1MC04 Main Works - Contract Lot S2

Drainage Report - Ruislip Golf Course S2

MDL Code:

Document no.: 1MC04-SCJ-DR-REP-SS05_SL07-000003

Rev	Author	Checked by	Approved by		Date approved	Reason for revision
C01	Vicente Balanza	Noemí Guerrero	Mark Gaby	Richard Patten	23/11/18	For acceptance
C02	Vicente Balanza	Noemí Guerrero	Mark Gaby	Richard Patten	28/02/2019	For acceptance
C03	Vicente Balanza	Noemí Guerrero	Mark Gaby	Richard Patten	28/10/2019	For acceptance
C04	Vicente Balanza Elena Cabo	Noemí Guerrero	Isobel Byrne Hill	Richard Patten	01/04/2020	For acceptance
C05	Vicente Balanza Elena Cabo	Noemí Guerrero	Isobel Byrne Hill	Christiane Hof	23/06/2020	For acceptance

SECURITY CLASSIFICATION: OFFICIAL

Handling instructions: None

Revisions:

Revision	Author	Checked by	Approved by		Date approved	Reason for revision	Changes track
C01	Vicente Balanzá	Noemí Guerrero	Mark Gaby	Richard Patten	23/11/18	For information	
C02	Vicente Balanzá	Noemí Guerrero	Mark Gaby	Richard Patten	28/02/2019	For acceptance	
C03	Vicente Balanzá	Noemí Guerrero	Mark Gaby	Richard Patten	28/10/2019	For acceptance	Section 4.1.1 and 5.1.1: replaced "lines" by other terms
C04	Vicente Balanzá Elena Cabo	Noemí Guerrero	Isobel Byrne Hill	Richard Patten	01/04/2020	For acceptance	Included new item in the section 5.1.1, which explains the connection between HS2 drainage system and that from the Golf Course Included new line in the Table 18 which explains the connection between HS2 drainage system and that from the Golf Course Included new comment in section 8.1.1 introducing the connection between HS2 drainage system and the that from the Golf Course Included new table (current table) as a summary of the changes made in the document Amended the text of section 7.1.1, now it mentions the FRA document
C05	Vicente Balanzá Elena Cabo	Noemí Guerrero	Isobel Byrne Hill	Richard Patten	23/06/2020	For acceptance	Water storage volumes in tanks have been reduced to 1/3. The irrigation guarantee of 100 days has been removed (Table 19, 5.2.18, 5.2.20).

							It is not dismissed the water from the borehole for irrigation purposes (5.1.1 point 2, 5.2.22, 8.1.5). Run off attenuation is a side effect of the resultant volumes of the water harvesting system and the landscape design. (5.1.1 point 3, 5.2.7, 5.2.15, 5.2.21, 5.2.23, 5.2.24, 5.2.25, 5.2.26, 5.2.27,5.3.1 (removed), 6.1.3, 6.1.4; 6.1.6, 8.1.6). The HS2 drainage system discharges over the 1 in 1,000 yr event flooding (5.1.1 point 5). It is clarified that the blockage of the Ickenham Stream under the CML will be assessed in the corresponding HS2 assets (3.1.6, 4.3.8, 6.1.8).

Contents

1 Introduction

1.1 Background to the proposed development

1.1.1 This Drainage Report is prepared by Skanska Costain Strabag (SCS JV) on behalf of High Speed Two Ltd. (the applicant), to support the planning application for Ruislip Golf Course, London.

1.1.2 Ruislip Golf Course is a municipal golf course, owned and operated by the London Borough of Hillingdon (LB Hillingdon). It falls partially within the alignment of the HS2 development. The High Speed Rail (London-West Midlands) Act 2017 (the HS2 Act), which gained Royal Assent in February 2017, conferred the necessary powers required to construct Phase One of the railway from London Euston to Birmingham Curzon Street. The southern part of Ruislip Golf Course falls within this boundary.

1.1.3 Construction of HS2 will result in land take from Ruislip Golf Course. The applicant has committed to designing and delivering a reconfigured golf course as part of a number of Undertakings and Assurances (U&A) that were agreed with LB Hillingdon (and which eventually formed part of the Hillingdon Agreement) during the passage of the Hybrid Bill through parliament.

1.2 Site location

1.2.1 The application site is in west London within LB Hillingdon. The application site comprises the majority of the existing golf course, the area of which is 36 hectares. The southern part of the existing golf course is acquired for HS2 railway works and is not included in the application boundary.

1.2.2 It is located to the north of West Ruislip Station, and is bounded: to the north and north-east by the Glenhurst Avenue allotments and Hill Lane playground and the rear curtilages of residential properties on Field Way and Hill Rise; to the east and south-east by the rear curtilages of residential properties on Sharps Lane, Ickenham Road and Harwell Close; to the south-west and the far south-east by the boundary of the HS2 development; and to the west and north-west by the River Pinn.

1.3 Description of development

1.3.1 This application is for the redevelopment of the existing 18 hole Ruislip Golf Course to provide a nine hole golf course and six hole academy course, the creation of a new channel for the Ickenham Stream (canal feeder), and the demolition and replacement of the driving range with a new 20 bay driving range and the construction of a single storey rifle range.

1.3.2 The description of development is as follows:

1.3.3 *Full application for remodelling of Ruislip Golf Course, incorporating: reconfiguration of 18 existing hole course into a nine hole course, short game practice area, putting green and six hole academy course; construction of a single storey rifle range; demolition of existing covered driving bays and construction of replacement 20 bay driving range, including associated floodlights and safety netting; a new drainage system and associated ponds; ecological and landscaping works; realignment and enhancement of the Hillingdon Trail and creation of a new public footpath; excavation of a new channel for the Ickenham Stream (canal feeder); and other associated works.*

1.4 Purpose of this document

1.4.1 The purpose of this document is to describe the designed drainage network for the remodelled golf course. It also sets out, a hydrological assessment of the golf course catchment.

1.4.2 This document is structured as follows:

- Chapter1: introduces the scheme;
- Chapter 2: defines the abbreviations used in the document;
- Chapter 3: provides a hydrological assessment of the application site catchment;
- Chapter 4: describes the existing drainage network;
- Chapter 5: describes the proposed drainage network;
- Chapter 6: compares the existing and proposed drainage networks;
- Chapter 7: explains how the drainage design affects flood risk in the application site;
- Chapter 8: summarises the findings of this document;
- Chapter 9: sets out references and standard forms; and
- Chapter 10: lists the appendices.

2 Definitions and Abbreviations

Abbreviation	Definition
ARF	Areal reduction factor
BF	Baseflow
BF_o	Initial baseflow
BL	Baseflow recession constant (or lag)
BR	Baseflow recharge
CC	Climate Change
C_{ini}	Initial soil moisture content
C_{max}	Maximum soil moisture capacity
CML	Chiltern Mainline
D	Duration of rainfall event
DDF	Depth-duration-frequency
DEM	Digital Elevation Model
DPLBAR	Mean drainage path length
DPSBAR	Mean drainage path slope
EA	Environmental Agency
FEH	Flood Estimation Handbook
FRA	Flood Risk Assessment
FSR	Flood Studies Report
HOST	Hydrology of Soil Types
GIS	Geographic Information System
PROPWET	Proportion of time when SMD < 6mm
Q	Flow
HS2	High Speed Two
IH124	The Institute of Hydrology Report 124
LIDAR	Light Detection and Ranging
LLFA	Lead Local Flood Authority
ReFH	Revitalised flood hydrograph model
SCS JV	Skanska Costain Strabag Joint Venture

Abbreviation	Definition
SuDS	Sustainable Drainage Systems
T	Return period
T_p	Unit hydrograph time to peak
TS	Technical Standard

3 Hydrology Assessment

3.1 Description of the catchment

3.1.1 The application site is within a drainage catchment area of 55.4ha as illustrated in Figure 1. The boundary of the catchment area closely aligns with the application site boundary. However, some residential areas located to the north-east and to the east of the application site drain to it from outside its limits. Although most of the catchment is quite flat, it mainly drains to the north (to the River Pinn) through the channels which form part of the existing golf course drainage system.

Figure 1 - Application site catchment area

3.1.2 The Ickenham Stream crosses the application site from the north-east to the south and leaves the application site through a culvert beneath the Chiltern Mainline (CML). The Ickenham Stream was originally constructed as a feeder for the Grand Union Canal from the Ruislip Lido reservoir. The Ickenham Stream is classified as a Lead Local Flood Authority (LLFA) 'Ordinary Watercourse' as far south as the existing railway track, downstream of which the watercourse is an Environmental Agency (EA) classified 'Main River', as illustrated in Figure 2. However, there is no significant water flow under the culvert to the south of the application site. Therefore, the CML is considered the current boundary between the catchments of the River

Pinn and the section of the Ickenham Stream classified as 'Main River', which joins downstream to the Yeading Brook western arm.

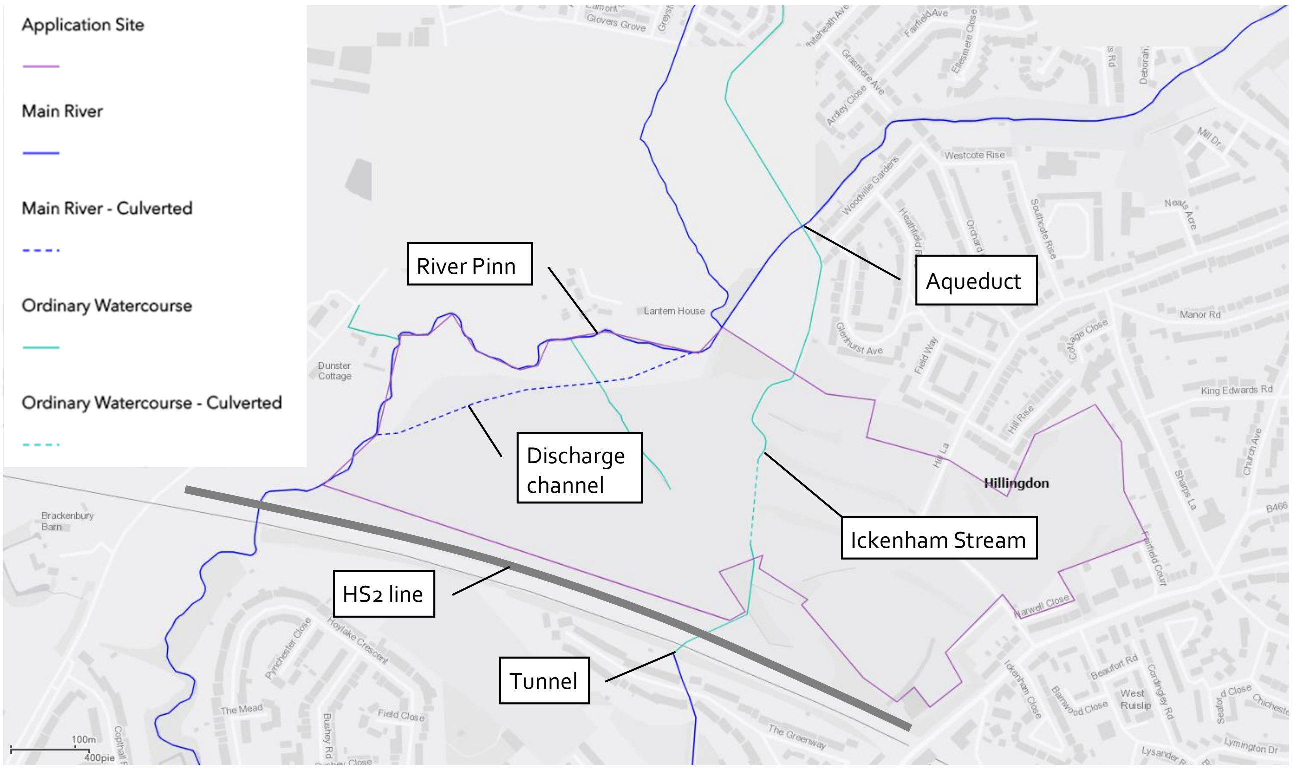


Figure 2 - EA River classifications

3.1.3 The Ickenham Stream is carried over the River Pinn on an aqueduct close to Woodville Gardens. As it crosses the application site it is intercepted by several channels which drain to the River Pinn. The Ickenham Stream channel is also interrupted in several points between the aqueduct and the northern edge of the application site. Once the Ickenham Stream enters the centre of the application site, it is connected to the channels which form part of the existing golf course drainage infrastructure.

3.1.4 The Ickenham Stream cannot be considered as a continuous channel between the aqueduct and the culvert under the CML. It locally intercepts the surface runoff along its route through the application site, but it does not run the drained water to the south of the CML. Although the culvert beneath the CML is connected to the channels of the golf course drainage, these channels mainly drain to the north according to the ground elevations.

3.1.5 Figure 3 illustrates how the application site catchment currently operates from a hydrological-hydraulic point of view, according to the detailed digital elevation model (DEM) made for the HS2 development and several visits to the site.

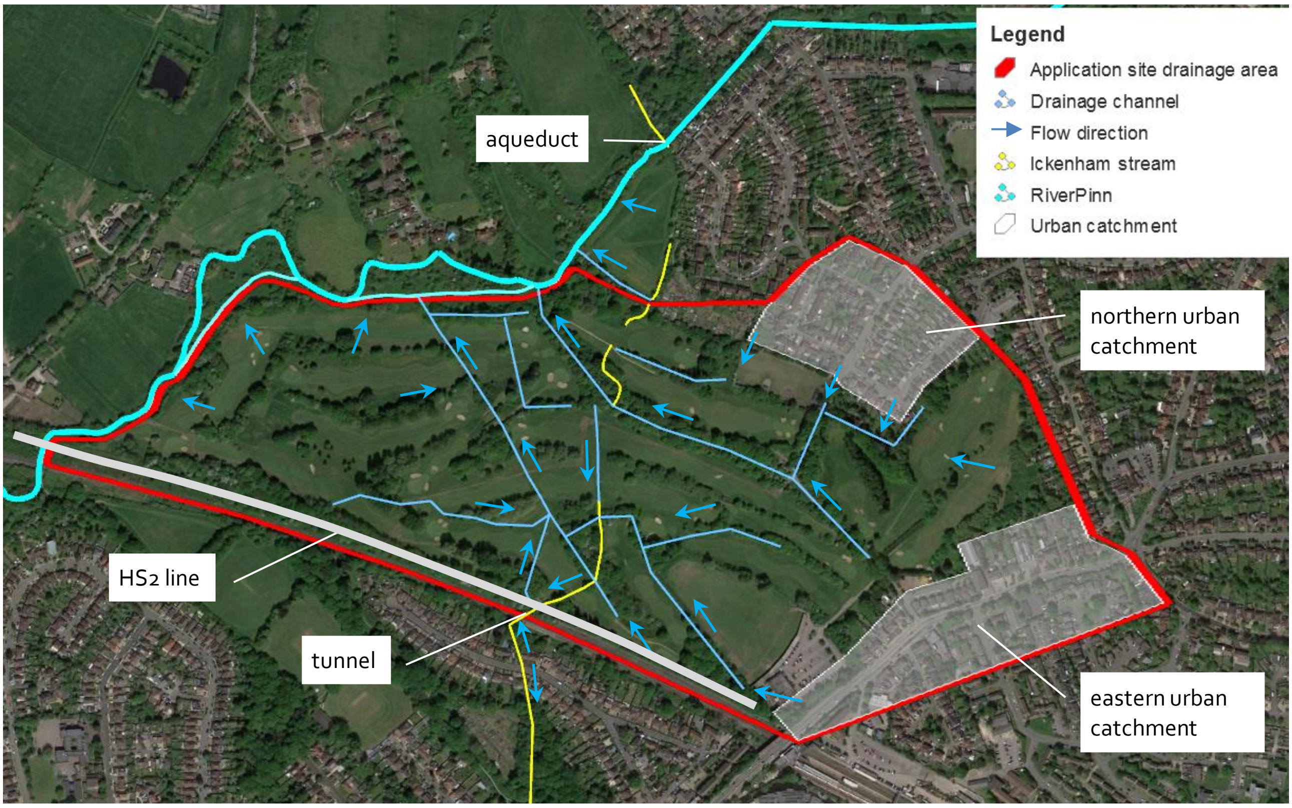


Figure 3 - Hydrological-hydraulic operation of catchment

3.1.6 The Ickenham Stream flow path under the CML will be blocked because of the HS2 development. As discussed in Section 4, there will be a negligible change in the local contributing catchments to the north of the CML and consequently no significant alteration of the water flows within the application site. However, this blockage could locally affect to the drainage of the small sub-catchment to the south of the CML which is outside of the application site boundaries. The effect of the blockage of the Ickenham Stream by the HS2 scheme will be assessed in the corresponding HS2 asset (West Ruislip Portal). At this moment, the drainage solution for this catchment to the south of the CML is work in progress.

3.2 Catchment demarcation

3.2.1 Catchment boundaries have been obtained based on the following information:

- HS2 LIDAR, cell size 0.20 m;
- Environmental Agency LIDAR, cell size 1.0 m;
- SCS JV utilities map: Thames Water sewer network; and
- Site visits.

3.2.2 ArcMap software within the terrain processing module has been used to demarcate catchments boundaries and drainage flow paths. Resulting drawings have been checked and, when necessary, corrected in order to make them coherent with the DEM data and other information sources.

3.2.3 The application site catchment area is 55.4ha. As Figure 4 illustrates, this catchment has been divided into three sub-catchments, depending on the discharge points to the River Pinn:

- Sub-catchments SC1 and SC2 drain to the River Pinn through an existing secondary channel (discharge channel). The sum of the area of both sub-catchments is 50.9ha;
- Sub-catchment SC3 drains along the left bank of the River Pinn without a defined watercourse. The area of this sub-catchment is 4.5ha; and
- Sub-catchment SC4, it comprises the area located to the south of the Chiltern Mainline and to the north of the Greenway Road which partially drains to the north, to the application site.

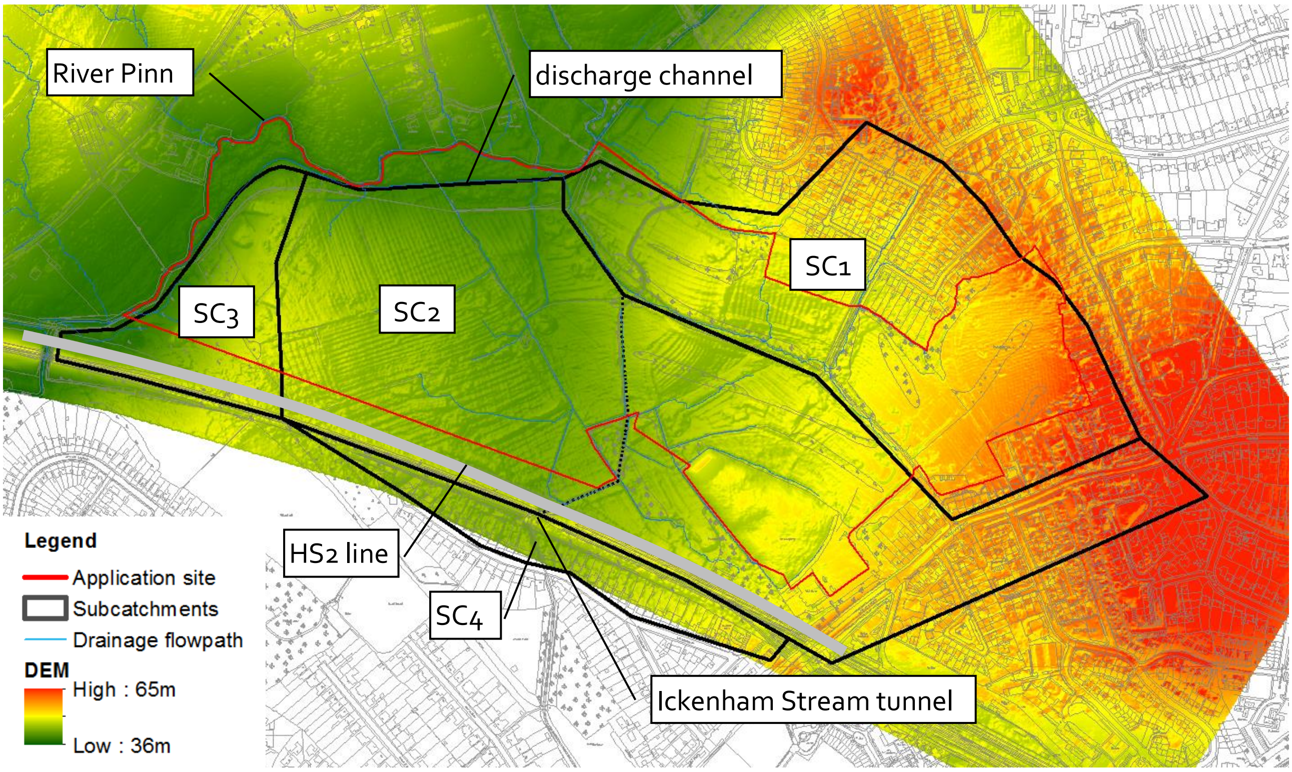


Figure 4 - DEM and sub-catchments

3.2.4 In order to simplify the following hydrological assessment, it is assumed that:

- sub-catchments SC1 and SC2 discharge at the same point and are therefore considered as a single catchment;
- sub-catchment SC3 can be considered an independent catchment; and
- Sub-catchment SC4 will be disconnected to the golf course catchment by HS2

development.

3.3 Greenfield runoff rates

3.3.1 It is assumed that runoff rates for the existing golf course catchment are very similar to greenfield rates. Therefore, according to the reference Rainfall runoff management for developments, the following methods are suitable for estimating the peak flows:

- The Institute of Hydrology Report 124 (IH 124) method; and
- The Flood Estimation handbook (FEH) statistical method.

3.3.2 Both methods are considered below, and their results are compared.

IH124 method

3.3.3 Flow rates have been calculated through the application of the IH124 method, which is based on the following expression:

$$Q_{BAR} = 0.00108\ AREA^{0.89} \times SAAR^{1.17} \times SOIL^{2.17}$$

3.3.4 For development sites of 50ha or less, 50ha shall be used when applying the formula. Subsequently the resulting value should be factored by the ratio of the site area to 50ha.

3.3.5 Parameters shown in the formula are as follows:

- Q_{BAR}: mean annual flood (a return period in the region of 2.3 years);
- AREA: area of the catchment (km²);
- SAAR: Standard Average Rainfall for the period 1941 – 1970 in mm. Rainfall values have been obtained by means of the online FEH (https://fehweb.ceh.ac.uk); and
- SOIL (SPR): soil index. The approach included in the manual *Rainfall runoff management for development*s has been followed.

3.3.6 London Clay has been considered as the predominant soil formation from the drainage point of view, and therefore soil type number 4 has been chosen. For this reason, a SOIL (or SPR) value of 0.47 has been used.

3.3.7 Taking into account previous data, Q_{BAR} value is obtained.

Parameter	Value
AREA (km²)	0.51
SAAR (mm)	645
SPR	0.47
QBAR (l/s)	223

Table 1: Q_{BAR} estimation

3.3.8 Once Q_{BAR} is calculated, the greenfield runoff rates for 1 in T years can be obtained from the following formula:

$$Q_T = GCF \times Q_{BAR}$$

Where:

- QT: greenfield rate for the 1 in T year event; and
- GCF: growth Curve Factors. FSSR 14 curves have been used, considering Hydrometric Area number 6.

Hydrometric area	Return period								
	1[1]	2	5	10	25	30[2]	50	100	500
1	0.85	0.90	1.20	1.45	1.81	1.99	2.12	2.48	3.25
2	0.87	0.91	1.11	1.42	1.81	1.99	2.17	2.63	3.45
3	0.86	0.94	1.25	1.45	1.70	1.75	1.90	2.08	2.73
9	0.88	0.93	1.21	1.42	1.71	1.80	1.94	2.18	2.86
10	0.87	0.93	1.19	1.38	1.64	1.70	1.85	2.08	2.73
4	0.83	0.89	1.23	1.49	1.87	1.99	2.20	2.57	3.62
5	0.87	0.89	1.29	1.65	2.25	2.55	2.83	3.56	5.02
6/7	0.85	0.88	1.28	1.62	2.14	2.40	2.62	3.19	4.49
8	0.78	0.88	1.23	1.49	1.84	1.98	2.12	2.42	3.41
Ireland	0.83[2]	0.95	1.20	1.37	1.60	1.65	1.77	1.96	2.40

Notes
1 1 year return period growth curve factors are taken from NERC (1977)
2 30 year (and 1 year for Ireland) return period growth curve factors are interpolated estimates

Figure 5 - Hydrometric area and return period

3.3.9 Calculated greenfield runoff rates are as follows:

Q_T	Flow rate (l/s)
Q2	196
Q25	478
Q100	712

Table 2 - IH124 Greenfield rates estimation

FEH statistical method

3.3.10 The catchment area is smaller than the minimum area which can be imported from FEH website catchment descriptors due to its limited grid resolution. For the same reason, the defined catchment for the golf course does not match exactly with the one from the FEH website. Therefore, the index flood Q_{MED} has been estimated through the correlation formula.

3.3.11 The FEH statistical method correlation formula is:

$$QMED_{cds} = 8.3062\ AREA^{0.8510} \times 0.1536^{\left(\frac{1000}{SAAR}\right)} \times FARL^{3.4451} \times 0.0460^{\ BFIHOST^2}$$

3.3.12 Parameters shown in the formula are:

- $QMED_{cds}$: index flood which is the median of the set of annual maximum flow peaks and it is equivalent to approximately the 1 in 2-year flow return period. The subscript cds refers to an estimate obtained from catchment descriptors;
- FARL: is a measurement of water bodies in the catchment so that their attenuation effects are considered. If the equation is applied to development sites, it is unlikely that FARL will be relevant, so this term becomes 1.0.and therefore drops out; and
- BFIHOST: is a measure of base flow runoff (IH 126).

3.3.13 Taking into account all these data, QMED value can be obtained as follows:

Parameter	Value
AREA (km^2)	0.51
SAAR (mm)	645
BFIHOST	0.17
QMED (l/s)	232

Table 3 - Q_{MED} estimation

3.3.14 For growth curves calculation, within the FEH tool growth curves are computed by merging gauged data from hydrologically similar catchments (pooling group method) implemented in WINFAP 4 software. Obtained growth factors are showed in Table 4.

GCF	Value
GCF 2	1.00
GCF 25	2.12
GCF 100	2.97

Table 4 - Growth factors

3.3.15 Calculated greenfield runoff rates are showed in Table 5.

Q_T	Flow rate (l/s)
Q2	235
Q25	497
Q100	698

Table 5 - FEH Greenfield rates estimation

Comparison of results

3.3.16 Resulted greenfield rates from both methods are compared in Table 6.

Q_T	FEH flow rate (l/s)	IH 124 flow rate (l/s)	Difference %
Q2	235	196	+17%
Q25	497	478	+4%
Q100	698	712	-2%

Table 6 - Results comparison

3.3.17 FEH peak flows are 4-17% higher than IH124 ones for lower return periods (1 in 2-25 years). For higher return periods, results are very similar. Therefore, results are considered consistent.

3.3.18 According to the reference document *Estimating flood peaks and hydrographs for small catchments: Phase 1* it is recommended that flood estimates on small catchments should be derived from FEH methods in preference to other existing methods. Therefore, FEH peak flood flows are considered for further calculations.

3.4 Hydrographs

3.4.1 The Revitalised Flood Hydrograph (ReFH) model is an event-based rainfall-runoff model which is used to convert design storm events of appropriate duration and rarity into a corresponding design flood event of similar rarity.

3.4.2 The ReFH model has four model parameters controlling hydrological losses (maximum soil capacity, C_{max}), routing using a unit hydrograph (time to peak, T_p) and two baseflow parameters (recharge and lag-time, BR and BL). The four parameters can be estimated using the catchment descriptors.

Loss model

3.4.3 The loss model parameter Cmax is estimated based on the baseflow index BFIHOST and PROPWET as:

$$Cmax = 596.7\ BFIHOST^{0.95}\ PROPWET^{-0.24}$$

Parameter	Value
PROPWET	0.29
C_{MAX} (mm)	149
$C_{INI,WINTER}$ (mm)	86
$C_{INI,SUMMER}$ (mm)	47

Table 7 - Loss model parameters

Routing model

3.4.4 The routing model parameter is the time-to-peak (T_p) of the instantaneous unit hydrograph. The resulting equation for T_p in the ReFH model is:

$$Tp = 1.56\ PROPWET^{-1.09}\ DPLBAR^{0.60}(1 + URBEXT_{1990})^{-3.34}\ DPSBAR^{-0.28}$$

Parameter	Value
DPLBAR (km)	0.59
DPSBAR (m/km)	64.67
URBEXT	0.15
T_p (hours)	0.85

Table 8 - Routing model parameters

Base flow model

3.4.5 The final model for baseflow lag, BL, is:

$$BL = 25.5\ BFIHOST^{0.47}\ PROPWET^{-0.53}\ DPLBAR^{0.21}(1 + URBEXT_{1990})^{-3.01}$$

3.4.6 The equation for Baseflow recharge, BR, is:

$$BR = 3.75\ BFIHOST^{1.08}\ PROPWET^{0.36}$$

Parameter	Value
BL (hours)	12.56
BR	0.35
$BF_{0,winter}$ (m^3/s)	0.007
$BF_{0,summer}$ (m^3/s)	0.004

Table 9 - Base flow model parameters

Rainfall

3.4.7 In the revitalised rainfall-runoff method, the seasonal design rainfall is derived from the FEH DDF model by multiplying FEH estimates of design rainfall with a seasonal correction factor. The seasonal correction factor depends on the $SAAR$ of the considered catchment. With the introduction of the seasonal correction factor, the catchment average seasonal design rainfall depth is calculated as:

$$P = RDDF \times ARF \times SCF$$

3.4.8 $RDDF$ is the point estimate of design rainfall obtained from the FEH DDF model, ARF is the areal reduction factor transforming point rainfall to catchment average rainfall and SCF is the seasonal correction factor transforming annual maximum rainfall to seasonal maximum rainfall.

3.4.9 The design storm duration (D) for a particular catchment depends on the response time of the catchment (time to peak, T_p) and the general wetness of the catchment (as measured by the standard average annual rainfall, SAAR) as:

$$D = Tp\left(1 + \frac{SAAR}{1000}\right)$$

3.4.10 The design rainfall inputs are as follows:

Parameter	Value
D (hours)	1.41
Design storm profile	75% winter

Table 10 - Design rainfall inputs

3.4.11 The resulted storm depths are:

Return period	Depth (mm)
2	16.0
25	37.15
100	56.36

Table 11 - Resulted storm depths

Simulations and results

3.4.12 Calculations have been performed by Infoworks RS software, where the ReFH model is implemented. The resulting hydrographs are scaled in order to fit the peak flow to the estimated by FEH statistical method. Figure 6 below shows the resulting hydrographs for the considered return periods. Figure 7 below shows the1 in 100-year rainfall as well as the detailed resulting hydrograph for this event.

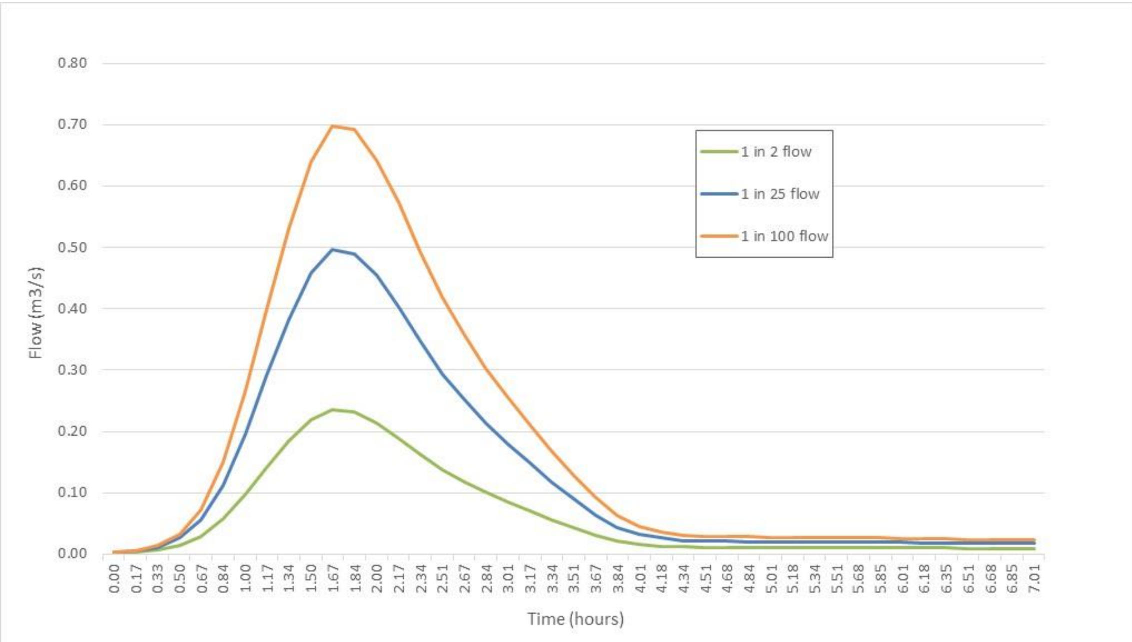


Figure 6 - Resulted hydrographs

Return period (1 in T years)	Peak flow (l/s)	Peak flow scaling factor	Total runoff volume (m3)
2	235	0.49	1,590
25	497	0.45	3,309
100	698	0.43	4,634

Table 12 - Simulation results

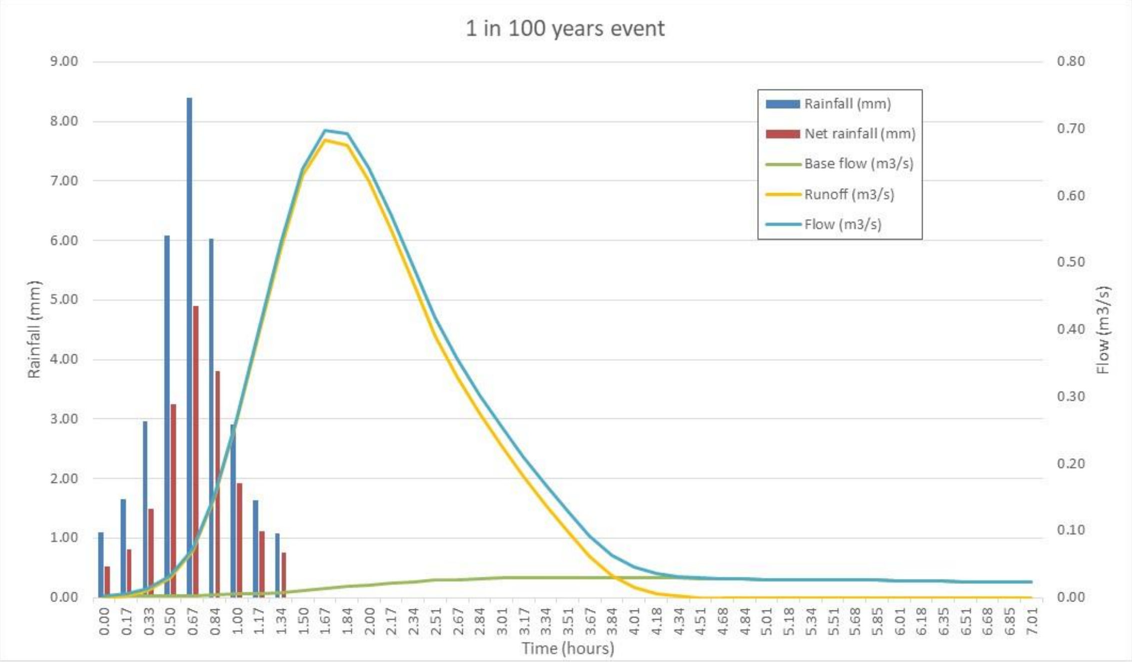


Figure 7 - 1 in 100-year event rainfall and detailed hydrograph

Climate change allowances

3.4.13 According to the HS2 Approach Document *Climate change allowances for flood risk assessments and drainage design peak*, rainfall intensity climate change allowances should be used for any assessment within a catchment of a size smaller than 5 km². A peak rainfall intensity allowance of 40% should be used to assess the future performance of track drainage and runoff attenuation elements.

3.4.14 Rainfall depth has been increased 40 % of the FEH depth-duration frequency (DDF) model.

3.4.15 ReFH model has run taken into account the previous 100 years peak flow scaling factor. Figure 8 below shows the resulting hydrograph.

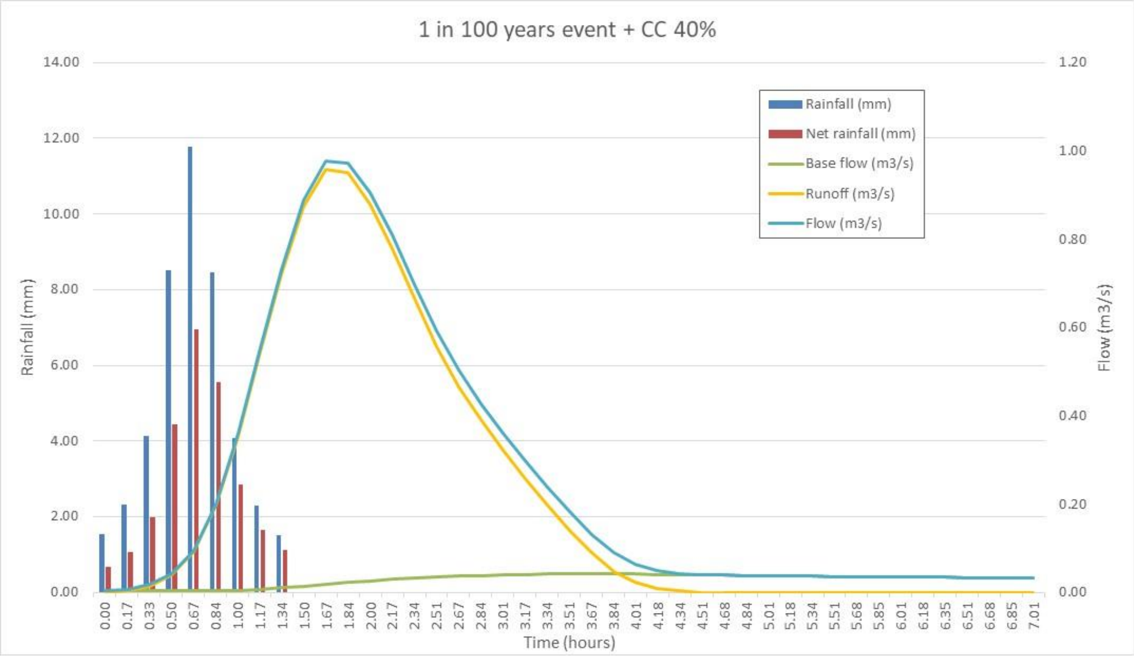


Figure 8 - 1 in 100 year + 40% for climate change event rainfall and hydrograph

Peak flow scaling factor	Peak flow (l/s)	Total runoff volume (m3)
0.43	976	6,469

Table 13 - 1 in 100 year + 40% for climate change results

3.5 Low flow statistics

3.5.1 The annual and seasonal flow statistics for the application site catchment have been carried out by WHS (Wallingford HydroSolutions Limited).

3.5.2 The estimated monthly mean flows and annual flow duration statistics are showed in the table and Figure 9 below. The complete report is included in Appendix A.

Mean Flows	Flow (m³/s)
Annual	**0.0034**
January	0.0070
February	0.0051
March	0.0038
April	0.0030
May	0.0022
June	0.0019
July	0.0012
August	0.0013
September	0.0015
October	0.0037
November	0.0043
December	0.0060

Percentile	Flow (m³/s)
5	0.0129
10	0.0074
20	0.0035
30	0.0021
40	0.0014
50	0.0010
60	0.0007
70	0.0006
80	0.0005
90	0.0004
95	0.0003
98	0.0002
99	0.0002

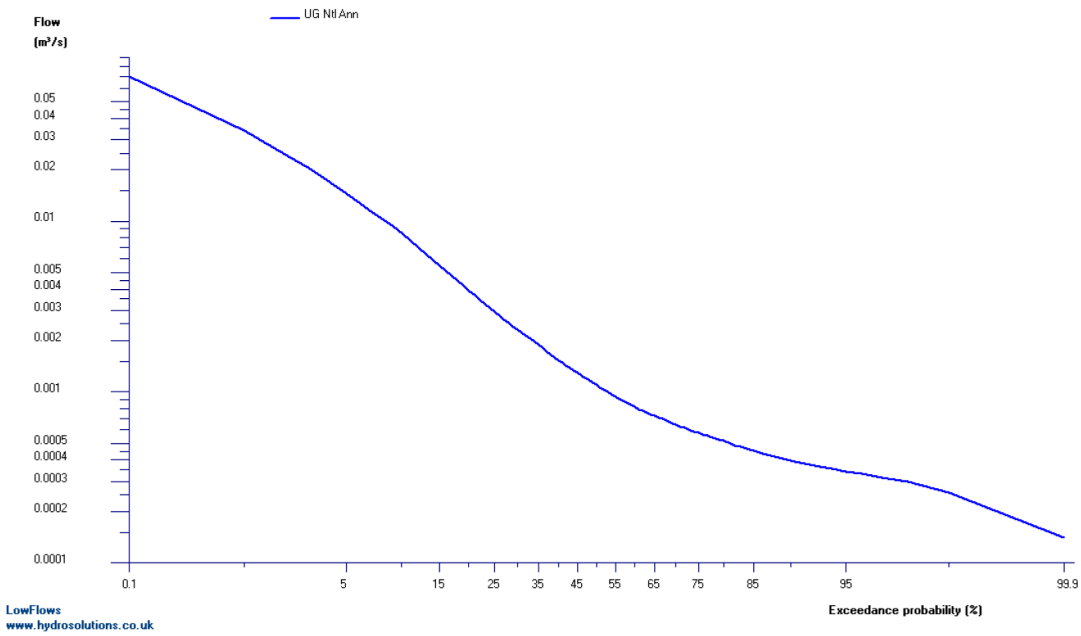


Figure 9 - Estimated monthly mean flows and annual flow duration

4 Existing drainage network

4.1 Description

4.1.1 The existing drainage network of the application site is formed by several channels which also receive runoff water from external urban areas as shown on Figure 3. The main drainage channels within the application site are:

- channels along Clacks Lane; and
- central channel from the Chiltern Mainline tunnel to the River Pinn.

Clacks Lane's channels

4.1.2 There is one channel running along each side of Clacks Lane to the River Pinn. They receive the runoff from the catchment located to the north, including the urban area.

4.1.3 The northern channel starts downstream of Hill Lane where it receives drained water from the northern urban catchment. Two ditches along Hill Lane run water from the urban area to Clacks Lane. These ditches are connected to the Clacks Lane´s northern channel by two culverts as Figure 10 shows.

Figure 10 - Hill Lane ditches and culverts

4.1.4 The northern channel is intercepted by the Ickenham Stream where it crosses Clacks Lane. Once the Ickenham Stream crosses Clacks Lane, it is integrated into the Clacks Lane´s southern channel running to the River Pinn. Figure 11 shows the Ickenham Stream crossing.

Figure 11 - Ickenham Stream crossing and culvert (view from south to north)

4.1.5 When Clacks Lane turns to the right, the southern channel continues straight to reach the River Pinn. The channel's cross section in this point is drastically reduced as Figure 12 shows. The channel discharges to the River Pinn through one Ø 200mm pipe under the Celandine Route.

Figure 12 - Southern channel to the River Pinn and discharge pipe at River Pinn

4.1.6 From the Ickenham Stream crossing, there isn´t any significant channel to the north side of Clacks Lane.

Central channel to the River Pinn

4.1.7 There is a channel crossing from south-east to north-west the application site, following the lowest ground levels of the catchment as Figure 13 illustrates. This channel starts just to the north of the Chiltern Mainline tunnel and discharges to the River Pinn. It intersects the Ickenham Stream and intercepts several lateral channels. Several ponds can be found along the channel's route.

Figure 13 - Central channel through the golf course

4.1.8 This channel also receives the runoff from the eastern urban catchment. The storm sewer network of the urban area releases into a ditch located at the south-east corner of the car park. This ditch continues to the north-west parallel to the Chiltern Mainline embankment and finally to a pond located just to the north of the Chiltern Mainline tunnel. From this pond, the central channel runs to the north crossing the golf course.

4.1.9 In case of flooding, part of the runoff of the area located between the Chiltern Mainline tunnel and the Greenway will drain to the above-mentioned northern pond and part to the south to the Ickenham Stream. Figure 14 shows the north and the south sides of the Chiltern Mainline tunnel.

Figure 14 - Tunnel under Chiltern Mainline. Northern and southern side

4.1.10 The central channel releases to the River Pinn's discharge channel which runs along the river´s south bank. The channel crosses the Celandine Route by a pedestrian bridge as Figure 15 shows.

Figure 15 - Discharge to the River Pinn´s discharge channel

4.2 Sub-catchments

4.2.1 According to the catchment demarcation developed in Section 3.2, following sub-catchments have been considered to estimate existing runoff flows and volumes:

- SC1 sub-catchment: area to the north of Clacks Lane that drains to the River Pinn;
- Golf course sub-catchment: it comprises the SC2 sub-catchment plus the SC4 (area to the south of Chiltern Mainline). It drains to the River Pinn through the central channel;
- SC4 sub-catchment: it comprises the area located to the south of the Chiltern Mainline and to the north of The Greenway which partially drains to the north;

- Ickenham sub-catchment: it comprises the area of the SC2 sub-catchment to the east of the Ickenham Stream. It drains to the tunnel and central channel; and
- SC3 sub-catchment. It drains to the River Pinn along the west boundary of the application site.

4.2.2 The main characteristics of the sub-catchments above are described as follows:

Sub-catchment	Area (ha)	Type	Drains to
SC1	18.2	Mixed: rural (71%), urban (29%)	Clacks Lane´s channels to the River Pinn
Golf course (SC2+SC4)	35.5	Mixed: rural (82%), urban (18%)	central channel to the River Pinn
Ickenham (part of SC2)	16.8	Mixed: rural (67%), urban (33%)	tunnel / central channel
SC4	2.8	Mixed: rural (70%), urban (30%)	tunnel / Ickenham south
SC3	4.6	Rural	River Pinn

Table 14 - Sub-catchment characteristics

4.3 Runoff estimation

Methodology

4.3.1 Two different methodologies for runoff estimation have been used depending on the sub-catchment type: rural or urban-rural mixed.

4.3.2 For mixed type sub-catchments, MicroDrainage software has been used and one model has been developed for each sub-catchment. Volumetric coefficients C_v have been estimated according to the equations 7.3 and 7.21 of the reference Volume1 of the Wallingford Procedure, considering the urban areas as impermeable.

4.3.3 For each mixed sub-catchment, it has been considered the storm duration which causes the higher flow rate (30 or 60 minutes). Runoff volumes have been obtained for a six hours storm duration.

4.3.4 SC3 rural sub-catchment runoff estimation is based on the Greenfield calculations developed in sections 3.3 and 3.4.

Calculations

4.3.5 Runoff calculations for mixed type sub-catchments are showed in Table 15 and Table 16:

Sub-catchment	Cv,sum	Cv,wint	Storm duration (min)	Q2 (l/s)	Q30 (l/s)	Q100 (l/s)	Q100+40% (l/s)
SC1	0.25	0.33	30	463	1,144	1,509	2,101

Sub-catchment	Cv,sum	Cv,wint	Storm duration (min)	Q2 (l/s)	Q30 (l/s)	Q100 (l/s)	Q100+40% (l/s)
Golf course (SC2+SC4)	0.15	0.24	60	481	1,195	1,583	2,215
Ickenham (part of SC2)	0.28	0.36	30	450	1,114	1,480	2,064
SC4	0.26	0.34	30	106	243	323	450

Table 15 - Mixed type sub-catchments runoff flow results

Sub-catchment		Cv,sum	Cv,wint	Storm duration (min)	V2 (m³)	V30 (m³)	V100 (m³)	V100+40% (m³)
SC1		0.25	0.33	360	1,783	3,553	4,741	6,050
Golf course (SC2+SC4)		0.15	0.24	360	2,527	5,037	6,720	8,792
Ickenham (part of SC2)		0.28	0.36	360	1,790	3,568	4,760	6,075
SC4		0.26	0.34	360	282	562	749	1,048

Table 16 - Mixed type sub-catchments runoff volume results

4.3.6 Runoff estimation for rural sub-catchment is showed in Table 17:

Sub-catchment	Area (ha)	Qmed (l/s)	Q2 (l/s)	Q30 (l/s)	Q100 (l/s)
SC3	4.6	21.0	21.0	46.5	62.6

Table 17 - Rural sub-catchment runoff flow results

Conclusions

4.3.7 The results demonstrate how external urban areas significantly increase the runoff flow and volume rates of the golf course.

4.3.8 The blockage of the Ickenham Stream under the CML could locally affect to the drainage of the small sub-catchment to the south of the CML which is outside of the application site boundaries. The effect of the blockage of the Ickenham Stream by the HS2 scheme will be assessed in the corresponding HS2 asset (West Ruislip Portal). At this moment, the drainage solution for this catchment to the south of the CML is work in progress.

4.3.9 Estimated values to the north of the Chiltern Mainline are considered for the post-development design.

5 Proposed drainage network

5.1.1 This section presents the design solution for the proposed development. This section includes the drainage strategy, a description of the drainage system and its supporting calculations.

5.1 Drainage strategy

5.1.1 The drainage design is based on the following:

- The proposed drainage network discharges into the River Pinn, as it currently does. The Ickenham Stream diversion is integrated into the proposed drainage network of the golf course. The existing tunnel of the Ickenham Stream to the south of the Chiltern Mainline will be disabled by the HS2 development;
- The irrigation needs of the application site are met by drained water which is collected and stored on site. A water harvesting system is designed as part of the drainage network. The drainage network is connected to three ponds and three tanks which provide the required water storage volume;
- The proposed use of land will remain be the same, i.e. a golf course, so the runoff conveyed from the site will not be increased. The existing runoff rates from urban areas external to the application will be attenuated in the golf course, as it currently is. However, this attenuation will be bigger in the proposed scheme as a side effect of the resultant volumes of the surface of the terrain and of the water harvesting system;
- The proposed drainage network is designed for a 1 in 5 years return period rainfall. However, the main drainage network which receives water from external urban catchments are designed for a 1 in 30 years return period.
- HS2 West Ruislip Portal and Embankment drainage systems discharges to the Ruislip Golf Course drainage network. Flow rates from the HS2 infrastructure will be attenuated before being discharged into the application site. The drainage network of the Hs2 scheme will discharge over the maximum water levels in the golf course for a 1 in 1000 yr event flooding.

5.2 Description of the proposed drainage network

Drainage scheme

5.2.1 The drainage scheme is formed by gravity drain pipes and channels. The main drainage conduits receive the storm water from the external urban catchments. The storm water from the northern urban catchment is drained by ditches running along Clacks Lane to the Ickenham Stream, in the same way it does currently. The water from the eastern urban catchment is received by a pipeline which runs along the south-east perimeter of the application site and discharges to the proposed ponds. This conduit also receives the storm water from the car park and the club house. These two main drainage ducts are designed for a 1 in 30 years return period.

5.2.2 A surface drainage system is provided for the fairways and rough areas. Surface water is collected by gullies located along the perimeter of the playable areas and runs into the main gravity drain pipes. The drainage network in these areas is designed for a 1 in 5 return period rainfall. The minimum size provided for drain pipes is Ø200mm and the minimum slope is 0.5%

5.2.3 Footpaths are in general drained by gullies connected to the main drain conduits which runs along them. When a drain pipeline is not projected along the footpath, the footpath is drained by a ditch.

5.2.4 Green and tee areas, bunkers and the driving range outfield are drained by subsurface drainage. This consists of an array of perforated pipes (field drains) connected to a common pipe which connects to the main gravity drain pipes.

5.2.5 Filter drains are used in some areas as surface runoff interceptor for protecting areas downslope. Filter drains consist of a trench filled with a permeable aggregate material with a perforated pipe in the base.

5.2.6 The area located to the north to the tanks (that is the hole 5 fairway and green, the hole 6 tee and the hole 8 tee) does not drain to the water storage system. This area drains directly to the River Pinn through the existing and proposed channels due to its lower ground levels.

5.2.7 Designed channels and diverted Ickenham Stream will collect the surface runoff in case of an intense rainfall event which exceeds the design return period. These channels discharge into the water storage system or the basins.

5.2.8 Table 18 summarises the drainage scheme.

Area	**Draining to**	**Drainage Element**	**Return period**
Northern urban catchment	Ickenham / tank 2	channel along Clacks Lane	1 in 30
Eastern urban catchment / car park / club house and rifle range roofs	ponds 1 and 2	main drain pipe	1 in 30
holes 3, 4 and 7 / hole 5 tee / hole 6 fairway and green	tank 1	drain pipes	1 in 5
hole 2 / driving range	ponds 1 and 2	drain pipes	1 in 5
hole 1	tank 2	drain pipes	1 in 5
academy	pond 3 and tank 2	drain pipes	1 in 5
hole 9 / hole 8 fairway and green	tank 3	drain pipes	1 in 5

Area	Draining to	Drainage Element	Return period
hole 5 fairway and green / hole 6 tee / hole 8 tee	River Pinn	drain pipes and channels	1 in 5
West Ruislip Portal attenuation tank flow rates	Western and Eastern ponds	drain pipes	Attenuated to 1 in 1 year

Table 18 - Drainage scheme summary

5.2.9 The car park area is drained by gullies connected to the main pipeline which runs along the south-east perimeter of the application site. In case of heavy rainfall event, the runoff from the car park floods this area due to ground elevations, the driving range building walls and an insufficient drainage network. Designed gullies and pipe will collect the runoff from the car park and carry it to the attenuation ponds. An oil separator is provided to the pipeline downstream the car park area. The existing drainage network of the club house roof is also connected to this pipeline.

5.2.10 A second oil separator is provided for the green keeper's compound, as part of the pollution prevention strategy to put in practise in the interior drainage of this area. The good practise water quality design standards described in the *CIRIA SuDS Manual* and in the Environmental Agency's guidance *Pollution prevention for business* should be followed. The compound is located to the north of Harwell Close and east of Clacks Lane. The current drainage system is connected directly to the external surface sewage network.

5.2.11 The remodelling of the Ruislip Golf Course incorporates the construction of two buildings: the driving range and the rifle range. The roofs of the buildings are divided up into areas that are sloped to gutters placed along the edge of the roof. These gutters convey water into a vertical rainwater pipe on the outside of the building that runs down the water to an inspection chamber. A drain connects the inspection chamber to the main conduit of the proposed drainage network.

5.2.12 The rainwater pipes of the driving range building are connected to the main pipeline of the proposed drainage network as indicated in Figure 16 below.

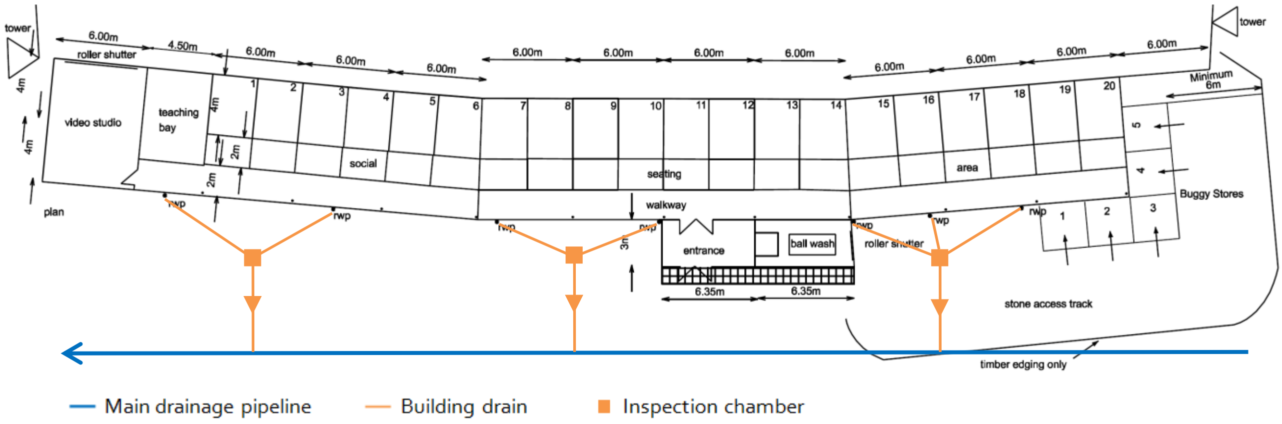


Figure 16 - Driving range drainage scheme

5.2.13 The rainwater pipes of the rifle range building are connected to the main drainpipe of the proposed drainage network as indicated in Figure 17 below.

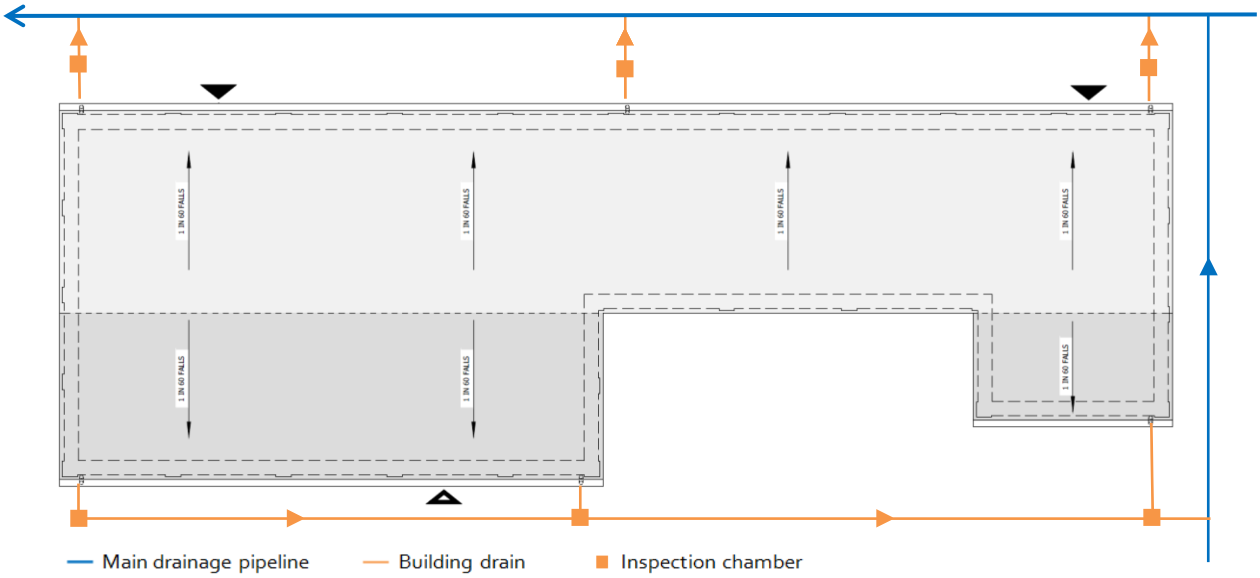


Figure 17 - Rifle range drainage scheme

Water harvesting

5.2.14 The water harvesting system is formed by three tanks and three ponds. The drainage network discharges into these elements in order to receive the maximum amount of water possible.

5.2.15 When the water storage elements are completely filled, they discharge to the basins. The tanks and ponds are also connected to a pumping station which supplies the water for the irrigation system. The pumping station is located in a house attached to tank 1.

5.2.16 The water storage system is formed of three sub-systems that could be operated independently through a valve system located at the pumping station. There are three independent inlets (one for each sub-system) to the pumping station. In addition, valve system makes it possible to connect the three water storage sub-systems. The three water harvesting sub-systems are:

- Sub-system 1: tank 1;
- Sub-system 2: tanks 2 and 3; and
- Sub-system 3: ponds 1, 2 and 3.

5.2.17 The main characteristics of each water storage element are showed in Table 19.

	Sub-system 1	Sub-system 2	
	Tank 1	Tank 2	Tank 3
Length (m)	25.00	15.00	15.00
Width (m)	20.00	15.00	15.00
Cover level (m)	42.00	42.00	42.50
Soffit level (m)	40.50	40.50	40.50
Invert level (m)	36.50	37.00	37.25
Height (m)	4.00	3.50	3.25
Water storage level (m)	40.00	40.00	40.00
Depth (m)	3.50	3.00	2.75
Water storage volume (m^3)	1,750.00	675.00	618.75

	Sub-system 3		
	Pond 1	Pond 2	Pond 3
Water storage area (m^2)	1,290.00	2,266.00	1,134.00
Top level (m)	41.00	41.00	45.00
Water storage level (m)	40.50	40.50	44.75
Bottom level (m)	39.00	39.00	43.75
Depth (m)	1.50	1.50	1.00
Water storage volume (m^3)	1,117.50	2,100.75	586.00

Table 19 - Water storage characteristics

5.2.18 The total volume provided for water storage purposes is 6,848m³ (3,043m³ in tanks and 3,804m³ in ponds). This storage volume will be optimized in the Ruislip Golf Course Detail Design.

5.2.19 Water storage levels vary between the three sub-systems, therefore pressure sustaining valves will be used at the pumping station in order to optimise the dimensions of the tanks and ponds. In the same way, a pressure sustaining valve must be provided at the junction of the intake pipes of pond 3 and pond 1.

5.2.20 The potential amount of water that can be collected by the drainage network is higher (111,633m³) than the volume provided for water storage (6,848 m³). This ensures the water storage system will be filled. Table 20 shows the potential rainfall water to be collected. It is assumed that 50% of the rainwater is collected from the soil by the drainage network.

Element	Drained area (m²)	Annual average rainfall (mm)	% of rainfall collected	Potential collected volume (m³)
Tank 1	48,047	645	50 %	15,495
Tank 2 and pond 3	105,017	645	50 %	33,868
Tank 3	85,823	645	50 %	27,678
Ponds 1 and 2	107,263	645	50 %	34,592
			Total potential volume:	111,633

Table 20 - Potential collected volume

5.2.21 Overflow elements (pipes and weirs) over the water storage levels in tanks and ponds are provided in order to release excess water to the basins. The resultant volume in the tanks and ponds over the water storage level (freeboard) provides a runoff attenuation, as set out below.

5.2.22 The existing irrigation system is supplied by a borehole located to the north-east of the car park, out of the application boundary. It is proposed to keep the existing borehole operating in order to supply water to the proposed irrigation network. For this purpose, the existing borehole outlet pipeline is intercepted within the application site boundary and connected to proposed pond 3. Pond 3 is connected to tank 1 and the pumping station by a pressure pipe.

Runoff Attenuation

5.2.23 The drainage system formed of basins, ponds and swales are connected to the water harvesting system in order to collect as much water as possible. As a side effect, this system provides a higher runoff attenuation than the current situation.

5.2.24 The runoff from the golf course surface is mainly attenuated in two basins. These comprise depressed areas connected to the water storage systems by overflow pipes whose invert levels are above the water storage level. The outfalls of the basins are controlled by flow control outlets.

5.2.25 The first basin is located to the north of the application site, between the green and the fairway of the hole 3. This is connected to tank 2 (which is also connected to tank 3) and to ponds 1 and 2. The outlet consists of a Ø800mm pipe whose invert level is at 40.0m. The top level of the basin is at 41.25m. The resultant volume in the basin and in the tanks and ponds over the elevation 40.0m is 5,701m³.

5.2.26 The second basin is located to the north-west of the application site, between the green and the fairway of the hole 6, along the diverted Ickenham Stream. It is connected to tank 1. This receives the outflow of the first basin. The outlet consists of a Ø500mm pipe whose invert level is at 40.0m. The top level of the basin is at 41.0m. The resultant volume in the basin and by tank 1 over the elevation 40.0m is 5,727m³.

5.2.27 The resultant attenuation volume is, therefore, 11,428m³.

5.2.28 The runoff from the area located to the north of the previous flow control outlets is not attenuated. It corresponds to hole 5 fairway and green, hole 6 tee and hole 8 tee. The runoff from these areas discharges directly to the River Pinn, as they currently do through the existing channels.

5.3 Calculations

Attenuation calculations

Methodology

5.3.1 The flow rates and attenuations volume have been calculated using the following method:

- define the application site catchments;
- estimate the application site's Greenfield rates;
- attenuation calculations performed with the Source Control module of MicroDrainage software; and
- analysis of results.

Catchment definition

5.3.2 There are two catchments in the remodelled application site which drain to the attenuation areas, called "west catchment" and "east catchment".

5.3.3 The east catchment drains to the first attenuation basin located to the north of the application site, as shown in Figure 18. The area of this catchment is 36.5ha. This catchment also includes some of the urban area outside the application site boundary. The east catchment outflows to the west catchment.

5.3.4 The west catchment drains to the second attenuation area located to the north-west of the application site, as shown in Figure 18. The area of this catchment is 6.3ha.

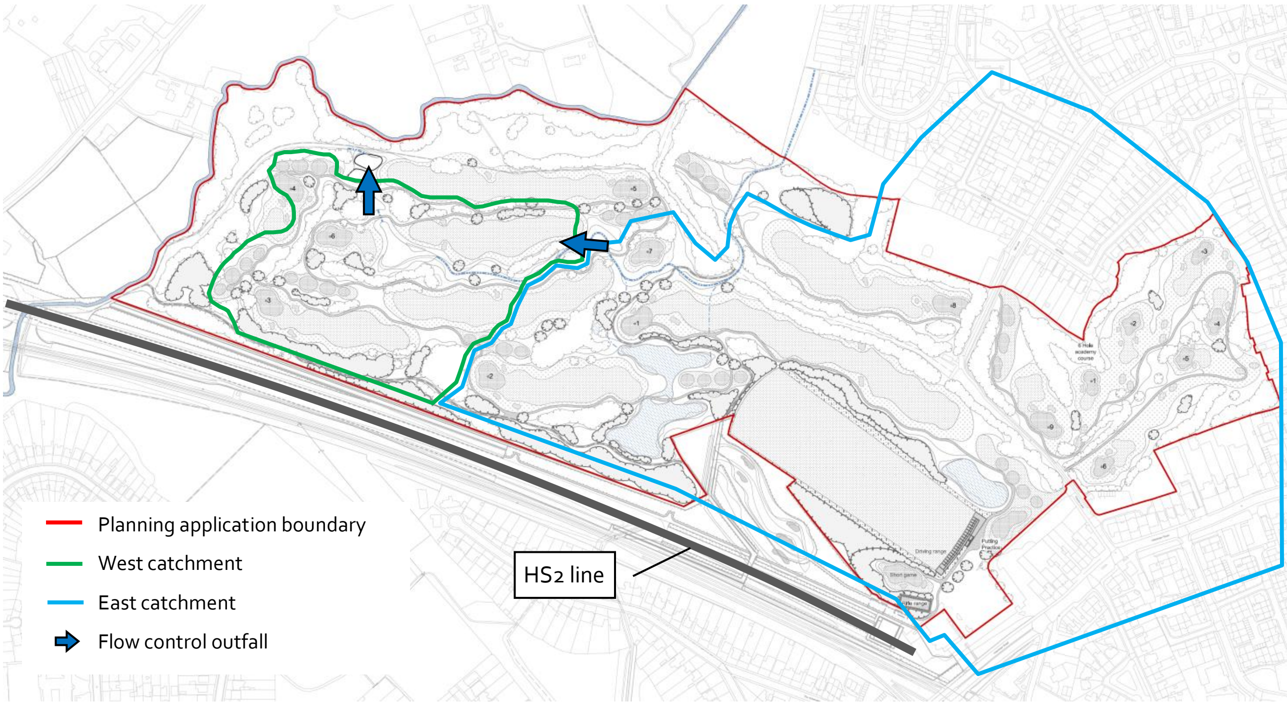


Figure 18 - West and east catchments and flow control outfalls

Greenfield rates

5.3.5 The Greenfield rate are estimated using the formula of the improved FEH statistical method, as developed in Section 3. The formula is applied for an area of 50ha and the obtained Q_{MED} is scaled down to the area's ratio for each catchment. The growth factors obtained in the Section 3 are used. Results are summarised as follows:

	West catchment	East catchment
SAAR (mm)	645	
BFIHOST	0.17	
Q_{MED} 50 ha (l/s)	230.77	
Area (ha)	6.31	36.55
Q_{MED} (l/s)	29.14	168.67
Q1 (l/s)	27.68	160.23
Q2 (l/s)	29.14	168.67
Q25 (l/s)	61.71	357.24
Q100 (l/s)	86.65	501.61

Table 21 - Greenfield rates

Assumptions and inputs

5.3.6 The following assumptions are made for the attenuation calculations:

- Runoff rates of the proposed development are similar to the Greenfield rates, due to the use of the site remaining the same. However, the urban catchments which discharge to the application site have been considered impervious. The considered volumetric coefficient (C_v) for runoff calculations considers this urban area;
- The volumes provided for water harvesting are not considered for attenuation purposes. That means it is considered the system is filled when a rainfall event is applied;
- The different elements which integrate the attenuation system (tanks, ponds and basins) work as one single element; and
- The storage volume in the pipe network has not been considered.

5.3.7 The attenuated flow rates are calculated using MicroDrainage software, Source Control model. Two models, one for each catchment, have been developed. Then, the two models have been combined. The following inputs have been considered:

- Rainfall period of return: 1 in 100 year;
- Climate change allowance: 40%; and
- Volumetric coefficients (C_v): 0.28 (summer) and 0.37 (winter). For the east catchment, C_v has been estimated according to the equations 7.3 and 7.21 of the reference *Volume1 of the Wallingford Procedure*, considering a 33% of impermeable area in order to take into account the urban areas.

East catchment model results

5.3.8 The following table and Figure 19 summarises the results for a 1 in 100-year return period plus 40% climate change for the east catchment. The worst storm event is 2 hours duration and winter profile. The maximum depth is 1.05m, which means a water level of 41.05m. The maximum outflow through the pipe is 1,103 l/s.

Storm Event	Rain (mm/hr)	Time to Vol Peak (mins)	Max Water Level (m)	Max Depth (m)	Flooded Volume (m³)	Max Control (l/s)	Discharge Volume (m³)	Max Overflow (l/s)	Σ Max Outflow (l/s)	Overflow Volume (m³)	Maximum Volume (m³)	Status
240 min Summer	25.326	162	40.893	0.893	0.0	873.3	10318.3	0.0	873.3	0.0	5595.4	O K
360 min Summer	18.419	228	40.857	0.857	0.0	819.0	11256.5	0.0	819.0	0.0	5208.7	O K
480 min Summer	14.525	292	40.816	0.816	0.0	758.0	11835.0	0.0	758.0	0.0	4785.4	O K
600 min Summer	12.012	356	40.777	0.777	0.0	700.2	12233.6	0.0	700.2	0.0	4398.2	O K
720 min Summer	10.254	418	40.741	0.741	0.0	649.4	12530.7	0.0	649.4	0.0	4058.4	O K
960 min Summer	7.942	544	40.680	0.680	0.0	562.2	12938.8	0.0	562.2	0.0	3508.6	O K
1440 min Summer	5.510	788	40.587	0.587	0.0	447.9	13454.8	0.0	447.9	0.0	2733.9	O K
2160 min Summer	3.811	1144	40.497	0.497	0.0	353.8	13981.9	0.0	353.8	0.0	2062.2	O K
2880 min Summer	2.939	1500	40.446	0.446	0.0	292.5	14372.4	0.0	292.5	0.0	1718.8	O K
4320 min Summer	2.049	2220	40.388	0.388	0.0	212.2	15014.7	0.0	212.2	0.0	1370.5	O K
15 min Winter	163.240	30	40.817	0.817	0.0	759.5	5465.5	0.0	759.5	0.0	4795.0	O K
30 min Winter	106.848	41	40.932	0.932	0.0	930.5	7163.0	0.0	930.5	0.0	6025.5	O K
60 min Winter	66.444	62	41.005	1.005	0.0	1040.1	8942.9	0.0	1040.1	0.0	6880.4	Flood Risk
120 min Winter	41.769	100	41.047	1.047	0.0	1103.3	11244.7	0.0	1103.3	0.0	7389.4	Flood Risk
180 min Winter	31.355	136	41.043	1.043	0.0	1098.1	12662.3	0.0	1098.1	0.0	7346.7	Flood Risk
240 min Winter	25.326	172	41.021	1.021	0.0	1065.0	13636.7	0.0	1065.0	0.0	7083.8	Flood Risk
360 min Winter	18.419	242	40.961	0.961	0.0	974.7	14876.7	0.0	974.7	0.0	6368.1	Flood Risk

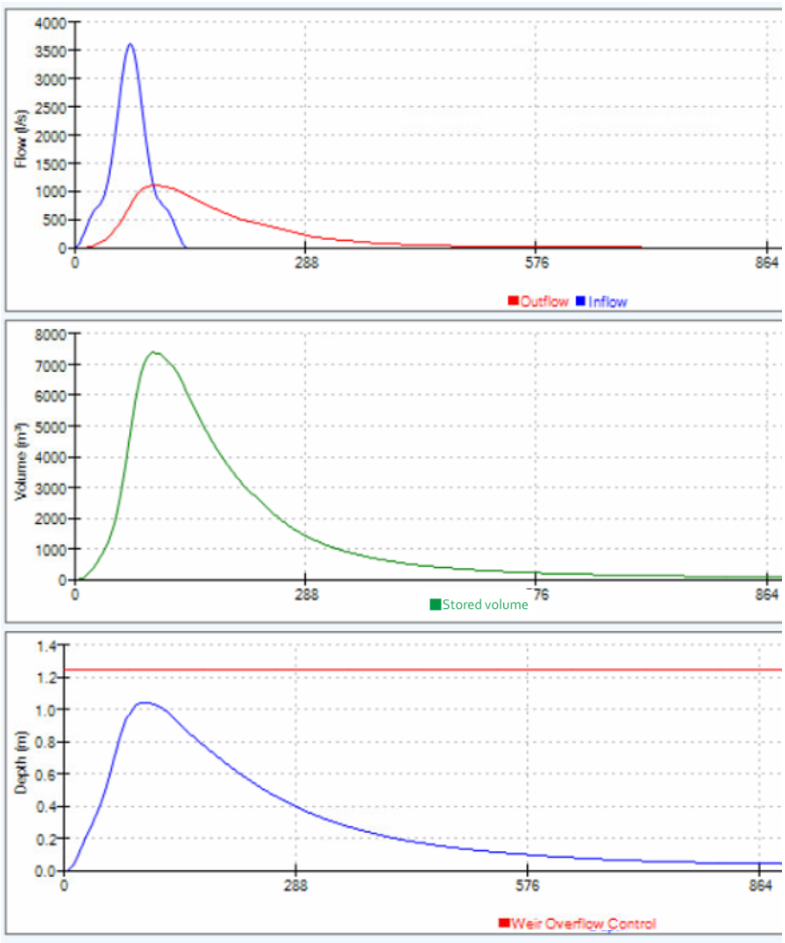


Figure 19: East catchment model results

East & West catchment model results

5.3.9 The models of the east and west catchments have been combined, so the east catchment outflow is the inflow of the west catchment. Following table and Figure 20 summarise the modelling results for a 1 in 100-year return period plus 40% climate change. The worst storm event is 6 hours duration and winter profile. The maximum depth is 1.50m, which means a water level of 41m. The maximum outflow through the pipe is 583 l/s which corresponds approximately to the 1 in 100 years Greenfield rate.

Storm Event	Rain (mm/hr)	Time to Vol Peak (mins)	Max Water Level (m)	Max Depth (m)	Flooded Volume (m³)	Max Control (l/s)	Discharge Volume (m³)	Max Overflow (l/s)	Σ Max Outflow (l/s)	Overflow Volume (m³)	Maximum Volume (m³)	Status
240 min Summer	25.326	266	40.659	1.159	0.0	497.6	12039.7	0.0	497.6	0.0	5087.5	O K
360 min Summer	18.419	344	40.674	1.174	0.0	501.5	13138.0	0.0	501.5	0.0	5175.2	O K
480 min Summer	14.525	402	40.649	1.149	0.0	494.8	13814.2	0.0	494.8	0.0	5026.0	O K
600 min Summer	12.012	462	40.616	1.116	0.0	485.5	14279.2	0.0	485.5	0.0	4823.3	O K
720 min Summer	10.254	522	40.578	1.078	0.0	474.9	14624.8	0.0	474.9	0.0	4603.0	O K
960 min Summer	7.942	646	40.501	1.001	0.0	452.1	15097.0	0.0	452.1	0.0	4158.1	O K
1440 min Summer	5.510	888	40.367	0.867	0.0	410.0	15682.3	0.0	410.0	0.0	3438.0	O K
2160 min Summer	3.811	1232	40.224	0.724	0.0	359.4	16361.1	0.0	359.4	0.0	2727.3	O K
2880 min Summer	2.939	1584	40.139	0.639	0.0	304.2	16808.9	0.0	304.2	0.0	2335.4	O K
4320 min Summer	2.049	2304	40.029	0.529	0.0	228.9	17521.9	0.0	228.9	0.0	1854.0	O K
15 min Winter	163.240	118	40.212	0.712	0.0	354.3	6282.0	0.0	354.3	0.0	2671.6	O K
30 min Winter	106.848	136	40.388	0.888	0.0	416.9	8267.4	0.0	416.9	0.0	3547.2	O K
60 min Winter	66.444	160	40.572	1.072	0.0	473.0	10429.4	0.0	473.0	0.0	4563.7	O K
120 min Winter	41.769	204	40.794	1.294	0.0	533.1	13127.8	0.0	533.1	0.0	5939.7	Flood Risk
180 min Winter	31.355	244	40.909	1.409	0.0	561.7	14789.3	0.0	561.7	0.0	6718.1	Flood Risk
240 min Winter	25.326	284	40.969	1.469	0.0	576.2	15931.2	0.0	576.2	0.0	7147.8	Flood Risk
360 min Winter	18.419	362	40.998	1.498	0.0	583.0	17383.3	0.0	583.0	0.0	7358.9	Flood Risk
480 min Winter	14.525	432	40.958	1.458	0.0	573.6	18277.9	0.0	573.6	0.0	7067.6	Flood Risk
600 min Winter	12.012	492	40.903	1.403	0.0	560.4	18893.6	0.0	560.4	0.0	6680.4	Flood Risk

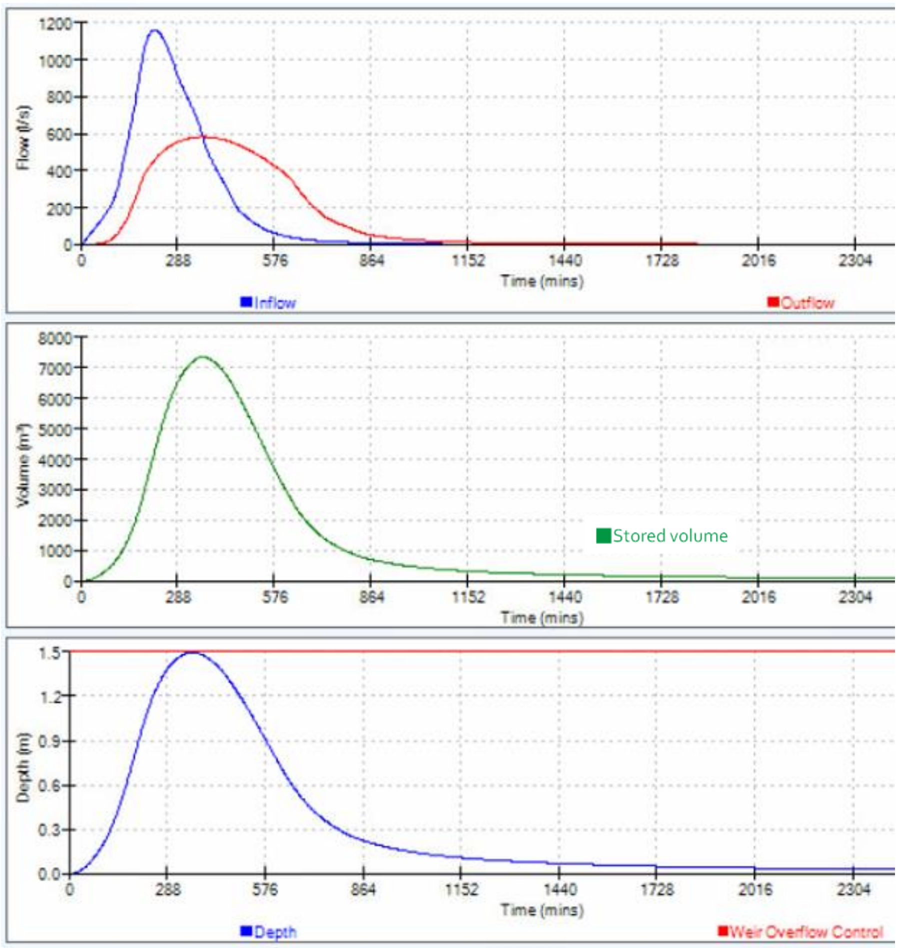


Figure 20 - West catchment model results

Network calculations

5.3.10 The tributary catchments of the proposed main drainage subsystems have been defined. The design flows have been estimated using the following methods:

- IH 124 method for rural catchments. Golf course surface is considered as a rural area;
- Modified Rational Method (MicroDrainage software) for urban catchments. The considered volumetric coefficients (C_v) are 0.75 for winter storm profile and 0.84 for summer profile; and
- The design flows downstream the flow control elements have been estimated from the previous attenuation calculations.

5.3.11 The resulted flows are showed in Table 22.

Zone	Catchment area (m²)	Catchment type	Return period	Flow (l/s)	Drainage element
Academy	51,846	Rural	1 in 5	29	Pipe Ø200mm, slope 0.5%
Hole 2	10,108	Rural	1 in 5	6	Pipe Ø200mm, slope 0.5%
Hole 3	13,390	Rural	1 in 5	8	Pipe Ø200mm, slope 0.5%
Hole 4	18,877	Rural	1 in 5	11	Pipe Ø200mm, slope 0.5%
Hole 6	7,369	Rural	1 in 5	4	Pipe Ø200mm, slope 0.5%
Hole 9	21,014	Rural	1 in 5	12	Pipe Ø200mm, slope 0.5%
Clacks Lane channel	94,186	Urban and rural	1 in 30	484	Trapezoidal channel, slope 0.5%, bottom width 0.5m, 0.75m height, side slope 2H:1V
Eastern urban area / car park / driving range	108,611	Urban and rural	1 in 30	725	Pipe Ø600mm, slope 1%
Channel 1 (pond-flow control 1)	108,611	Urban and rural	1 in 30	725	Trapezoidal channel, slope 0.5%, bottom width 0.75m, 0.5m height, side slope 2H:1V
Ickenham (flow control 1- flow control 2)	9,545	Attenuation calculations	1 in 30	600	Trapezoidal channel, slope 0.5%, bottom width 0.75m, 0.5m height, side slope 2H:1V
Channel 2 (flow control 1-River Pinn)	11,850	Rural	1 in 30	11	Trapezoidal channel, slope 0.5%, bottom width 0.3m, 0.3m height, side slope 2H:1V

Zone	Catchment area (m²)	Catchment type	Return period	Flow (l/s)	Drainage element
Channel 3 (footpath ditches)	12,083	Rural	1 in 5	7	Trapezoidal channel, slope 0.5%, bottom width 0.3m, 0.3m height, side slope 2H:1V

Table 22 - Design flow estimations

6 Comparison of the existing and proposed drainage scheme

6.1.1 Remodelling of the golf course will result in the completely modification of existing ground elevations to the south-west of Clacks Lane and its drainage network. The main drainage elements of the existing network are modified as described in the following sections.

6.1.2 The Ickenham Stream is realigned. The proposed channel recovers the continuity of the channel downstream of the Clacks Lane's crossing. The proposed channel discharges to the River Pinn and it is also used as an attenuation basin and as an ecological corridor. The minimum cross section designed is trapezoidal, 0.75m bottom width, 0.5m height and 2H:1V side slopes. The longitudinal slope is 0.5%. This section is able to carry the 1 in 30 years return period flow. For a higher return period events, the Ickenham Stream performs as an attenuation basin.

6.1.3 The Clacks Lane's channels are intercepted by the Ickenham Stream and their flow is diverted to the proposed basins. Therefore, in the proposed drainage scheme the runoff from the northern urban area will be attenuated before discharging to the River Pinn. In addition, it is proposed to redefine the Clacks Lane's channels downstream of the Ickenham Stream, crossing and replacing the existing culverts at Hill Lane and Celandine Route to improve channels capacity up to 1 in 30 years return period (420 l/s).

6.1.4 The existing central channel is replaced by two ponds (1 and 2) which receive most of the runoff of the application site, including the water from the eastern urban catchment, the West Ruislip Retained embankment, the attenuation tank of West Ruislip Portal asset and the car park. The ponds form part of the first basin, and they are connected to the realigned Ickenham Stream. Therefore, the runoff from the eastern urban catchment is attenuated before discharging to the River Pinn. The eastern urban catchment and the car park drainage are connected to the ponds by a Ø600mm pipeline designed for a 1 in 30 years return period (700 l/s). The channel which connects the pond with the Ickenham Stream and the first basin is designed for the same return period.

6.1.5 The runoff flow rates and volume comparison between the existing and post-development state are shown in Table 23 and Table 24.

Discharge point	**Catchment**	**Q2 (l/s)**	**Q30 (l/s)**	**Q100 (l/s)**	**Q100+ 40% (l/s)**	**V2 (m^3)**	**V30 (m^3)**	**V100 (m^3)**	**V100+ 40% (m^3)**
River Pinn (Clacks Lane)	SC1	463	1,144	1,509	2,101	1,783	3,553	4,741	6,050
River Pinn (central channel)	Golf course (SC2 + SC4)	481	1,195	1,583	2,215	2,527	5,037	6,720	8,792

Discharge point	Catchment	Q2 (l/s)	Q30 (l/s)	Q100 (l/s)	Q100+ 40% (l/s)	V2 (m³)	V30 (m³)	V100 (m³)	V100+ 40% (m³)
Chiltern Mainline tunnel	SC4	106	243	323	450	282	562	749	1,048

Table 23 - Runoff estimation. Existing state

Discharge point	Catchment	Q2 (l/s)	Q30 (l/s)	Q100 (l/s)	Q100+ 40% (l/s)	V2 (m³)	V30 (m³)	V100 (m³)	V100+ 40% (m³)
River Pinn (Ickenham diversion)	East	324	635	823	1,103	1,866	3,963	5,236	7,389
	East and West	216	406	483	583	1,776	3,373	4,763	7,359

Table 24 - Runoff estimation. Post-development

6.1.6 Results comparison shows how flow rates and volumes that discharge to the River Pinn are reduced in the post-development state as a side effect of the volumes provided by the water harvesting system and the landscaping design. The post-development discharging point is located downstream of the two existing discharging points and its flow and volume rates are lower than the sum of the two existing discharging points.

6.1.7 The sub-catchment SC3 which drains to the River Pinn in the west of the application site is not modified from the existing state.

6.1.8 The closure of the tunnel under the Chiltern Mainline by the HS2 development will avoid the area to the south of the railway line draining to the application site. The effect of this closure to the area located to the south of the railway line is being analysed by the HS2 development.

7 Flood Risk Assessment

7.1.1 A site-specific Flood Risk Assessment (FRA) has been carried out and the results are set out in the document 1MC04-SCJ-DR-ASM-SS05_SL07-000001 Flood Risk Assessment.

7.1.2 The proposed drainage design does not significantly alter the way the application site's drainage catchment functions. Currently, the application site's catchment mainly drains to the north, to the River Pinn, and this remains the case in the proposed drainage network.

7.1.3 The designed drainage network will reduce the current runoff flow rates to the River Pinn. The 1 in 100 rainfall event plus 40% climate change is attenuated to 1 in 100 Greenfield rates.

8 Summary

8.1.1 The proposed drainage network discharges into the River Pinn, as it currently does. The Ickenham Stream diversion is integrated into the proposed drainage network of the golf course. The existing tunnel of the Ickenham Stream to the south of the Chiltern Mainline will be disabled by the HS2 development. Attenuated drainage flow rates from HS2 West Ruislip Portal and Embankment are designed to be connected to the Ruislip Golf Course drainage network.

8.1.2 The drainage scheme is formed by gravity drainpipes and channels. The main drainage conduits receive the storm water from the external urban areas. These main drainage conduits are designed for a 1 in 30 years return period.

8.1.3 A surface drainage system is provided for the fairways and rough areas. Surface water is collected by gullies located along the perimeter of the playable areas and run into the main gravity drainpipes. The drainage network will be designed for a 1 in 5 return period rainfall.

8.1.4 Green and tee areas, bunkers and the driving range outfield are drained by subsurface drainage which is connected to the main gravity drainpipes. Footpaths are drained by gullies or ditches.

8.1.5 The irrigation needs of the application site are mainly met by drained water which is collected and stored on site. A water harvesting system is designed as part of the drainage network. The drainage network is connected to three ponds and three tanks which provide the required water storage volume.

8.1.6 The existing runoff rates from urban areas external to the application are considered. This attenuation is a side effect of the resultant volumes of the water harvesting system and the proposed surface of the terrain.

9 References and standards forms

9.1 Standard forms and templates

Title	Reference
HS2-HS2-DR-STD-000-000001	Technical Standard - Cross Drainage
HS2-HS2-EV-STD-000-000011	Technical Standard - Flood Risk
HS2-HS2-EV-STR-000-000022	Approach Document: Climate Change Allowances for Flood Risk Assessments and Drainage Design

9.2 References

Title	Reference
The SuDS Manual	CIRIA Document C753, Construction Industry Research and Information Association, 2015
Rainfall runoff management for developments	Report SC030219, Environmental Agency 2013
Estimating flood peaks and hydrographs for small catchments: Phase 1	Report SC0900, Environment Agency 2012
Flood estimation for small catchments	Report No. 124, Institute of Hydrology, 1994
Hydrology for soil types: a hydrologically based classification of the soils of the United Kingdom	Report No. 126, Institute of Hydrology, 1994
The revitalised FSR/FEH rainfall-runoff method. FEH Supplementary Report No. 1	Thomas Rodding Kjeldsen
Design and analysis of urban storm drainage - the Wallingford procedure.	Volume 1. Principles, methods and practice

10 Appendices

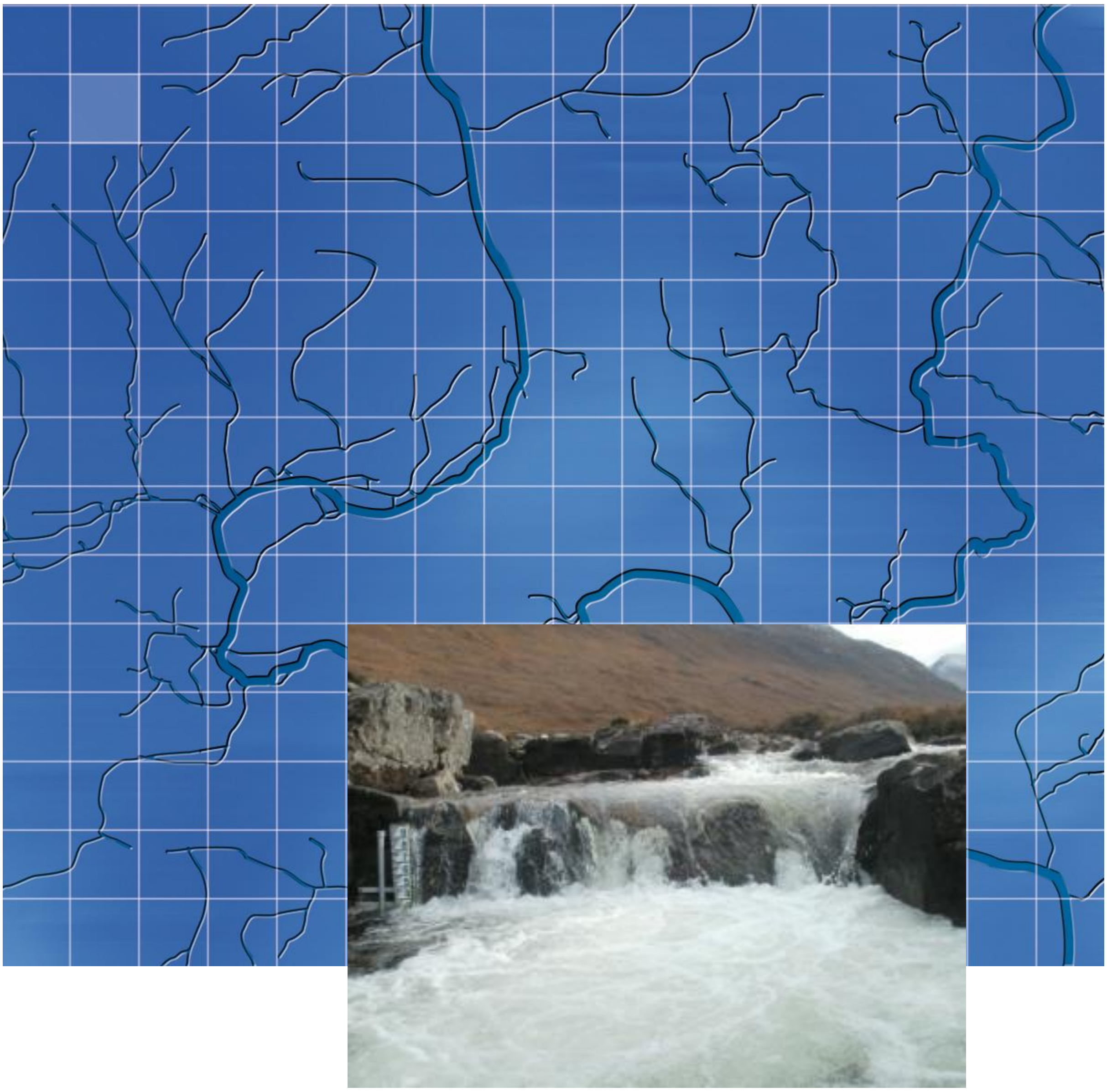
Appendix A: Low flow estimate

Appendix A: Low flow estimate

LowFlows Report 599/18

June 2018

Flow estimate for River Pinn & Ickenham Stream



Wallingford HydroSolutions Limited

For and on behalf of Wallingford HydroSolutions Ltd

Client	Typsa
Prepared by	Daniel Hamilton
Approved by	Jude Jeans
Position	*Technical Director*
Invoice value	435 (excl. VAT)

This report has been produced in accordance with the WHS Quality Management system which is certified as meeting the requirements of ISO 9001:2008.

Registered Office Maclean Building, Benson Lane, Wallingford OX10 8BB
www.hydrosolutions.co.uk

Contents

1 Introduction

This report presents the annual and seasonal flow statistics for the site(s) requested using the LowFlows Enterprise model. The site location(s) have been confirmed using a digital map and copies of the correspondence are contained within Annex 1.

The LowFlows software system is the standard software system used by the Environment Agency, the Scottish Environment Protection Agency and the Northern Ireland Environment Agency for providing estimates of river flows within ungauged catchments. The software and underpinning science have been widely published in the scientific literature. The LowFlows software system is available for purchase as two versions; LowFlows 2 and LowFlows Enterprise. Wallingford HydroSolutions (WHS) is the sole appointed developer and distributor of the LowFlows software system.

Section 2 of the report provides an overview of our consultancy services; specifically our hydrometry services for supplementing the flow statistics presented within this report with at site measurements and flood event estimation services. We also provide a range of software products ranging from the Flood Estimation Handbook (FEH) software through to Hydra 2 to support hydropower design.

Section 3 presents the methods for the derivation of catchment characteristics and the annual and monthly flow estimates. Following the results for each site, Sections 6 and 7 present the assumptions and uncertainties within the flow estimates, followed by the consideration for use in section 8 and the warranty and liability in section 9.

2 WHS Consultancy Services

WHS was founded by the Natural Environment Research Council (NERC) to deliver high quality consultancy services and environmental software systems. WHS has a team of experienced technical staff including leading UK scientists and specialists. We have a proven track record in provision of flood risk, water resources and Environmental (including EIA) consultancy services across the whole of the UK.

WHS has extensive project experience and can offer a service that meets any of your water resources requirements. Water resources and the estimation of river flows is a core WHS capability and we continue to develop methodologies for estimation of flow statistics within ungauged catchments. Our staff have authored all recognised design methods for estimating flow duration curves within the UK since the 1980s.

WHS also has a strong background of working directly with our clients to meet their requirements for field services. Our in-house field team is well equipped to undertake a wide range of field measurement services, ranging from hydrometric, topographic and geomorphological surveys through to aquatic habitat mapping. We provide hydrometric measurements for resource assessment (to include improving the estimation of flood risk) and WHS has substantial experience undertaking both continuous river flow gauging and event driven gauging at remote, rural and urban locations. We are currently operating hydrometric installations at over thirty sites on behalf of our private and public sector clients. Installations can include additional security measures and/or discrete installations to meet the specific requirements of your site. We offer telemetered data transfer and management to ensure data continuity and fast response to vandalism or equipment problems. Our expertise also includes ecology surveys and water quality measurement and analysis.

WHS is committed to continuously improving company performance and customer satisfaction. We are proud of our ISO 9001 certification for the provision of environmental consultancy services, development of hydrological software and associated training. For further information on all of our services and software, please visit our website www.hydrosolutions.co.uk.

3 Derivation of the LowFlows Results

Section 3.1 presents the methods used to define the catchment characteristics, and section 3.2 provides an overview of the long term annual and monthly flow statistics provided for the site(s). The flow statistic estimates contained in this report have been produced by LowFlows Enterprise[(1)] using models and relationships that relate these flow statistics to the climatic and hydrological characteristics of the catchment of interest. All flow statistics provided in this report are for natural flows, thus do not contain any artificial influences such as abstractions, discharges or impounding reservoirs.

3.1 Catchment Characteristics

The following catchment characteristics are provided in the results section of this report:

- **Catchment Area:** The catchment boundary may be derived using either a digital terrain model or an analogue river network based method. The digital method is the default option used in preference to the analogue method but may be misleading or not possible in some areas. The estimation method used to estimate the catchment boundary is identified within the results section for the site(s).
  - The digital method uses a Digital Terrain Model (DTM) to determine the topographic boundaries of the catchment.
  - The analogue method associates grid squares (200 m resolution) to the nearest stretch of river and defines the boundary by selecting grid squares which are assigned to river reaches upstream of the ungauged point.

- **Base-Flow Index (BFI):** The proportion of a hydrograph occurring as base flow, hence varying between zero and unity. BFI is indicative of catchment permeability with values approaching unity associated with highly permeable systems. BFI is estimated from a revised form of the HOSTBFI multivariate linear regression equation [(2)].

[(1)] Young A. R., Grew R. and Holmes M.G.R. 2003. Low Flows 2000: A national water resources assessment and decision support. Water Science and Technology, 48 (10).
[(2)] Boorman, D.B., Hollis, J.M. and Lilly, A. 1994. Hydrology of Soil Types: a Hydrologically-based Classification of the Soils of the United Kingdom. IH Report 126.

3.2 Long Term Natural Flow Statistics

The following long term flow statistics are provided in the results section of this report.

- **Annual Mean Flow (MF):** The estimation of Mean Flow is based on a grid of long term average annual runoff developed by the Centre for Ecology and Hydrology (CEH). This was derived using the outputs from a deterministic water balance model using observed data from over 500 gauged catchments[3].
- **Mean Monthly Flows (MMF):** The MMF for each month are derived from the natural MF estimate by distributing the total average flow volume for the year between the months of this year. This distribution is based upon observed data from hydrologically similar gauged catchments.
- **Annual Flow Duration Curve (FDC) statistics:** The flow duration curve statistics are estimated using a procedure based on measured flow data from hydrologically similar gauged catchments[4]. This methodology was further updated by WHS in 2009. Flows are provided for the following exceedence percentiles: 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, 95, 99.
- **Mean Monthly Flow Duration Curves (MFDC):** The MFDC for each month is estimated using gauged MFDCs from hydrologically and climatologically similar catchments and the estimate of MMF for that month. The MFDC statistics are presented, by month for the following exceedence percentiles: 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, 95, 99.

If these long term natural flow statistics were calculated directly from a gauged flow record the annual statistics would be equivalent to those calculated using all of the daily flow data from all years of record and the monthly statistics for a month equivalent to those calculated from the gauged data for that month from all years.

---

(3) Holmes, M.G.R., Young, A.R., Gustard, A.G. and Grew, R. 2002. A new approach to estimating Mean Flow in the United Kingdom. Hydrology and Earth System Sciences. 6(4) 709-720.

(4) Holmes, M.G.R., Young, A.R., Gustard, A.G. and Grew, R. 2002. A Region of Influence approach to predicting Flow Duration Curves within ungauged catchments. Hydrology and Earth System Sciences. 6(4) 721-731.

4 LowFlows Results for River Pinn

4.1 Catchment Characteristics

The catchment characteristics and map for this catchment are presented in the table and figure below. The catchment is predominantly underlain by impermeable soft massive clays. This is overlain by mineral soils, with a shallow depth to the gleyed layer.

The Pinn at Uxbridge (39098) which is sited downstream of the target catchment (Green catchment in Figure 4.1) was used to provide local data to improve the flow estimates.

Table 4.1 Catchment Characteristics

Basin Details	
Outlet grid reference	507345, 187163
Hydrometric area	39 (South East and West)
Catchment definition method	Digital
Basin area (km²)	28.19
Base-Flow Index	0.18

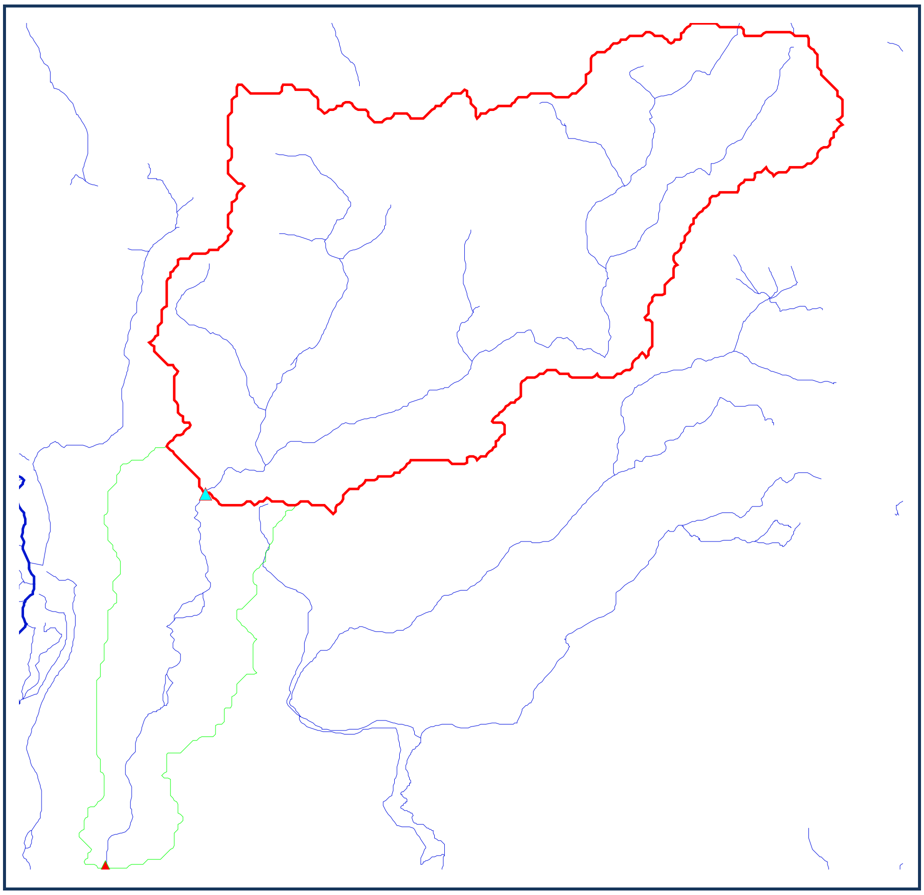


Figure 4.1 Catchment Boundary

4.2 Long Term Natural Flow Statistics

This section presents the long term natural flow statistics. The table below presents both the monthly mean flows and annual flow duration statistics. The annual flow duration curve is also presented in the figure below. It is followed by a table displaying the monthly flow duration statistics.

Table 4.2 Mean Flows and Annual Flow Duration Curve Statistics

Mean Flows	Flow (m³/s)
Annual	**0.212**
January	0.407
February	0.304
March	0.229
April	0.193
May	0.142
June	0.128
July	0.082
August	0.094
September	0.102
October	0.241
November	0.275
December	0.354

Percentile	Flow (m³/s)
5	0.956
10	0.542
20	0.238
30	0.138
40	0.088
50	0.060
60	0.041
70	0.031
80	0.023
90	0.015
95	0.014
98	0.013
99	0.011

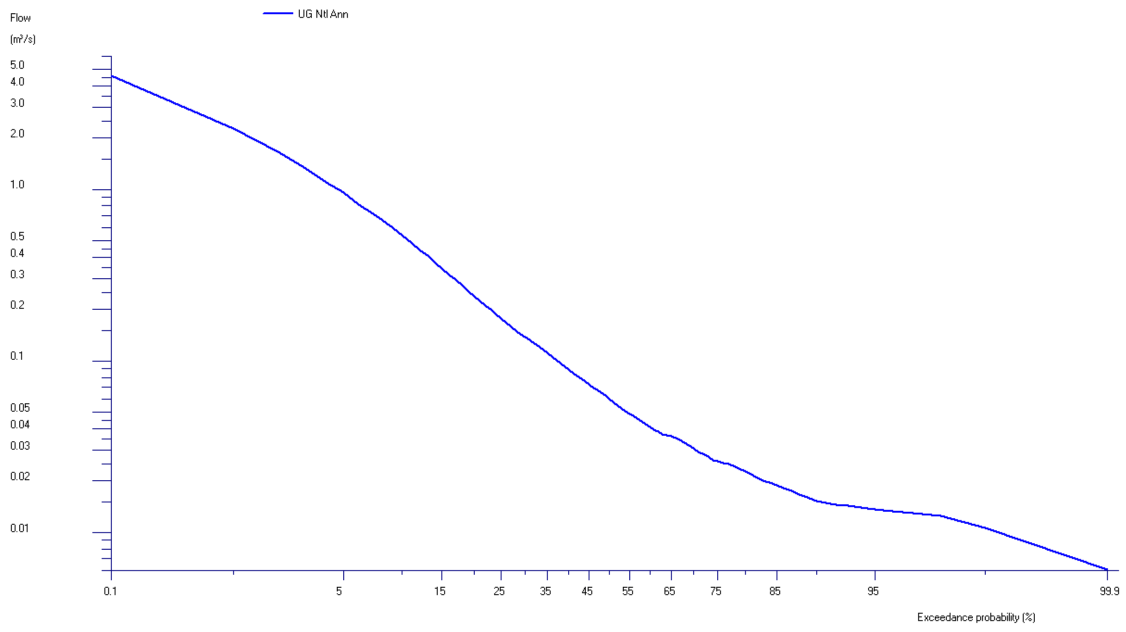


Figure 4.2 Annual Flow Duration Curve

Table 4.3 Monthly Flow Duration Curve Statistics

January		February		March		April	
Percentile	**Q (m³/s)**	**Percentile**	**Q (m³/s)**	**Percentile**	**Q (m³/s)**	**Percentile**	**Q (m³/s)**
5	1.479	5	1.093	5	0.847	5	0.739
10	1.054	10	0.726	10	0.547	10	0.442
20	0.579	20	0.388	20	0.278	20	0.247
30	0.339	30	0.246	30	0.173	30	0.146
40	0.219	40	0.157	40	0.120	40	0.103
50	0.159	50	0.115	50	0.086	50	0.067
60	0.106	60	0.086	60	0.066	60	0.049
70	0.078	70	0.066	70	0.049	70	0.037
80	0.055	80	0.046	80	0.036	80	0.033
90	0.037	90	0.034	90	0.025	90	0.028
95	0.030	95	0.026	95	0.018	95	0.023
99	0.023	99	0.018	99	0.011	99	0.019

May		June		July		August	
Percentile	**Q (m³/s)**	**Percentile**	**Q (m³/s)**	**Percentile**	**Q (m³/s)**	**Percentile**	**Q (m³/s)**
5	0.465	5	0.556	5	0.324	5	0.415
10	0.232	10	0.284	10	0.182	10	0.174
20	0.128	20	0.131	20	0.081	20	0.084
30	0.084	30	0.085	30	0.050	30	0.050
40	0.058	40	0.058	40	0.039	40	0.032
50	0.040	50	0.041	50	0.028	50	0.023
60	0.034	60	0.029	60	0.022	60	0.019
70	0.027	70	0.025	70	0.018	70	0.016
80	0.024	80	0.021	80	0.015	80	0.015
90	0.019	90	0.016	90	0.013	90	0.014
95	0.015	95	0.013	95	0.013	95	0.013
99	0.009	99	0.011	99	0.012	99	0.010

September		October		November		December	
Percentile	**Q (m³/s)**	**Percentile**	**Q (m³/s)**	**Percentile**	**Q (m³/s)**	**Percentile**	**Q (m³/s)**
5	0.525	5	0.963	5	1.123	5	1.335
10	0.193	10	0.517	10	0.700	10	0.857
20	0.081	20	0.233	20	0.349	20	0.538
30	0.047	30	0.132	30	0.203	30	0.289
40	0.031	40	0.083	40	0.137	40	0.172
50	0.022	50	0.051	50	0.092	50	0.120
60	0.018	60	0.039	60	0.061	60	0.083
70	0.015	70	0.026	70	0.040	70	0.064
80	0.014	80	0.018	80	0.029	80	0.043
90	0.013	90	0.015	90	0.021	90	0.031
95	0.012	95	0.014	95	0.018	95	0.026
99	0.010	99	0.011	99	0.014	99	0.019

5 LowFlows Results for Golf Course/Ickenham Stream

5.1 Catchment Characteristics

The catchment characteristics and map for this catchment are presented in the table and figure below. The catchment boundary has been manually derived by the client using a 0.2m DTM contours. The catchment is predominantly underlain by the London Clay formation which is composed of a combination of clay, silt and sand.

As the catchment is under 5km^2, the guidance associated with small catchments available in section 8 should be considered. Furthermore, the precision of the standard LowFlows output is 1 ls^{-1}, therefore due to the size of this catchment some of the flow estimates are below this threshold. To address this the percentage of mean flow (%MF) estimated by LowFlows, has been multiplied by the mean flow to obtain flows at a higher precision outside of the software.

Table 5.1 Catchment Characteristics

Basin Details	
Outlet grid reference	508002, 186979
Hydrometric area	39 (Thames)
Catchment definition method	Manual
Basin area (km²)	0.45
Base-Flow Index	0.17

Figure 5.1 Catchment Boundary

5.2 Long Term Natural Flow Statistics

This section presents the long term natural flow statistics. The table below presents both the monthly mean flows and annual flow duration statistics. The annual flow duration curve is also presented in the figure below. It is followed by a table displaying the monthly flow duration statistics. Flows in the catchment are very low, and in many cases below the precision of the software. The flow estimates for higher percentiles especially should only be used as guide values.

Table 5.2 Mean Flows and Annual Flow Duration Curve Statistics

Mean Flows	Flow (m³/s)
Annual	**0.0034**
January	0.0070
February	0.0051
March	0.0038
April	0.0030
May	0.0022
June	0.0019
July	0.0012
August	0.0013
September	0.0015
October	0.0037
November	0.0043
December	0.0060

Percentile	Flow (m³/s)
5	0.0129
10	0.0074
20	0.0035
30	0.0021
40	0.0014
50	0.0010
60	0.0007
70	0.0006
80	0.0005
90	0.0004
95	0.0003
98	0.0002
99	0.0002

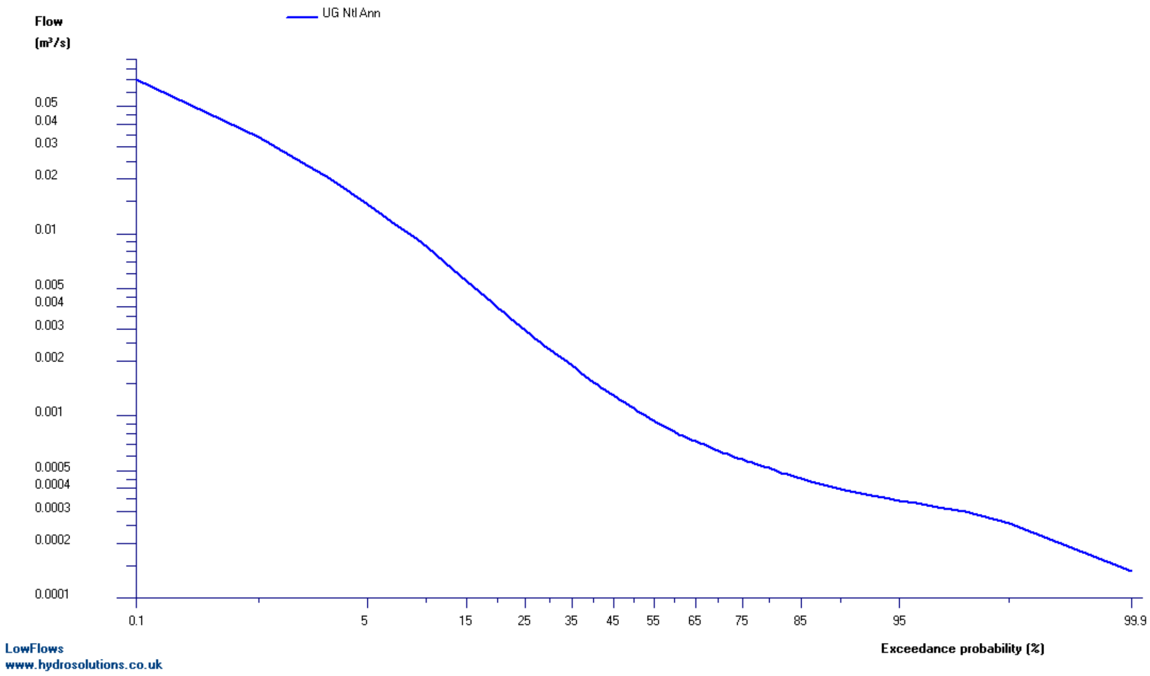


Figure 5.2 Annual Flow Duration Curve

Table 5.3 Monthly Flow Duration Curve Statistics

January		February		March		April	
Percentile	Q (m³/s)	Percentile	Q (m³/s)	Percentile	Q (m³/s)	Percentile	Q (m³/s)
5	0.0238	5	0.0176	5	0.0136	5	0.0115
10	0.0165	10	0.0112	10	0.0094	10	0.0071
20	0.0096	20	0.0062	20	0.0050	20	0.0040
30	0.0059	30	0.0041	30	0.0032	30	0.0024
40	0.0039	40	0.0028	40	0.0022	40	0.0017
50	0.0028	50	0.0021	50	0.0017	50	0.0012
60	0.0021	60	0.0016	60	0.0013	60	0.0009
70	0.0016	70	0.0013	70	0.0010	70	0.0007
80	0.0012	80	0.0010	80	0.0009	80	0.0006
90	0.0010	90	0.0008	90	0.0007	90	0.0006
95	0.0008	95	0.0007	95	0.0006	95	0.0005
99	0.0007	99	0.0006	99	0.0004	99	0.0004

May		June		July		August	
Percentile	Q (m³/s)	Percentile	Q (m³/s)	Percentile	Q (m³/s)	Percentile	Q (m³/s)
5	0.0073	5	0.0082	5	0.0040	5	0.0040
10	0.0038	10	0.0045	10	0.0022	10	0.0019
20	0.0020	20	0.0021	20	0.0010	20	0.0009
30	0.0012	30	0.0013	30	0.0007	30	0.0006
40	0.0009	40	0.0009	40	0.0005	40	0.0005
50	0.0007	50	0.0007	50	0.0005	50	0.0004
60	0.0006	60	0.0006	60	0.0004	60	0.0003
70	0.0005	70	0.0005	70	0.0003	70	0.0003
80	0.0005	80	0.0005	80	0.0003	80	0.0003
90	0.0004	90	0.0004	90	0.0003	90	0.0002
95	0.0004	95	0.0004	95	0.0003	95	0.0002
99	0.0003	99	0.0003	99	0.0002	99	0.0002

September		October		November		December	
Percentile	Q (m³/s)	Percentile	Q (m³/s)	Percentile	Q (m³/s)	Percentile	Q (m³/s)
5	0.0046	5	0.0157	5	0.0157	5	0.0202
10	0.0020	10	0.0087	10	0.0097	10	0.0140
20	0.0009	20	0.0041	20	0.0051	20	0.0086
30	0.0006	30	0.0024	30	0.0031	30	0.0048
40	0.0004	40	0.0016	40	0.0021	40	0.0031
50	0.0004	50	0.0011	50	0.0014	50	0.0023
60	0.0003	60	0.0008	60	0.0011	60	0.0017
70	0.0003	70	0.0007	70	0.0008	70	0.0013
80	0.0003	80	0.0006	80	0.0007	80	0.0010
90	0.0002	90	0.0005	90	0.0005	90	0.0008
95	0.0002	95	0.0004	95	0.0005	95	0.0007
99	0.0002	99	0.0003	99	0.0004	99	0.0006

6 Assumptions

Assumptions implicit in the estimated flow estimates are:

- Only natural flow statistics have been estimated and the impact of any artificial influences (for example abstractions, discharges or impounding reservoirs) is not included.
- The topographic catchment area identified is assumed to accurately reflect the true catchment area contributing to flows at the catchment outlet.
- The flow estimates are based on long term average records.

7 Model Uncertainty

The figures for factorial standard error of estimate for long term mean flow and Q95 are shown in Table 7.1. So, as an example the uncertainty in the estimate of mean flow in Scotland will generally be less than 11%. These standard errors are presented as a general guide only and should be considered in the context of the information presented within section 8. These errors are broadly comparable to the sampling errors that might be expected if mean flow was calculated from two to three years of error free gauged data and Q95 for in the order of five years error free gauged data.

Table 7.1 Model Factorial Standard Error (FSE)

Regions of the UK	FSE Mean Flow	FSE Q95
England and Wales	16	42
Scotland	11	35
Northern Ireland	11	30

8 Consideration for Use

The predictive performance of the Mean Flow and FDC Estimation Models may vary according to local conditions. The following is a list of significant, but not comprehensive, issues that need to be considered when estimating flows within ungauged catchments:

- Care needs to be taken when interpreting the results in smaller groundwater catchments in which river flows may be strongly influenced by point geological controls (such as spring lines and swallow holes).
- A catchment water balance is assumed within the LowFlows software; this assumption may be incorrect in smaller groundwater fed catchments where part of the regional groundwater flow bypasses the surface water catchment.
- The estimation of Mean Flow is based on a grid of long term average annual runoff developed by CEH. This was derived using the outputs from a deterministic water balance model using observed data from over 500 gauged catchments. The predictive performance of the model may therefore be reduced in areas of low rainfall gauge density.
- Care needs to be taken when interpreting the result in very small catchments as the size of the catchment approached the spatial resolution of the underlying catchment characteristic datasets within LowFlows (1 km^2).

- Where available local measured flow data should be used to corroborate the LowFlows software estimates. This is good practice when using any generalised hydrological model.

9 Warranty and Liability

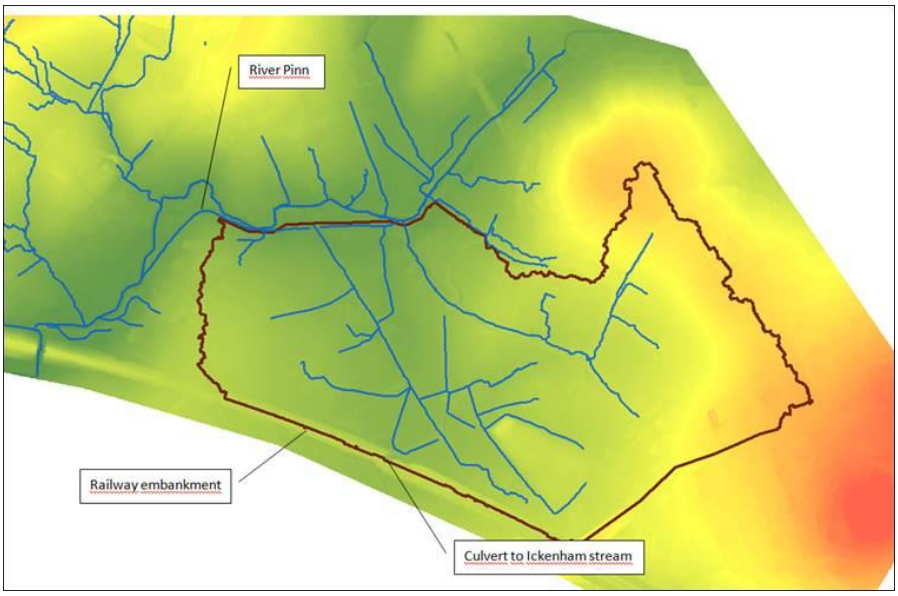
1. The assumptions and uncertainties associated with the flow estimation methods must be considered when making use of flow estimates produced by the system.
2. You are responsible for the interpretation of the Results presented within this report and training in the use of the estimation methods is strongly recommended.
3. Subject to 1 and 2 above, WHS do not seek to limit or exclude liability for personal injury or death arising from our negligence.
4. Except for 3 above our entire liability for any breach of our duties, whether or not attributable to our negligence, is limited to the fee that you have paid for this report.
5. Except for 3 and 4 above, in no event will WHS be liable to you for any damages, including lost profits, lost savings or other incidental or consequential damages arising on your use of the results even if we have been advised of the possibility of such damages.
6. Should any of these provisions be ruled invalid under any law or Act of Parliament, they shall be deemed modified or omitted only to the extent necessary to render them valid and the remainder of these provisions shall be upheld.

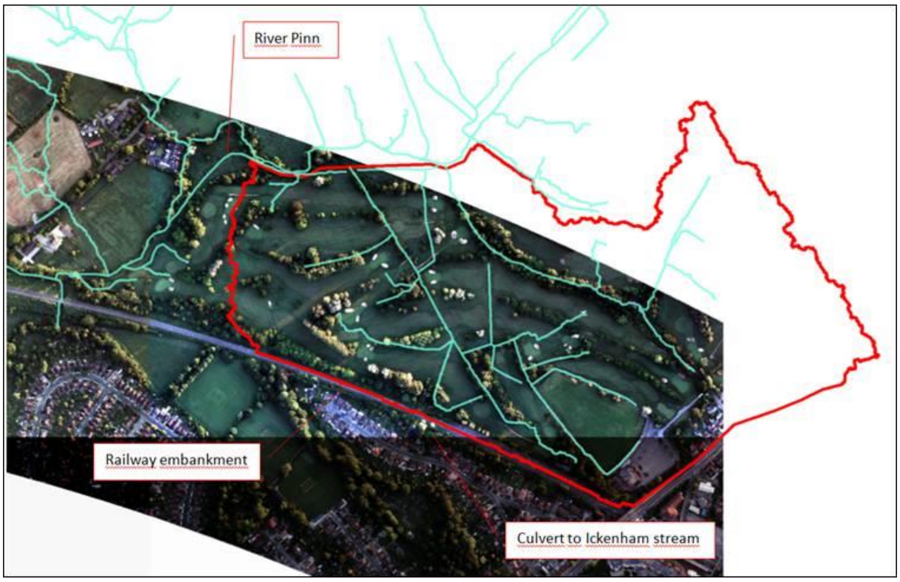
Annex 1: Copies of key correspondence with the client

From: GUERRERO GUERRERO NOEMI <nguerrero@typsa.es>
Sent: 14 June 2018 11:58
To: lowflows@hydrosolutions.co.uk
Cc: BALANZA GARZON VICENTE <vbalanza@typsa.es>
Subject: FW: WHS Website enquiry - Tue, 05 Jun 2018 15:36:48 +0000

Dear Daniel,
We are studying the area between the River Pinn and the existing railway, which belongs to the Ruislip golf course.
Initially, we thought this area was draining to the South, to the Ickenham Stream. However, we have just studied in detail this area using an accurate DEM (cell size 0.2 m) and the results show a different performance. Right now, we see how the whole area of the golf course drains to the North, to the River Pinn (at least for low flows).
We are interested in the low flows of this area (approximately 45 ha).
Please see below a scheme of the golf course catchment performance.
Please, let me know any other doubt you have.
Thank you in advance.
Regards,

Noemí Guerrero





De: GUERRERO GUERRERO NOEMI
Enviado el: miércoles, 13 de junio de 2018 12:28
Para: BALANZA GARZON VICENTE
Asunto: FW: WHS Website enquiry - Tue, 05 Jun 2018 15:36:48 +0000

Hola, te podrías encargar por favor?

From: lowflows@hydrosolutions.co.uk [mailto:lowflows@hydrosolutions.co.uk]
Sent: miércoles, 13 de junio de 2018 10:55
To: GUERRERO GUERRERO NOEMI <nguerrero@typsa.es>
Subject: RE: WHS Website enquiry - Tue, 05 Jun 2018 15:36:48 +0000

Hello Noemi,

We have completed an estimate for the River Pinn, however the Ickenham stream looks to be very complicated. The stream bifurcates from the River Pinn at E508195 N187609 (see attached). Therefore we can not simply estimate the catchment area, as this will also incorporate the catchment area of the River Pinn leading to a significant overestimation of flow.

To make a reasonable flow estimate we would need local information on how water is divided between the two watercourses at the point where the two watercourses split. If you do have any data on this please send this through, and we should be able to make estimate.

If not, we could provide you with a flow estimate at the divide (E508195 N187609) if this would be helpful? Alternatively a refund can be provided for the second estimate.

Any queries let me know.

Kind Regards,

Dan

Daniel Hamilton
Consultant

Wallingford HydroSolutions Ltd
Castle Court, 6 Cathedral Road, Cardiff, CF11 9LJ
Direct Tel : +44 2920647739
Email : daniel.hamilton@hydrosolutions.co.uk
www.hydrosolutions.co.uk

Hi Noemi

Please find attached our proforma invoice.

Could you pass this on to your accounts team for processing and payment. As soon as payment is received the lowflows team will start to prepare your report.

If you have any queries in the meantime, please feel free to contact this office and quote reference: LF

Kind regards,

Lindsey Ramsay

From: GUERRERO GUERRERO NOEMI [mailto:nguerrero@typsa.es]
Sent: 07 June 2018 11:40
To: WHS Accounts <accounts@hydrosolutions.co.uk>
Subject: RE: WHS Website enquiry - Tue, 05 Jun 2018 15:36:48 +0000

Good morning,

We are based in the UK, please see the company details:

Typsa Limited
6th Floor. 2 Kingdom Street
W2 6BD London - UK
VAT number: GB 268945054

Kind regards,

Noemí Guerrero

From: WHS Accounts [mailto:accounts@hydrosolutions.co.uk]
Sent: jueves, 7 de junio de 2018 10:57
To: GUERRERO GUERRERO NOEMI <nguerrero@typsa.es>
Subject: FW: WHS Website enquiry - Tue, 05 Jun 2018 15:36:48 +0000

Dear Noemi,

We are happy to issue a Proforma Invoice, and notice that you are not based in the UK.

Could you please send me your company address details and VAT number so that we can create the proforma invoice.

Kind regards,

Lindsey Ramsay
ACCOUNTS MANAGER

From: lowflows@hydrosolutions.co.uk [mailto:lowflows@hydrosolutions.co.uk]
Sent: 06 June 2018 15:52
To: nguerrero@typsa.es
Cc: 'WHS Accounts' <accounts@hydrosolutions.co.uk>
Subject: RE: WHS Website enquiry - Tue, 05 Jun 2018 15:36:48 +0000

Hello Noemi,

I can advise that low flows estimates at the locations specified will cost £435 + VAT. This includes £360 for the two estimates and a further £75 for manual definition of the catchment at TQ 07354 87175 given its size.

As you are a new customer we will require payment in advance before commencing the work. If you could also provide us with an invoice address for our records, that would be appreciated. Payment can be made via one of the following options:

By Cheque : Payable to Wallingford Hydrosolutions Ltd

By BACS : Account : Wallingford Hydrosolutions Ltd

Sort Code : 40-34-27 Account : 52177145

Alternatively I can arrange for our accounts team to provide you with a proforma invoice.

Once payment is received I will begin progressing the report straightaway. We will look to deliver the report within 10 working days on receipt of payment.

Kind Regards,

Dan

Daniel Hamilton

---------- Forwarded message ----------
From: **Noemi Guerrero** <software@hydrosolutions.co.uk>
Date: 5 June 2018 at 16:36
Subject: WHS Website enquiry - Tue, 05 Jun 2018 15:36:48 +0000
To: software@hydrosolutions.co.uk

Name: Noemi Guerrero
Email: nguerrero@typsa.es

Message:
Dear Sir/Madame We would like to order the river low flow estimation at the following points. - TQ 07354 87175. River Pinn - TQ 08002 86982. Ickenham Stream Please, find in the attached file two images of the FEH map where the previous points are showed. Could you please provide us an estimation of submission date of the required data? And how we should we the payment? It will be done by a company and we will need an invoce pro-forma, the instructions to proceed to the payment and which information of the company you need to generate the pro-forma. Thank you. Kind regards, Noemi Guerrero