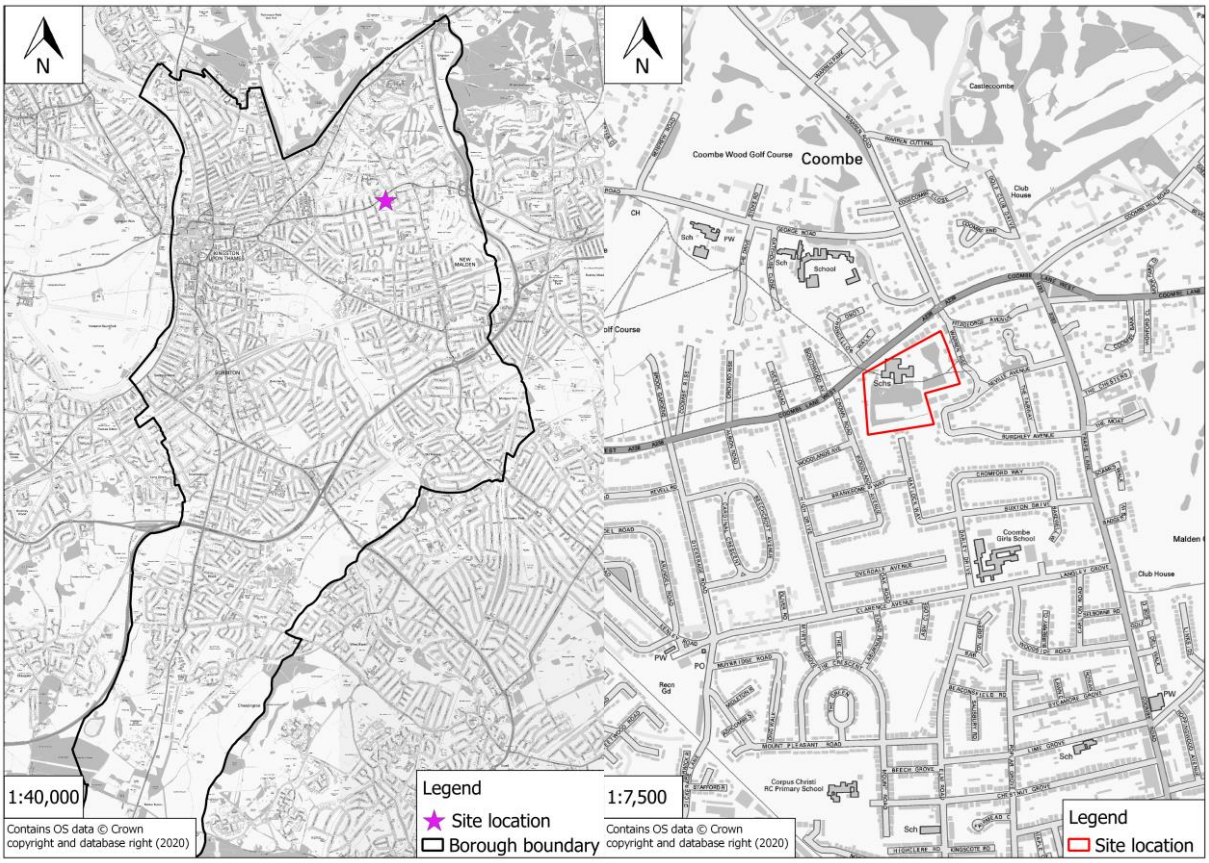

Figure 1.1. Location of Coombe Hill Infant School site

1.3 Methodology

A method was developed and followed to facilitate the flood investigation, enabling consistency with other Kingston Section 19 flood risk investigations. The first step was a data collection exercise to

identify the type of data that was required to inform the flood investigation. The data obtained as part of the exercise is listed in *Table 1.1.*

Table 1.1. Data sources assessed for this flood risk investigation

Data	Source
Rainfall data for historic events	EA
Topography	EA
Watercourse locations	EA / Kingston
Historic flood records	Kingston
OS Master Map	Kingston
Assets significant to flood risk	EA / Kingston / TWUL
Sewer network	TWUL / Kingston
Surface water, fluvial and artificial flood maps	EA
Groundwater information	EA
Geology information	British Geological Survey

The information collected was analysed in a desktop study to identify the flood mechanisms for the local area. The available historical, topographical, drainage, geological and land use data was used to explore how water might end up at the Coombe Hill Infant School site. The data was also used to establish the hydrological catchment and the area's primary overland flow route(s), showing where water flows in the area in relation to the site. The different RMAs were then identified alongside their responsibilities for the different flood risks posed to the Coombe Hill Infant School site. Further information on these can be found in *Chapters 3* and *4*.

Finally, the results of the investigation were compiled and are delivered in this report. Recommendations on flood risk mitigation and potential next steps are provided in *Chapter 5*.

2 FLOOD INCIDENT DETAILS

Coombe Hill Infant School is situated in a topographical low point compared to the land immediately to the north of the site. To the north of the site lies Secondary A superficial and bedrock aquifers. The Coombe Conduit, a historic man-made pipe system which transported water from springs in the Coombe area to Hampton Court Palace, runs underneath the site. This system is no longer operational. A topographical survey conducted in 2014 confirmed that levels on the site slope down from north to south. The highest point on the site is 37.286mAOD and the lowest point is 21.807mAOD, which is a change in level of approximately 15.4mAOD.

Anecdotal evidence from the school's Site Manager describes springs appearing on the site infrequently. In February 2019, the Site Manager reported that this has occurred over several years and was able to be managed. However, in the few months prior to the Site Manager's February 2019 report, large volumes of water were appearing on the play area mulch on the Adventure Playground. This caused the mulch to increase in size and the flow of water to increase quite quickly. Where water was running underneath the play area mulch, it appeared as though the earth was being washed away creating a hollow underneath the Playground. A photograph of the Adventure Playground can be seen in *Figure 2.1*. Hydrological analysis of the six months prior to the flood report being received shows that there have been three storm events which approximate to at least a 1 in 5 year rainfall event (see *Chapter 3.2*).

Figure 2.1 The Adventure Playground at the Coombe Hill Infant School site

3 FLOOD MECHANISMS

3.1 Potential Sources of Flooding

3.1.1 Hydrological catchment

To better understand the potential causes of flooding at Coombe Hill Infant School, the hydrological catchment area was defined. The catchment is an area of land where rain falls and drains towards the same waterbody, flow path or topographical low point. The hydrological catchment was established through an analysis of the wider area's topography. Light Detection and Ranging (LiDAR) data was used to help define the catchment, a surveying method that measures distance to a target by using light and sensors to make 3-D representations of target areas.

Analysis of the area using a Graphic Information System provided several outputs, including defined hydrological catchments and primary flow paths (shown as 'Hydrological Stream' in *Figure 3.1*). The primary flow paths represent the main overland flow routes for surface water in the catchment. These flow paths appear to flow towards the east of the catchment, before combining and flowing into the Coombe Brook which is a tributary of the Beverley Brook. This suggests that rain falling on this catchment drains towards these flow paths. Further hydrological catchment and primary flow path information is presented in *Figure 3.1.*

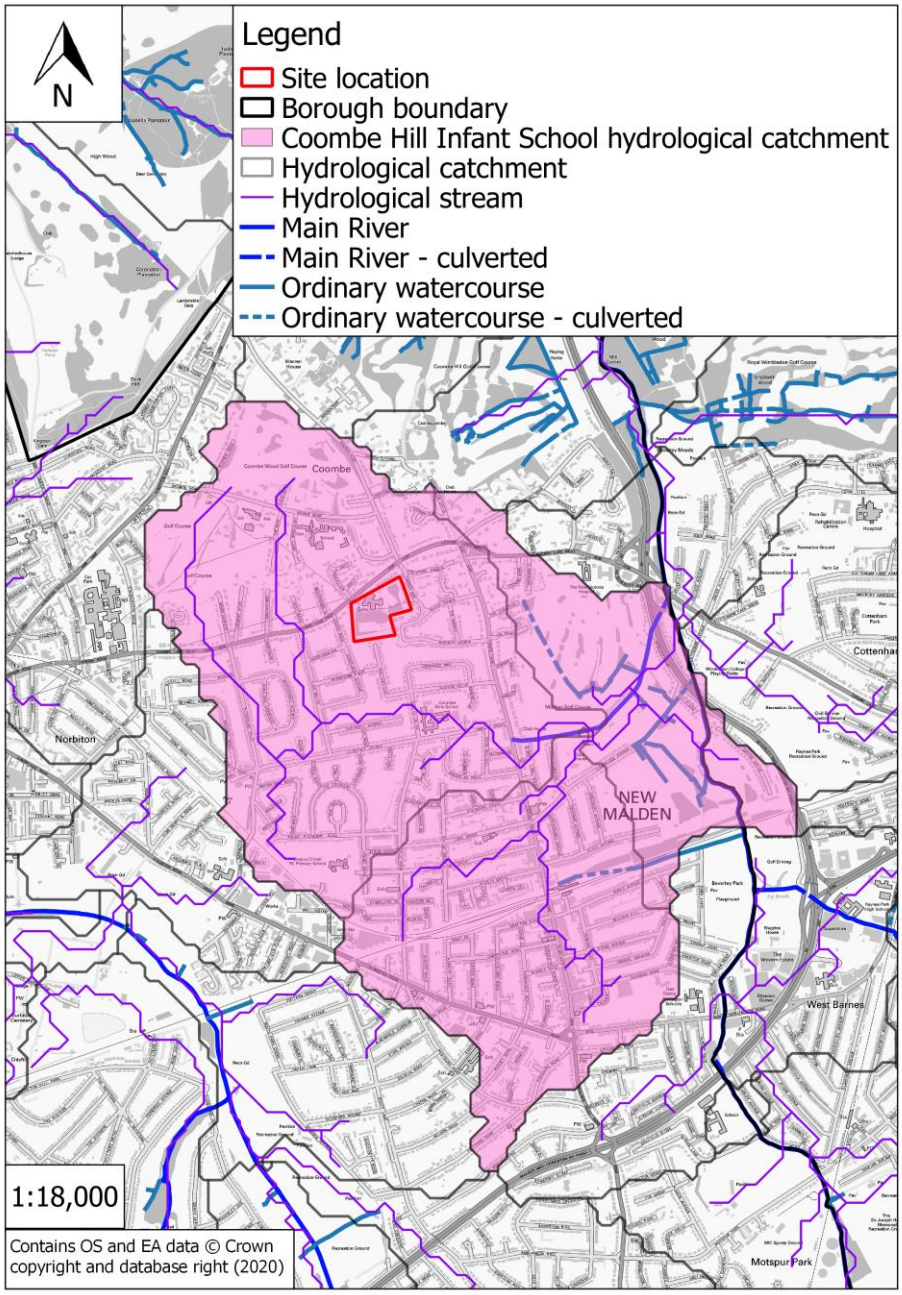

Figure 3.1 Hydrological catchment and primary flow path for Coombe Hill Infant School

3.1.2 Surface water flood risk

Surface water flooding arises due to the accumulation of water on the surface of the ground following heavy or prolonged periods of rainfall. Flooding is exacerbated when surface water cannot be drained away at a sufficient rate by a watercourse, sewer network or via infiltration.

There is a flood record at the Coombe Hill Infant school site in 2007 which was attributed to surface water flooding. No details of the exact location or extent of the flooding are available. Anecdotal evidence suggests that runoff from the main road to the north of the site flows towards the school

buildings. However, the EA's *Risk of Flooding from Surface Water (RoFSW)* online mapping shows the site to be at 'low' to 'very low' risk from surface water flooding. The majority of the site is predicted to be at 'very low' risk of surface water flooding, with some areas close to the school building in the northern part of the site predicted to be at 'low' risk of surface water flooding.

3.1.3 Ordinary watercourse flood risk

Flooding from ordinary watercourses can occur when heavy or prolonged periods of rain or other precipitation causes watercourses to exceed their hydraulic capacity. When watercourses rise above their banks or retaining structures, they can flow on to land and can cause flooding. Flooding from ordinary watercourses is included within the EA's *RoFSW* map. An ordinary watercourse is located along the southern site boundary, which is situated topographically lower than the rest of the school site. Coombe Hill Infant School is not at risk of flooding from ordinary watercourses.

3.1.4 Fluvial flood risk

Similarly to flooding from ordinary watercourses, fluvial flooding can arise as a result of heavy or excessive precipitation causing watercourses to exceed their hydraulic capacity. This source of flooding comes from watercourses that are designated as a Main River by the EA. Coombe Hill Infant School is situated in Flood Zone 1 and therefore is not at risk of fluvial flooding.

3.1.5 Groundwater flood risk

Groundwater flooding occurs when the underground water table rises. In extreme circumstances, water can emerge through the ground and cause flooding. This source of flooding tends to occur after extensive periods of heavy rainfall. The effects can be further exacerbated based on an area's ground composition and the presence of aquifers, which are significant influences on the potential rate of groundwater flooding.

Based on the EA's *Areas Susceptible to Groundwater Flooding* data, Coombe Hill Infant School falls within a '>= 25% <50%' flood risk class. This is shown in *Figure 3.2*. Anecdotal evidence describes infrequent springs appearing at the site. Secondary A superficial and bedrock aquifers are located approximately 225m and 130m to the north of the site, respectively. These are shown in *Figure 3.3*. The bedrock geology at the location of both aquifers is Claygate Member. The bedrock geology is overlain by superficial deposits of Black Park Gravel Member at the location of the superficial aquifer. The geology at the site is London Clay with no superficial deposits. Between the southern extent of the superficial aquifer and the northern boundary of the site (a distance of approximately 225m), the topography reduces by approximately 16m. Between the southern extent of the bedrock aquifer and

the northern boundary of the site (a distance of approximately 130m), the topography reduces by approximately 10m.

Due to the location of the aquifers upstream of the site and the steep topographical change, it is possible that water is travelling below the surface as throughflow towards the site. Throughflow occurs when the geology changes throughout a catchment with the change in topography. The upstream parts of the catchment tend to possess a productive aquifer and/or permeable superficial deposits, which change to unproductive and/or low permeable geology in the downstream parts. The geology in this location changes from a productive aquifer with permeable superficial deposits of Black Park Gravel Member in the upstream part of the catchment, to impermeable London Clay in the downstream part of the catchment. It is likely that there is a groundwater influence on the flooding issues at the Coombe Hill Infant School site.

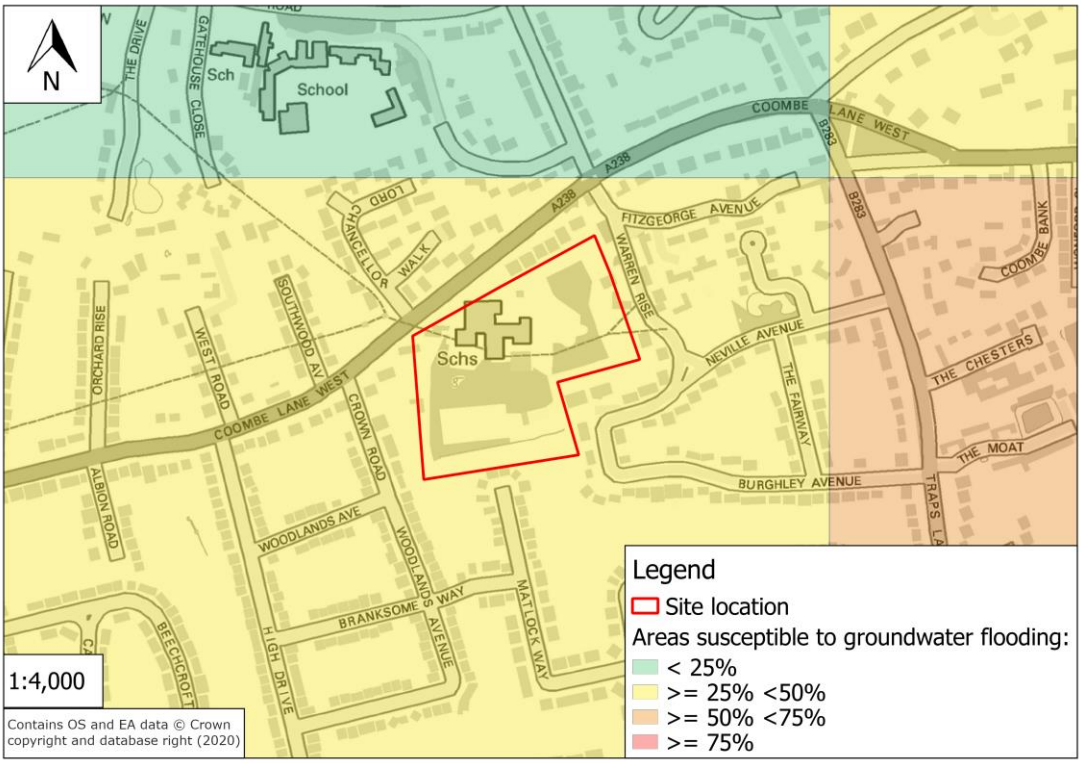

Figure 3.2 Areas susceptible to groundwater flooding

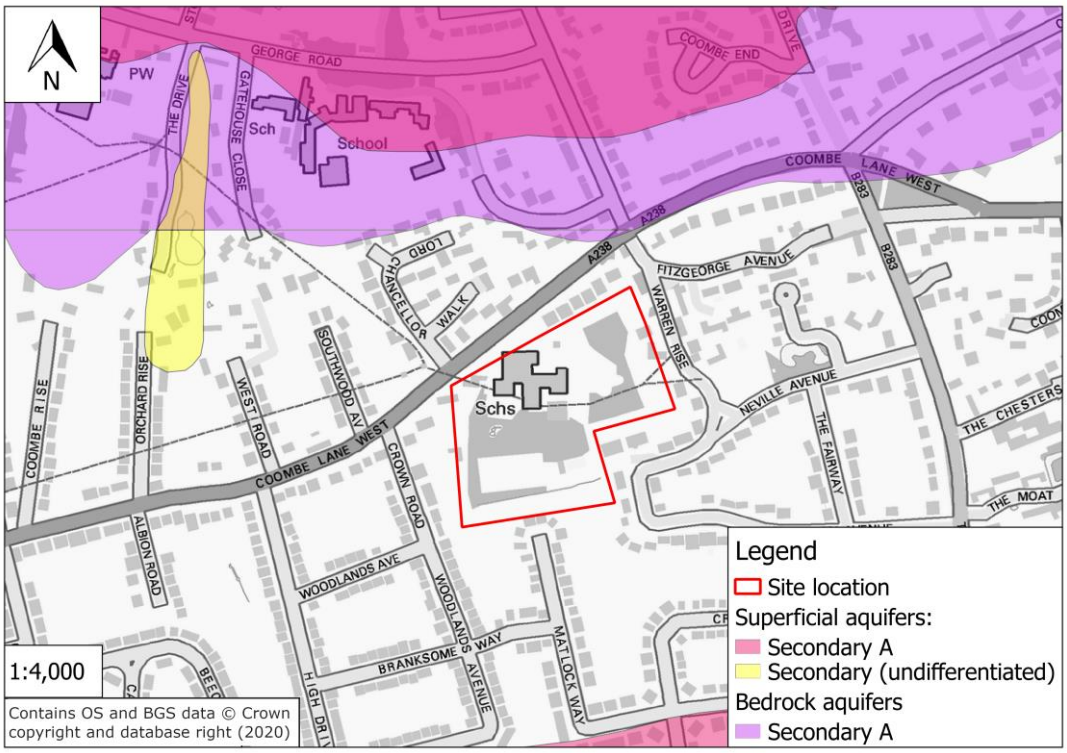

Figure 3.3 Aquifers at the Coombe Hill Infant School site

3.1.6 Sewer flood risk

Sewer flooding can occur as a result of heavy rainfall or precipitation causing an increased flow and volume of water to enter a sewer system. This increase can cause the sewer to exceed its hydraulic capacity, resulting in the system surcharging and flooding over land. In addition, blockages at sewer outfall points can cause water to back up in a sewer system and cause flooding.

Coombe Hill Infant School is served by a private drainage network which is assumed to connect into the Thames Water Utilities Limited (TWUL) surface water network surrounding the site. This information has been sought from the school but this has not been confirmed. There is no historical evidence of surcharging manholes or gullies, and no records of sewer flooding in the vicinity of the site. Coombe Hill Infant School is therefore likely to be at low risk of sewer flooding.

3.1.7 Flood risk from other sources

The Coombe Conduit runs underneath the school buildings. This is a pipe system which historically was used to transport water from springs in the Coombe area to Hampton Court Palace. It is no longer in operation, however there is a possibility that groundwater may be able to enter the remaining pipe work. Building work which took place at the school in 2015 may have altered any sub surface flows associated with the Coombe Conduit, potentially placing the site at greater risk of flooding from the

system. The approximate location of extensions to the school building in relation to the Coombe Conduit are shown in Figure 3.4.

The EA's *Risk of Flooding from Reservoirs* map shows that the site is not at risk of flooding from reservoirs.

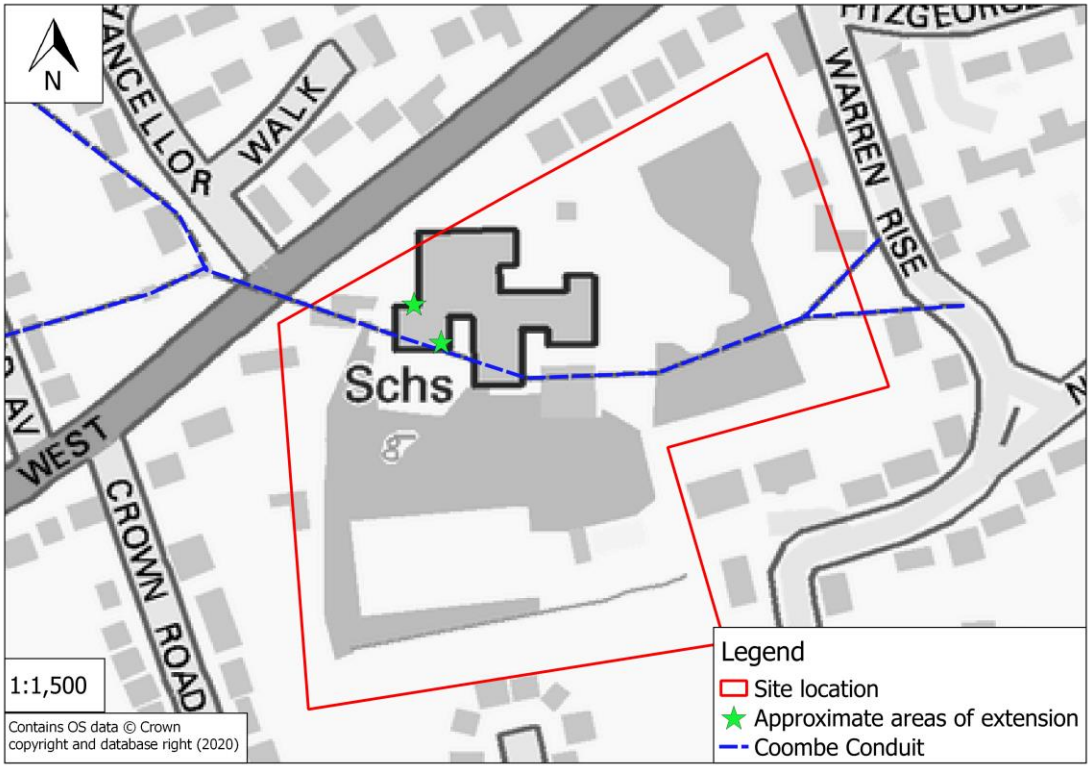

Figure 3.4 Approximate areas of building extension and Coombe Conduit

3.2 Rain gauge data

Rainfall data from a Tipping Bucket Raingauge (TBR) at Putney Heath was used to assess the reported rainfall event which resulted in flooding at the site. This is located approximately 5km north from Coombe Hill Infant School in the London Borough of Wandsworth (see *Figure 3.5* for approximate location). A TBR at the River Hogsmill lies within the Royal Borough of Kingston upon Thames and is located approximately 2km south west of the site. The recorded peak daily rainfall between the sites is comparable (both TBRs recorded similar amounts of rainfall on the three peak rainfall days in the six months prior to the flood event). Sometimes the Putney Heath TBR recorded a slightly higher amount in a day, other times it was the River Hogsmill TBR. The Putney Heath TBR was used in this instance.

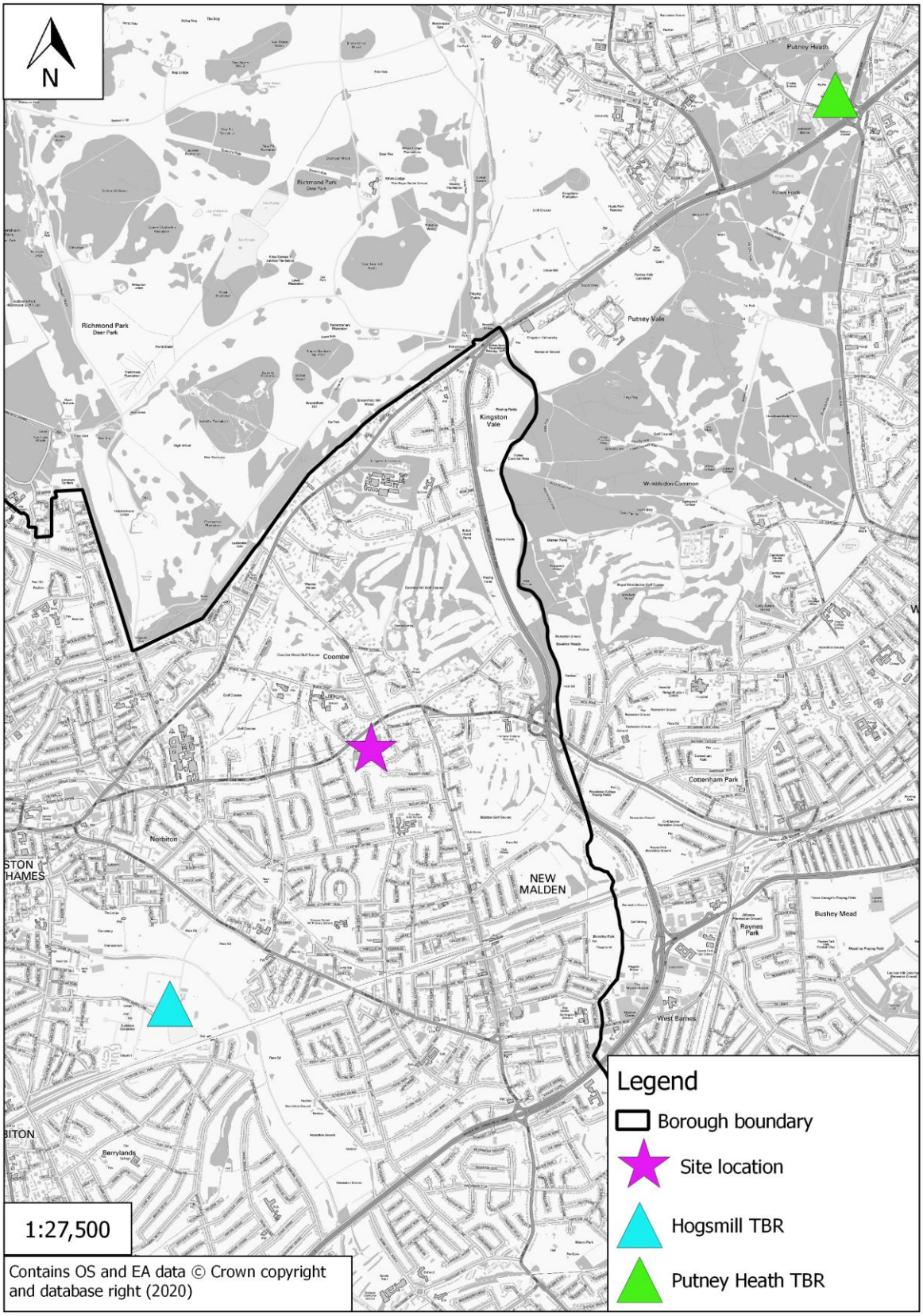

Figure 3.5 Location of the Putney Heath and Hogsmill TBRs

The data analysed from the Putney Heath TBR shows the variation in rainfall over a 24 hour period for three rainfall separate rainfall events. The Site Manager had confirmed that frequent flood issues over recent years had occurred leading up to the February 2019 flood event. Because the exact date of the flood events had not been recorded, three rainfall events were chosen between August 2018 to February 2019. The dates selected represent the heaviest recorded rainfall events over this period. No events from February 2019 were selected (the date of the flood event) because there were no days where the daily rainfall exceeded 8mm. The data recorded at the TBR provides accumulated totals for each 15-minute period. *Table 3.1* provides a summary of the three rainfall events investigated as part of this study. Rainfall event specific details on rainfall variation are shown in *Figure 3.6*, *Figure 3.7*, and *Figure 3.8*.

Table 3.1. Summary of Rainfall Events

Rainfall Event	First Significant Rainfall Period	First Recorded Peak (mm)	Peak Time	Second Significant Rainfall Period	Second Recorded Peak (mm)	Peak Time
August 2018	00:00 to 10:15 GMT on 16th August	2.46	10:00	10:15 to 15:00 GMT on 16th August	1.43	10:45
October 2018	00:00 to 12:00 GMT on 14th October	1.49	05:49	20:30 to 23:45 GMT on 14th October	2.88	23:15
November 2018	00:00 to 04:30 GMT on 10h November	1.85	02:45	14:30 to 19:30 GMT on 10th November	2.82	15:15

The data for the 2018 events indicates that the peak rainfall return period for the three flood events approximates to a 1 in 5 year event (20% probability of a rainfall of that intensity occurring in a given year). As highlighted in *Chapter 2*, Coombe Hill Infant School is situated in a topographical low point compared to the land immediately to the north of the site. In addition, anecdotal evidence suggests that runoff from the main road flows towards the school buildings in the north of the site. Further anecdotal evidence states that large volumes of water were appearing on the play area mulch on the Adventure Playground. This caused the mulch to increase in size and the flow of water to increase quite quickly. Based on the identified flood risk sources and the nature of flooding that has occurred on the site, it is possible that the flood events are greater than 1 in 5 year events.

The TBR result for the reviewed events have been labelled as “good and complete” by the EA. This means that the TBR was operational during the event to accurately record rainfall depth. Further information on the rainfall return period estimations can be found in *Appendix A*.

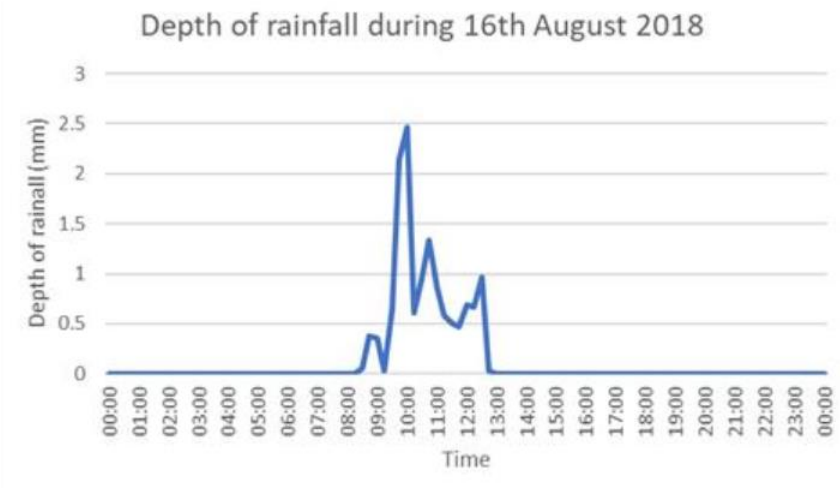

Figure 3.6 Rainfall depth on 16th August 2018

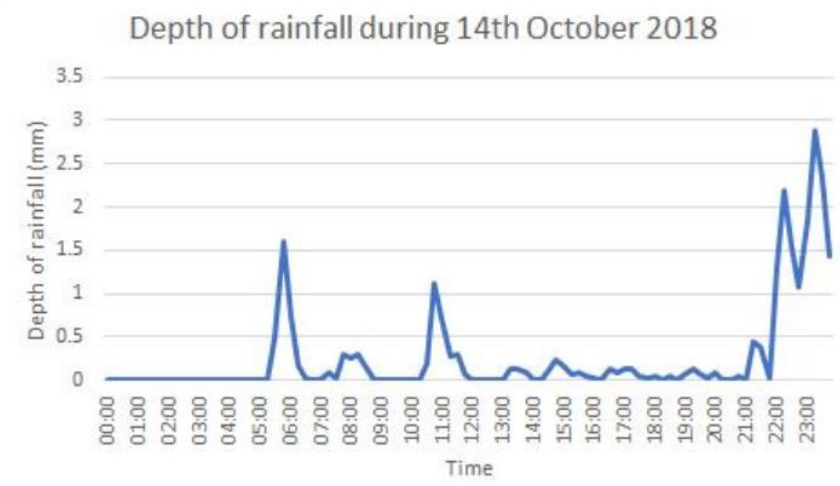

Figure 3.7 Rainfall depth on 14th October 2018

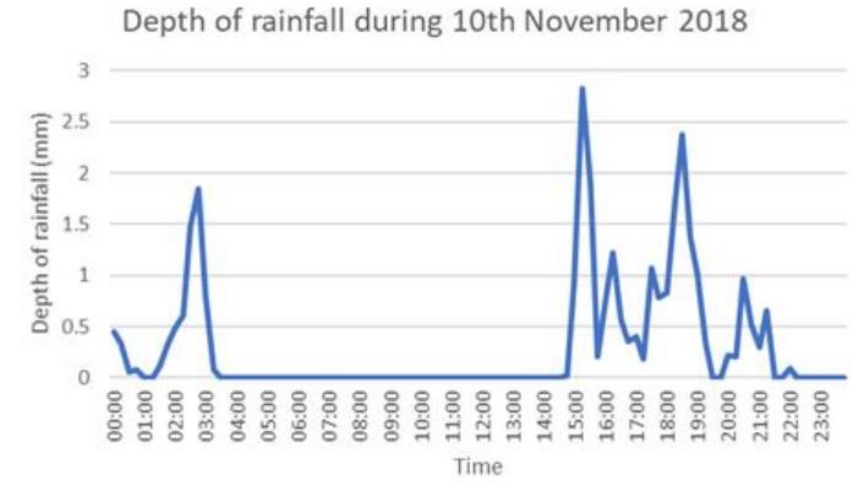

Figure 3.8 Rainfall depth on 10th November 2018

4 Risk Management Authorities

As per *Chapter 1.1*, there are several RMAs who are responsible for managing the potential risks posed by flooding. *Table 4.1* lists them at a borough level, with further information provided in *Chapters 4.1* to *4.5*.

Table 4.1. Borough level Risk Management Authorities

Risk Management Authorities	Authority	Risk management responsibilities
EA	EA	Main Rivers and reservoirs
LLFA	Kingston	Surface water, ordinary watercourse, and groundwater sources
Water and sewerage company	TWUL	Surface water and foul / combined sewer systems
Highway Authority	Kingston	Highway drainage
Highway Authority	TfL	Highway drainage

4.1 Environment Agency

4.1.1 Responsibilities

The EA are the lead RMA in managing flood risk from designated Main Rivers and reservoirs in the borough. They have a range of different powers and responsibilities including surveying, maintenance and improvement works to Main Rivers and the sea relating to flood and coastal erosion risk management. The EA plays a key role in advising planning authorities on the implications that proposed developments may have on flood risk, providing and operating flood warning systems, and improving the environment.

The identified flood risk sources for Coombe Hill Infant School are not from fluvial or reservoir sources. The EA therefore do not have direct responsibilities as an RMA to manage flood risk for the site.

4.1.2 Authority Contributing Action to Flood Event

As an RMA that does not have direct responsibilities for managing groundwater related flood risk, the EA have not carried out any actions in response to flood risk at Coombe Hill Infant School.

4.2 Royal Borough of Kingston upon Thames

4.2.1 Responsibilities

Kingston has different RMA roles as an LLFA, a Highway Authority and a landowner. As a unitary authority LLFA, Kingston has the lead responsibility for managing flood risk from surface water, ordinary watercourse, and groundwater sources. They are responsible for:

- Developing, applying, maintaining, and monitoring local flood risk management strategies.
- Maintaining a register of structures and features that have a significant effect on flood risk.

- Preparing and maintaining preliminary flood risk assessments, flood hazard maps, flood risk maps and flood risk management plans.
- Reviewing and consulting on surface water management plans for major developments.
- Undertaking Section 19 flood risk investigations as per the FWMA 2010.

Other RMAs have a duty to cooperate with LLFAs where necessary to undertake the above responsibilities. Kingston can also carry out work to help alleviate surface water, groundwater, and ordinary watercourse flooding in collaboration with other RMAs. Under the powers granted to them, Kingston can make by-laws to ensure that flood risk is properly managed.

As a Highway Authority, Kingston are responsible for providing and managing highway drainage that is not managed by Transport for London (TfL) or Highways England. Part of their responsibility is to carry out routine works such as gully cleansing to reduce the wider flood risk that may be presented from highways.

4.2.2 Authority Contributing Action to Flood Event

Before

No known actions were taken by Kingston before the flood event.

During

No known actions were taken by Kingston during the flood event.

After

Kingston conducted a site visit in February 2019 following a report of a flooding issue at the school playground. Kingston concluded that a survey (a land and structural survey) was needed. It is unknown if a survey has been carried out. A further site visit by the LLFA was carried out in November 2019. Previous flooding issues and the potential incorporation of sustainable drainage systems (SuDS) on the site were discussed.

4.3 Thames Water Utilities Limited

4.3.1 Responsibilities

TWUL is the water and sewerage company responsible for managing public surface water, foul, and combined sewer systems. They are responsible for any maintenance and repair work on their drainage assets. Coombe Hill Infant School is served by separate TWUL surface water and foul sewer networks.

When there are wet winters and high groundwater levels, TWUL investigate where the water may be forcing its way into the sewer network. TWUL use CCTV, Impermeable Area Surveys, flow monitors, and manhole surveys to identify problem areas. TWUL may also investigate potential flood impacts if a report has been submitted in writing to highlight internal property flooding.

The likelihood of the flooding at Coombe Hill Infant School coming from sewer flood sources is low because of the groundwater-related impacts described in *Chapter 3.1.5*. Although there are no records of how the site's private sewer network connects with the TWUL public sewer system, there is no evidence to suggest that the flooding was caused by any public or private sewer network failure or influence.

4.3.2 Authority Contributing Action to Flood Event

TWUL are not responsible for managing groundwater related flood risk and therefore have not taken any actions in response to flood risk at Coombe Hill Infant School.

4.4 Landowners

4.4.1 Responsibilities

Landowners have the primary responsibility of safeguarding their own land and property against flooding. Under common law they are also required to ensure that they do not use their property in a way that increases the risk of flooding to a neighbouring property. Common law also enables landowners to take reasonable measures to protect their property from flooding, provided the measures do not cause harm to others.

As a landowner, Kingston have a responsibility to safeguard their own land and property against flooding. Common law also requires that they do not increase the risk of flooding to a neighbouring property through carrying out tasks such as gully clearing and maintaining any existing flood defences. Kingston is the landowner of the Coombe Hill Infant School site.

4.4.2 Authority Contributing Action to Flood Event

The Site Manager was present at two site visits with Kingston staff, one with the Health and Safety officer and one with the LLFA.

4.5 Other Authorities

4.5.1 Transport for London

The roads surrounding Coombe Hill Infant School are not on TfL's highway network and do not fall within the same hydrological catchment as a TfL managed highway. TfL do not have responsibilities as an RMA to provide or manage drainage for the site.

4.5.2 Category One Responders

Blue light emergency services are categorised as Category One Responders under the Civil Contingencies Act (2004). They are organisations at the core of responding to most emergencies. Services such as the Metropolitan Police Service and the London Fire Brigade are the most relevant

responders with regards to flood incidents. None of the anecdotal evidence received from the School's site manager suggested that the flooding necessitated any response from a Category One Responder.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This flood risk investigation for Coombe Hill Infant School was triggered due to the number of reported flooding incidents that have occurred at the site. The first report was received in 2007, and the second in February 2019. The February 2019 report stated that the school had been experiencing a flooding problem over a period of several months.

The data collection and investigation exercises established that the site is potentially at risk of groundwater influenced flooding via throughflow. A catchment analysis provided hydrological catchment outputs for the site. The defined catchment shows that Coombe Hill Infant School falls within the same catchment as the superficial and bedrock aquifers to the north of the site.

From the investigations, it is concluded that the flood risk at the site is exacerbated due to several potential factors, including:

- The steep difference in topography between the aquifers and the site.
- The change in geology from a productive aquifer/permeable superficial deposits (Black Park Gravel Member) upstream of the site, to unproductive/low permeable geology (London Clay) at the site itself.
- Building work carried out at the site which may have altered sub-surface flows associated with the Coombe Conduit.

The RMA who is responsible for managing the potential risks posed by flooding to the Coombe Hill Infant School site is Kingston (as the landowner). To date, Kingston carried out two site visits to the school, one in February 2019 (the H&S officer) and one in November 2019 (the LLFA). The actions carried out by Kingston align with their roles and responsibilities. Recommendations for further actions are outlined in *Chapter 5.2.*

5.2 Recommendations

Following the flood risk investigation carried out for Coombe Hill Infant School, it is recommended that the following actions are carried out:

- The LLFA should continue to work with the school to better understand the extent of the flooding incident, the actions they have taken since the incident, and the site's private surface water drainage network.

- The LLFA should find out whether the recommended land and structural survey at the site was carried out, and what the results of this were.
- The LLFA should investigate mitigation measures such as SuDS which can be incorporated on the site to reduce the risk of flooding.
- The LLFA should investigate who the owner of the Coombe Conduit is and who maintains it. They should also arrange for a survey of the Coombe Conduit to be conducted and determine what impact this has on sub surface flows on the school site.
- For any future development at the school, Kingston's Planning team should work with Kingston's Education team to ensure that developers undertake any necessary investigations to understand the relationship between sub surface flows and potential flooding at the site. If necessary, these investigations should include mitigation measures to reduce the risk of further groundwater influenced flooding to the site.

APPENDICES

Appendix A – Rainfall Return Period Estimations

Rainfall Return Period Estimations

Time of Concentration - Kerby Method

$$t_c = 0.83\left(\frac{Ln}{S^{0.5}}\right)^{0.467}$$

Where:

L = Length of overland flow (ft, m)
S = Average catchment slope (ft/ft, m/m)
n = Retardance Roughness
Smooth pavement 0.02
Poor grass, bare soil 0.30
Average grass 0.40
Dense grass 0.80

n =	**0.15**
Top of catchment to School =	**23.61**
Length of overland flow =	**1000**
Slope =	**0.02361**

Tc to Coombe Hill School (min) = **20.66**

For a critical duration period of 15 minutes (Coombe Hill School FEH)						
Minute	5 Year	10 Year	20 Year	30 Year	40 Year	100 Year
1	17.20	22.20	28.37	32.66	36.07	49.39
2	18.91	24.41	31.19	35.91	39.66	54.31
3	21.54	27.81	35.53	40.91	45.18	61.87
4	25.86	33.39	42.65	49.11	54.24	74.27
5	34.32	44.31	56.60	65.17	71.98	98.56
6	58.81	75.91	96.98	111.66	123.32	168.87
7	116.39	150.24	191.94	220.98	244.07	334.22
8	180.63	233.18	297.90	342.98	378.80	518.73
9	116.39	150.24	191.94	220.99	244.07	334.23
10	58.81	75.91	96.98	111.66	123.32	168.87
11	34.32	44.31	56.60	65.17	71.98	98.56
12	25.86	33.39	42.65	49.11	54.24	74.27
13	21.54	27.81	35.53	40.91	45.18	61.87
14	18.91	24.41	31.19	35.91	39.66	54.31
15	17.20	22.20	28.37	32.66	36.07	49.39
Mean rainfall over the 15 minute period (mm/hr)	**51.11**	**65.98**	**84.30**	**97.05**	**107.19**	**146.78**

For a critical duration period of 30 minutes (Coombe Hill School FEH)						
Minute	5 Year	10 Year	20 Year	30 Year	40 Year	100 Year
1	10.30	13.13	16.57	18.95	20.83	28.09
2	10.83	13.81	17.43	19.93	21.91	29.54
3	11.37	14.49	18.29	20.92	22.99	31.00
4	11.87	15.13	19.10	21.84	24.00	32.37
5	12.72	16.21	20.47	23.40	25.72	34.68
6	13.75	17.53	22.13	25.31	27.81	37.51
7	15.07	19.21	24.25	27.73	30.48	41.11
8	16.70	21.30	26.88	30.74	33.78	45.56
9	19.00	24.22	30.57	34.96	38.42	51.81
10	23.17	29.54	37.29	42.64	46.87	63.20
11	30.08	38.35	48.41	55.35	60.84	82.04
12	42.17	53.76	67.86	77.60	85.28	115.01
13	60.47	77.10	97.32	111.28	122.31	164.93
14	82.52	105.20	132.80	151.84	166.89	225.05
15	110.96	141.47	178.58	204.19	224.42	302.64
16	110.96	141.47	178.58	204.19	224.42	302.64
17	82.52	105.20	132.80	151.84	166.89	225.05
18	60.47	77.10	97.32	111.28	122.31	164.93
19	42.17	53.76	67.86	77.60	85.28	115.01
20	30.08	38.35	48.41	55.35	60.84	82.04
21	23.17	29.54	37.29	42.64	46.87	63.20
22	19.00	24.22	30.57	34.96	38.42	51.81
23	16.70	21.30	26.88	30.74	33.78	45.56
24	15.07	19.21	24.25	27.73	30.48	41.11
25	13.75	17.53	22.13	25.31	27.81	37.51
26	12.72	16.21	20.47	23.40	25.72	34.68
27	11.87	15.13	19.10	21.84	24.00	32.37
28	11.37	14.49	18.29	20.92	22.99	31.00
29	10.83	13.81	17.43	19.93	21.91	29.54
30	10.30	13.13	16.57	18.95	20.83	28.09
Mean rainfall over peak 15 minute period (mm/hr)	**50.23**	**64.04**	**80.84**	**92.43**	**101.59**	**136.99**

Mean of the means	50.67	65.01	82.57	94.74	104.39	141.89
Depth in a 15 minute period	**12.67**	**16.25**	**20.64**	**23.68**	**26.10**	**35.47**

Rainfail TBR Data (Every 15 Minutes)
August 2018 Peak Rainfall Gauge Depth (mm) = **2.46**

Therefore:
August 2018 Event (Approximately) = **under 1 in 5 Year**

Rainfall TBR Data (Every 15 Minutes)
October 2018 Peak Rainfall Gauge Depth (mm) = **2.88**

Therefore:
October 2018 Event (Approximately) = **under 1 in 5 Year**

Rainfall TBR Data (Every 15 Minutes)
November 2018 Peak Rainfall Gauge Depth (mm) = **2.82**

Therefore:
Novemeber 2018 Event (Approximately) = **under 1 in 5 Year**