AAH planning consultants

FLOOD RISK ASSESSMENT

LAND AT NOS. 23-25 OLD ROW, BARROW, BB7 9AZ

PROPOSED RESIDENTIAL DEVELOPMENT

Our Ref: 46648

FEBRUARY 2016

FLOOD RISK ASSESSMENT

Contents

1.0 Introduction

1.1 AAH Planning Consultants have been commissioned to perform a Flood Risk Assessment (FRA) in support of the outline planning application for the erection of 23 dwellings on Land at 23-25 Old Row in Barrow located to the south of Clitheroe.

1.2 The National Planning Policy Framework (NPPF) identifies that Flood Risk Assessments should be conducted for new developments proposed on the floodplains of rivers, sites potentially subject to coastal flooding, and for developments of one hectare in size and above. Sites within critical drainage areas may also be subject to flood risk assessment irrespective of fluvial/tidal flood zoning.

1.3 The site is within the administrative area of Ribble Valley Borough Council Local Planning Authority in an area broadly classified by The Environment Agency (EA) as Flood Zone 1. The site area is just in excess of one hectare. The sewer network in the area is controlled by United Utilities, the drainage undertaker.

1.4 Consultation with Colin Worswick, the EA area development control engineer in June 2012, June 2014, and subsequent generic planning advice from the EA in February 2016 has agreed a proposed scope of FRA for the outline planning application. This assessment is constrained to calculation of a limiting discharge rate from the site based on the existing green runoff rate and calculation of critical storage/attenuation volumes.

1.5 The open/agricultural use of the site is cited in table 2 of the NPPF online matrix as 'water compatible' since there is no notable development on the open site. The proposal would be for a residential development (use class C3) and therefore a 'more vulnerable' development to flooding land use category. The proposal constitutes an increase in the flood risk vulnerability of the site.

1.6 A topographic survey of the site was undertaken by Survey Solutions in 2012. The site survey shows a significant fall from east to west, with the low point of the site adjacent to Whalley Road, whilst the extents of the site subject to residential development peak on its eastern boundary.

2.0 The Site as Existing

2.1 The site is located approximately halfway between the settlements of Clitheroe (to the north) and Whalley (which lies south), in the small settlement of Barrow in Lancashire, immediately east of Whalley Road. This highway provides both vehicular and pedestrian access to the plot.

2.2 The site subject to planning consideration has a plan area of 1.16 hectares and is predominantly undeveloped land which it is understood is currently used for agricultural purposes. On the northwest corner of the site are two small detached garage units which do not appear to benefit from any formal roof drainage. The site boundaries are predominantly lined with trees, and a small land drainage ditch is located on the southern boundary of the site.

2.3 Table 2 of the NPPFTG states that non residential buildings such as the garages on the site would be 'less vulnerable' development to flooding, however the overarching land use associated with the majority of the site footprint is open pasture which is 'water compatible'.

2.4 A topographic survey of the site has been undertaken on behalf of the client by Survey Solutions. In line with best practice, the Ordnance Survey national grid coordinates were used to establish survey control point ST01 using GPS and related to OSTN02(GB) and OSGM02(GB). The site survey shows a significant fall from east to west, with the low point of the site adjacent to Whalley Road 74.86m AOD whilst the extents of the site subject to residential development reach approximately 80.00m AOD on its eastern boundary.

3.0 Development Proposal

3.1 The proposed development would see the erection of approximately 23 residential dwellings on the site however due to the indicative nature of the outline planning application the layout is not fixed. The proposed C3 use class is ‘more vulnerable’ development to flooding in accordance with table 2 of the NPPF Matrix.

3.2 The proposal would incorporate areas of hardstanding to the front and side of each property and an access road which would be constructed to an adoptable standard. The remainder of the site would comprise soft landscaped areas.

3.3 The proposed dwellings on the site are assumed to have a footprint of approximately 0.14ha with areas comprising the road and private hardstanding 0.43ha. The combined impermeable footprint would be approximately 0.57ha which represents 49% of the 1.16ha site.

3.4 Preference would be for surface water from the developed areas of the site to connect to the open land drain which flanks the southern site boundary, with a rate equivalent to the calculated Greenfield runoff rate used as the limiting discharge rate and the base for attenuation storage calculations. Where connection to this watercourse is not possible due to third party land ownership issues, consent to discharge to the public sewer would be sought from the Drainage Undertaker.

4.0 Surface Water Drainage

4.1 The proposed development should not increase, and where possible reduce the risk of flooding to downstream properties from all perspectives, and upon this basis the sustainable management of surface water is a key consideration for the proposal. In accordance with the sustainable hierarchy contained in the NPPF preference should be for infiltration systems, discharge to an open watercourse, a surface water sewer or a combined sewer in that order of preference.

Site Control; Infiltration Systems

4.2 The published geology of the site shown on the British Geological Survey Geoindex implies drift deposits comprising Diamicton (usually glacial clay) whilst the bedrock geology of the site is a Hodder Mudstone formation. Both the above drift and bedrock of the site are characteristically impermeable and as such it is unlikely that infiltration systems for full disposal of surface water to the ground would be viable.

Discharge rainwater to a watercourse

4.3 It is proposed that the development would discharge surface water arising from the impermeable areas to the ordinary watercourse/ land drain adjacent to the southern border of the plot, unless specific third party land ownership issues prevent such an approach.

4.4 The EA has indicated in pre-application discussions that at the outline planning stage the limiting discharge rate from the site would be conditioned, based upon the Greenfield runoff rate calculated in accordance with the Institute of Hydrology Report 124, 'flood estimation for small catchments' methodology. The calculated permissible runoff rates for the site are provided for the 1, 30, and 100 year storm events without an allowance for climate change (30% increase in rainfall intensities).

4.5 The FRA assumes a precautionary limiting discharge rate from the site equivalent to the IOH124 Greenfield runoff rate for the 0.57ha impermeable footprint. The above is considered a prudent approach in terms of required storage and limiting discharge. A summary of the IOH124 Greenfield runoff rates are shown below;

Institute of Hydrology Report 124 Greenfield Runoff Rate						
1 year	2 year	5 year	30 year	100 year	200 year	Units
0.004	0.004	0.005	0.008	0.009	0.011	cumecs
3.80	4.47	5.41	7.51	9.39	10.73	l/s
6.67	7.85	9.49	13.18	16.47	18.83	l/s/Ha

Evaluation of Storage Solutions

4.6 The peak flow storage programme within the Masterdrain Drainage Software was used to calculate the critical storage volume and durations of the 1, 30 and 100 year storm events. Consideration is given to rainfall events both with and without a 30% increase in rainfall intensities over the lifetime of the development attributable to climate change. An assumption is made that the proposed impermeable footprint would be 0.57ha and that the Greenfield runoff rate is used as the limiting discharge rate. The calculated storage volumes are summarised below;

Storm Event	Limiting Discharge (l/s)	Critical Storage Volume (m^3)	Critical Storage Volume +CC (m^3)
1	3.80	50.2	65.2
30	7.51	113.8	147.9
100	9.39	153.1	199.0

Ponds and Swales

4.7 Due to the significant 199m^3 volume of storm water storage which is likely to be required on the site it as anticipated that the most economically viable solution will be above ground Sustainable Drainage Systems (SuDS) such as ponds and swales which may be incorporated in to any open space contribution offered as part of the development.

4.8 The most suitable location for these areas will be on the lowest ground comprising the southeast corner of the site. Here runoff can be stored as part of a site control SuDS system. The shallow gradient of SuDS used for water conveyance purposes can be as low as 1:500 thus allowing for easier lateral flow across the site to the south towards the outfall of the system in to the land drain. The use of ponds and swales will also afford a degree of surface water runoff treatment and potentially afford ecological benefits to the site.

4.9 A flow control device such an orifice would be used downstream of the storage crates to attenuate the rate of discharge.

Geocellular Storage

4.10 Where SuDS are not deemed viable by the developer, the 199m^3 of storm water storage could be provided on site to attenuate flows arising above the limiting discharge rate during the 1% AEP storm with an allowance for climate change in below ground geocellular tanks underlying hard or pervious external surfaces.

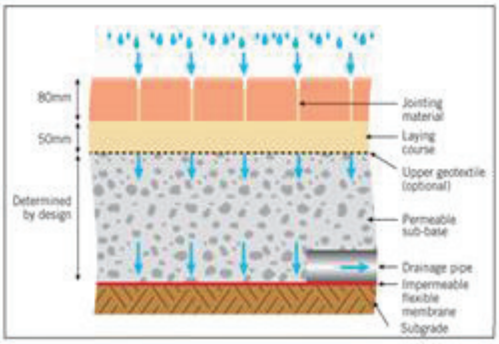
4.11 There are now a large number of pre-manufactured tanks available that could store storm water for later discharge to the adjacent land drain. These units would provide the most compact volume of storage with up to a 96% void spacing although it is noted that these systems are often more expensive than other alternatives.

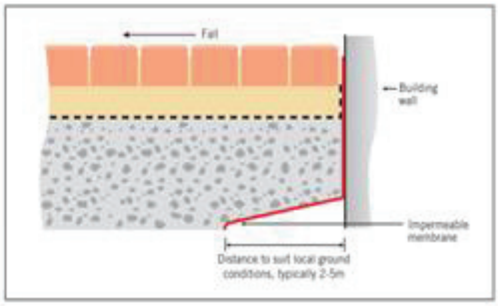
4.12 A flow control device such a hydrobrake (or similar vortex control device) or orifice would be used downstream of the storage crates to attenuate the rate of discharge.

Pervious Pavements

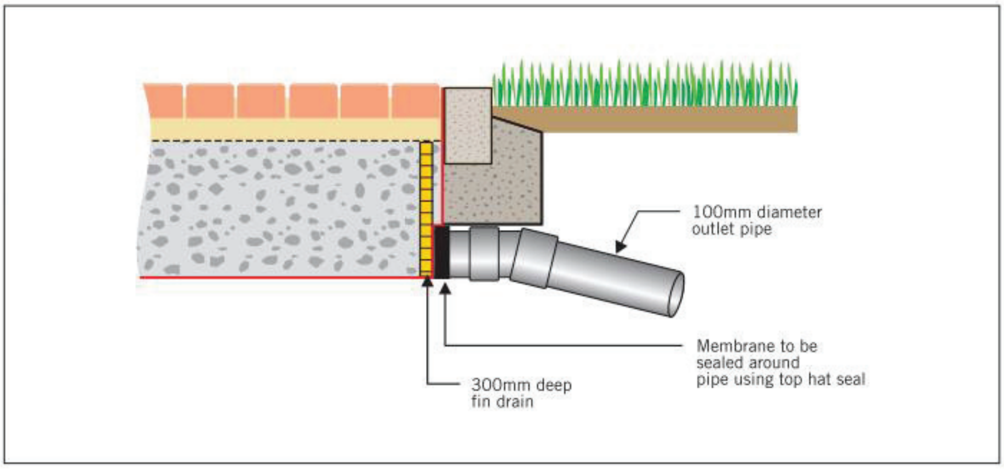
4.13 The use of pervious pavement for parking areas with an increased depth of sub-base to provide storage within aggregate voids could present the optimum solution. This approach would offer full onsite attenuation of storm water, with a modest depth of storage and minimal additional land take.

4.14 All pervious pavement areas for attenuation opposed to source control within a distance of 5m from building footings would need to be a closed system (Type C system in accordance with Interpave's permeable pavement design guidance) as this would reduce the risk of subsidence to the proposed dwellings. The pervious pavement would benefit from an outfall to the adjacent land drain. Indicative sealed pervious pavement cross sections are summarised in the illustration below;

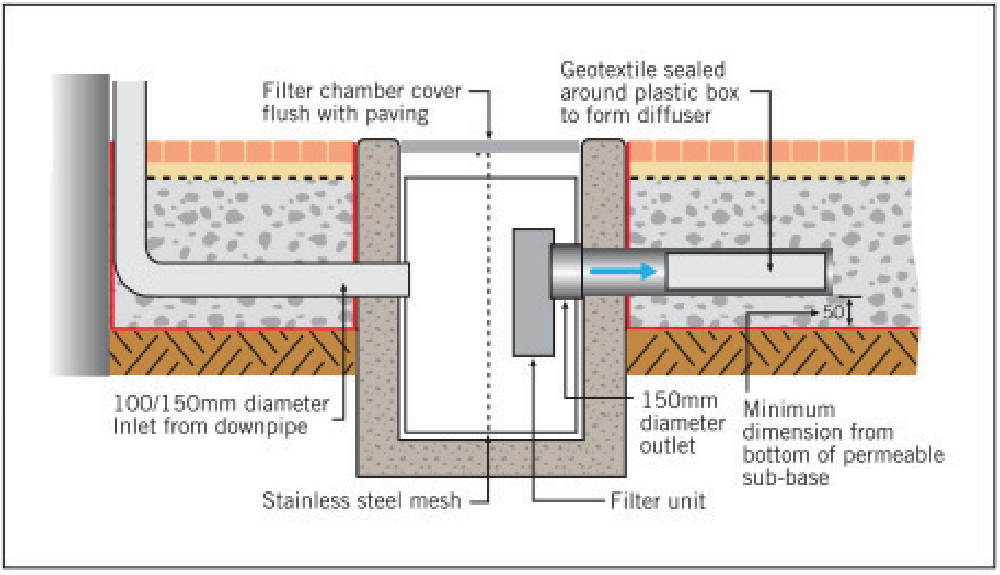




4.15 It is anticipated that any pervious pavement sub-base would discharge via fin drains to a Hydrobrake (or similar) flow control chamber for subsequent discharge to the receiving watercourse. Roof water flows from the proposed building could discharge into the pavement sub-base via a flow diffuser. A standard outlet and inlet are shown below, sourced from Guide to the Design, Construction and Maintenance of Concrete Block Permeable Pavements;



Standard Pervious Pavement outlet



Standard Pervious Pavement inlet

4.16 The surface of the assumed pervious pavement area could be formed from permeable block pavement, pervious asphalt, or decorative resin bound gravel, and each would allow infiltration through the hardstanding surface and into the lower levels of the pavement.

Drainage Summary

4.17 At the outline planning stage, the surface water drainage advice contained in this report is conceptual report may therefore be subject to change depending upon the final drainage design for the site and indeed the final site layout, which would be conditioned at the outline planning stage of the development.

4.18 In addition to the above, a fundamental point to consider is that the outfall from site surface water infrastructure is currently assumed on an area of land adjacent to the site boundary which it is understood is council owned. Where unexpected third party issues mean that it is not viable for the development to discharge to this watercourse, it would be necessary for the Drainage Undertaker to use their statutory powers to requisition a route for the new surface water sewer proposed to the land drain, or for consent to discharge to the public sewer to be sought.

5.0 Conclusion

5.1 The proposed development site solely comprises Flood Zone 1 the low flood risk area. Because the footprint of the plot is over 1 hectare, the proposal is subject to flood risk assessment in accordance with the National Planning Policy Framework.

5.2 The flood risk vulnerability of the site increases from 'water compatible' to 'more vulnerable' development to flooding. The location of the more vulnerable development in Flood Zone 1 is a principle encouraged by the both local and national planning policy.

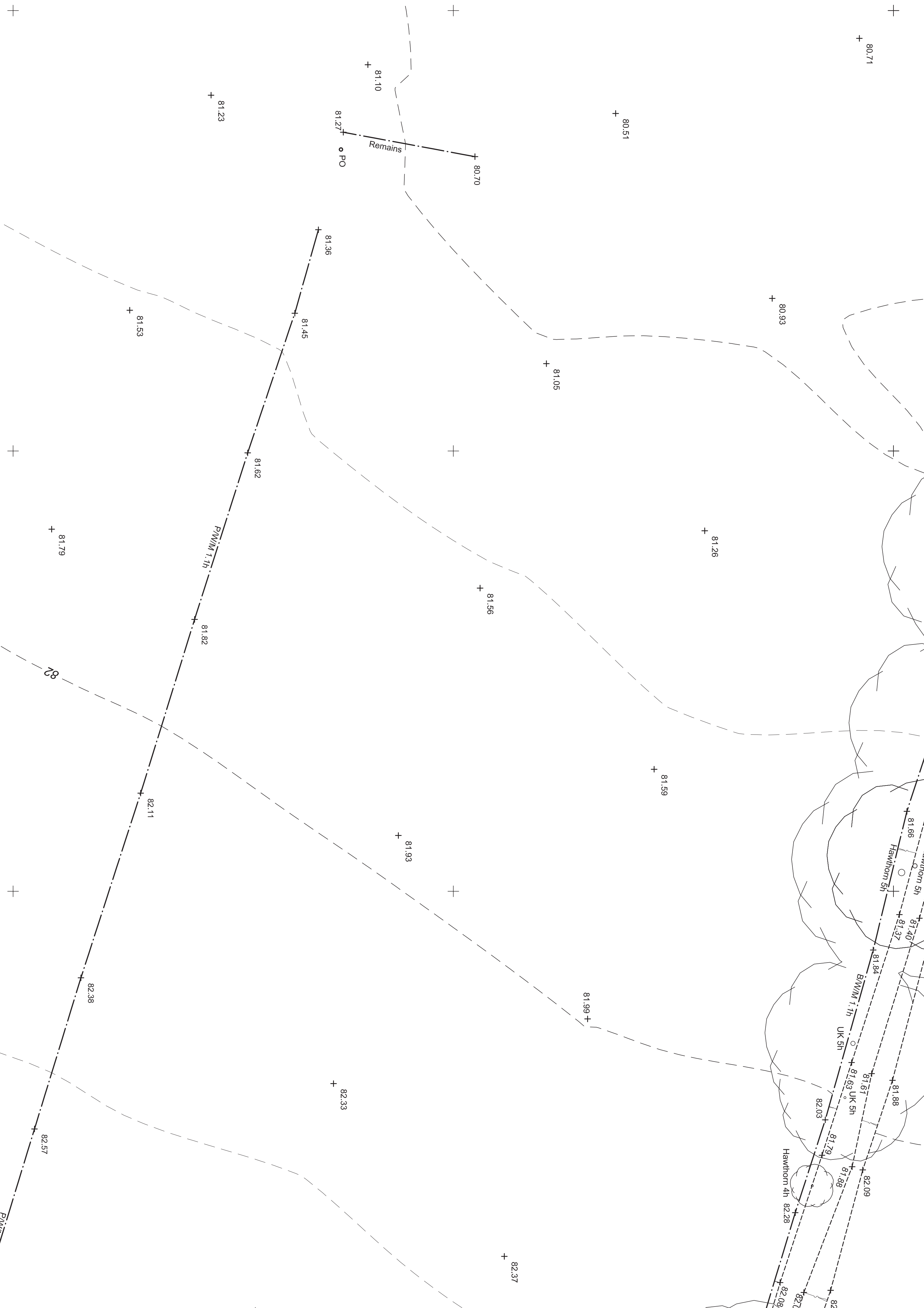
5.3 At the outline planning application stage, indicative surface water calculations imply that the site could utilise the calculated Greenfield runoff rate as the limiting discharge rate from the proposed surface water drainage network. At this early stage it is anticipated that the critical storage volume associated with the 100 year + Climate Change storm event would be provided via attenuations systems opposed to infiltration due to the impermeability of the local geology.

5.4 The proposal is considered to comply with both local and national planning policy requirements with regards for sustainable management of surface water.

APPENDIX A

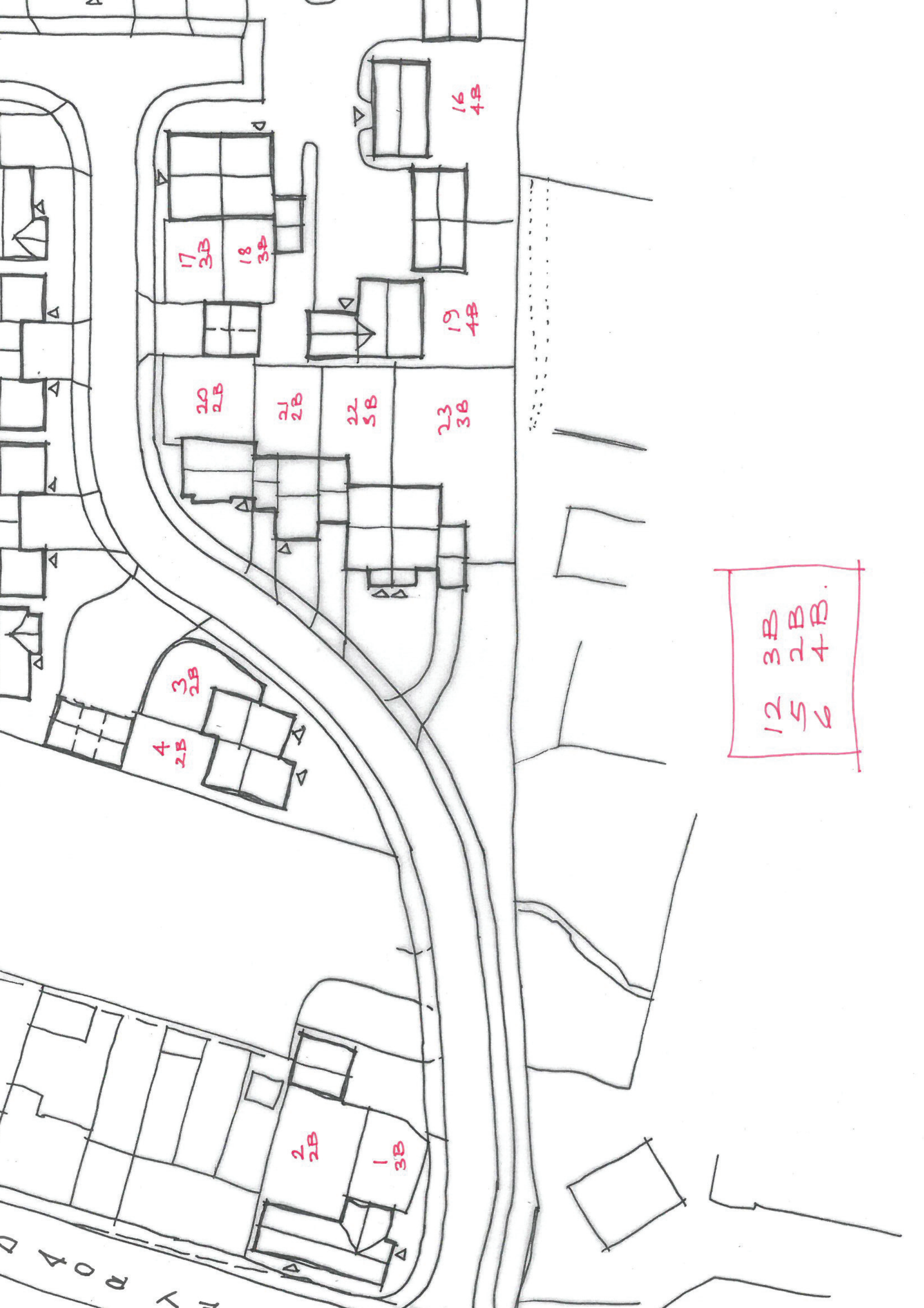
TOPOGRAPHIC SURVEY

La Traverna
Italian Restaurant
RL 84.01
EL 81.10
Drainage Channel
Coal Shute
Asphalt
Concrete
Wall 0.5h
Wall 0.3h
EL 81.60
Concrete paved
OHL
EL 79.45
RL 81.39
EL 79.41
RL 81.64
RL 81.66
RL 81.76
RL 81.92
Adjoining Properties
EL 79.92
EL 82.78
Bay Horse Inn
Adjoining Property
RL 85.35
RL 82.23
Conc
RL 79.01
EL 77.72
EL 78.10
Flat Roof 77.88
Unmade ground
Concrete paved
EL 78.38
EL 77.93
Syc 9h
EL 78.60
RL 79.51
Wall 1.1h
S402
Private Property
Conifer Tree hedge 4h
Wall 0.8h
RL 79.37
EL 78.55
C/B 1.6h
Wall 1.2h
EL 78.09
RL 78.91
Bush
Conc paved
Flat Level 79.15
C/B 1.6h
Wall 0.5hC/B 0.9h
Private Property
Unmade ground
UK 3h


81.10
81.23
81.27
Remains
PO
80.70
80.51
80.71
81.36
81.45
81.53
80.93
81.05
81.62
PWM 1.1h
81.79
81.26
81.56
81.82
82
82.11
81.59
81.66
Hawthorn 5h
81.93
81.37
81.40
81.84
B/WM 1.1h
UK 5h
81.99
81.63
81.61
UK 5h
81.88
82.03
82.33
81.79
81.86
82.09
Hawthorn 4h
82.28
82.57
82.38
82.37

APPENDIX B

PROPOSED DEVELOPMENT PLAN


16 4B
17 3B
18 3B
19 4B
20 2B
21 2B
22 3B
23 3B
3 2B
4 2B
2 2B
1 3B
12 3B
5 2B
6 4B.

APPENDIX C

SURFACE WATER DRAINAGE CALCULATIONS

Hydrological Data:-

FSR Hydrology:-

Location = WHALLEY	Grid reference = SD7335
M5-60 (mm) = 18.8	r = 0.30
Soil runoff = 0.47	SAAR (mm/yr) = 1060
WRAP = 4	Area = England & Wales
Hydrological area = 10	Hydrological zone = 4

Soil classification for WRAP type 4
Clayey, or loamy over clayey soils with an impermeable layer at shallow depth.

Design data:-

Area = 0.0057 Km² - 0.57 Ha - 5700 m²

Calculation method:-

Runoff is calculated from:-

$$Q_{BAR(rural)} = 0.00108\ AREA^{0.89}\ .\ SAAR^{1.17}\ .\ SOIL^{2.17}$$

where

AREA = Site area in Km²
SAAR = Standard Average Annual Rainfall (mm/yr)
SOIL = Soil value derived from Winter Rainfall Acceptance Potential
$Q_{BAR(rural)}$ = Runoff (cumecs)

$Q_{BAR(rural)}$ is then multiplied by a growth factor - GC(T) - for different storm return periods derived from EA publication W5-074/A.

Calculated data:-

For areas less than 50Ha, a modified calculation which multiplies the 50Ha runoff value by the ratio of the site area to 50Ha is used
Reducing factor used for these calculations is 0.011

Mean Annual Peak Flow $Q_{BAR(rural)}$ = 4.47 l/s

Values for $Q_{BAR(rural)}$

1 year	2 year	5 year	30 year	100 year	200 year	Units
0.004	0.004	0.005	0.008	0.009	0.011	cumecs
3.80	4.47	5.41	7.51	9.39	10.73	l/s
6.67	7.85	9.49	13.18	16.47	18.83	l/s/Ha
0.850	1.000	1.210	1.680	2.100	2.400	GC(T)

The above is based on the Institute of Hydrology Report 124 to which you are referred for further details (see Sect 7).
Note that the 200 year growth curve was taken from W5-074/A.

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Job No.		
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By	Checked	Approved

Project Land North of Barrow Brook Business Park

Title Peak flow storage calcs for WHALLEY

Data:-

FSR Hydrology:-

Location = WHALLEY
M5-60 (mm) = 18.8
Soil index = 0.45
Return period = 1
UCWI = 107.9

Grid reference = SD7335
r = 0.30
SAAR (mm/yr) = 1060
WRAP = 4

Clayey, or loamy over clayey soils with an impermeable layer at shallow depth.

User Runoff factor factors =

Factor for Impervious areas = 80%
Factor for Pervious areas = 47%

Design data:-

Imperv. area = 5700 m²
Total area (TA) = 5700 m²
Discharge to drain = 3.80 l/s
Additional flow = 0.00 l/s

Pervious area = 0 m²
Equiv area = 4674 m² (TA x RF).
Areal reduction factor = 1.000

Calculated data:-

Time to max = 115.0 mins
Rainfall at max = 8.74 mm/hr

Storage volume = 50.2 m³
Discharge rate per Ha = 6.67 l/s/Ha

Adjustments to result for climate change:-

Volume + 10% for normal discharge (W5-074) - Storage volume = 55.2 m³
Volume + 20% for discharge into river flows (DEFRA) - Storage volume = 60.2 m³
Volume + 30% for EA residential requirements - Storage volume = 65.2 m³
Volume + 50% for other residential requirements - Storage volume = 75.3 m³

Rainfall intensities calculated using the Wallingford Procedure

Storage lengths for initial calculation (x 1.1, 1.2, 1.3 or 1.5 as above if required) :-

Diam	Len	Diam	Len
100	6390.3	1125	50.5
150	2840.1	1200	44.4
225	1262.3	1275	39.3
300	710.0	1350	35.1
375	454.4	1425	31.5
450	315.6	1500	28.4
525	231.8	1575	25.8
600	177.5	1650	23.5
675	140.3	1725	21.5
750	113.6	1800	19.7
825	93.9	1875	18.2
900	78.9	1950	16.8
975	67.2	2025	15.6
1050	58.0	2100	14.5

Ovoid	Len
400 x 600	278.8
600 x 900	121.4
800 x 1200	68.3

Box culvert	Len
500 x 500	200.7
500 x 750	133.8
500 x 1000	100.4
750 x 1000	66.9
750 x 1200	55.8
750 x 1500	44.6
1000 x 1000	50.2
1000 x 1200	41.8
1000 x 1500	33.5
1000 x 1800	27.9
1000 x 2000	25.1
1500 x 1500	22.3
1500 x 1800	18.6
1500 x 2000	16.7

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Project Land North of Barrow Brook Business Park

Title Peak flow storage calcs for WHALLEY

Data:-

Time (mins)	Rain mm/hr	Inflow (m3)	Outflow (m3)	Balance (m3)
10	39.0	29.817	2.280	27.537
20	27.0	40.486	4.560	35.926
30	21.0	47.480	6.840	40.640
40	17.0	52.826	9.120	43.706
50	15.0	57.232	11.400	45.832
60	13.0	61.029	13.680	47.349
70	12.0	64.394	15.960	48.434
80	11.0	67.436	18.240	49.196
90	10.0	70.227	20.520	49.707
100	10.0	72.817	22.800	50.017
110	9.0	75.241	25.080	50.161
120	9.0	77.527	27.360	50.167
130	8.0	79.693	29.640	50.053
140	8.0	81.758	31.920	49.838
150	7.0	83.734	34.200	49.534
160	7.0	85.632	36.480	49.152
170	7.0	87.459	38.760	48.699
180	7.0	89.225	41.040	48.185
190	6.0	90.934	43.320	47.614
200	6.0	92.593	45.600	46.993
210	6.0	94.205	47.880	46.325
220	6.0	95.775	50.160	45.615
230	6.0	97.306	52.440	44.866
240	5.0	98.772	54.720	44.052
250	5.0	100.182	57.000	43.182
260	5.0	101.554	59.280	42.274
270	5.0	102.891	61.560	41.331
280	5.0	104.196	63.840	40.356
290	5.0	105.470	66.120	39.350
300	5.0	106.715	68.400	38.315
310	5.0	107.933	70.680	37.253
320	4.0	109.125	72.960	36.165
330	4.0	110.293	75.240	35.053
340	4.0	111.438	77.520	33.918
350	4.0	112.560	79.800	32.760
360	4.0	113.662	82.080	31.582
370	4.0	114.744	84.360	30.384
380	4.0	115.806	86.640	29.166
390	4.0	116.851	88.920	27.931
400	4.0	117.878	91.200	26.678
410	4.0	118.888	93.480	25.408
420	4.0	119.882	95.760	24.122
430	4.0	120.861	98.040	22.821
440	4.0	121.824	100.320	21.504
450	4.0	122.774	102.600	20.174
460	4.0	123.710	104.880	18.830
470	3.0	124.633	107.160	17.473
480	3.0	125.543	109.440	16.103
490	3.0	126.441	111.720	14.721
500	3.0	127.327	114.000	13.327
510	3.0	128.201	116.280	11.921
520	3.0	129.064	118.560	10.504
530	3.0	129.917	120.840	9.077
540	3.0	130.759	123.120	7.639
550	3.0	131.591	125.400	6.191
560	3.0	132.414	127.680	4.734
570	3.0	133.226	129.960	3.266
580	3.0	134.030	132.240	1.790
590	3.0	134.825	134.520	0.305
600	3.0	135.611	136.800	0.000

Storage volume (m^3) = 50.2 m^3

MasterDrain SW

MASTERDRAIN DRAINAGE DESIGN SOFTWARE

http://www.mstdrain.co.uk.

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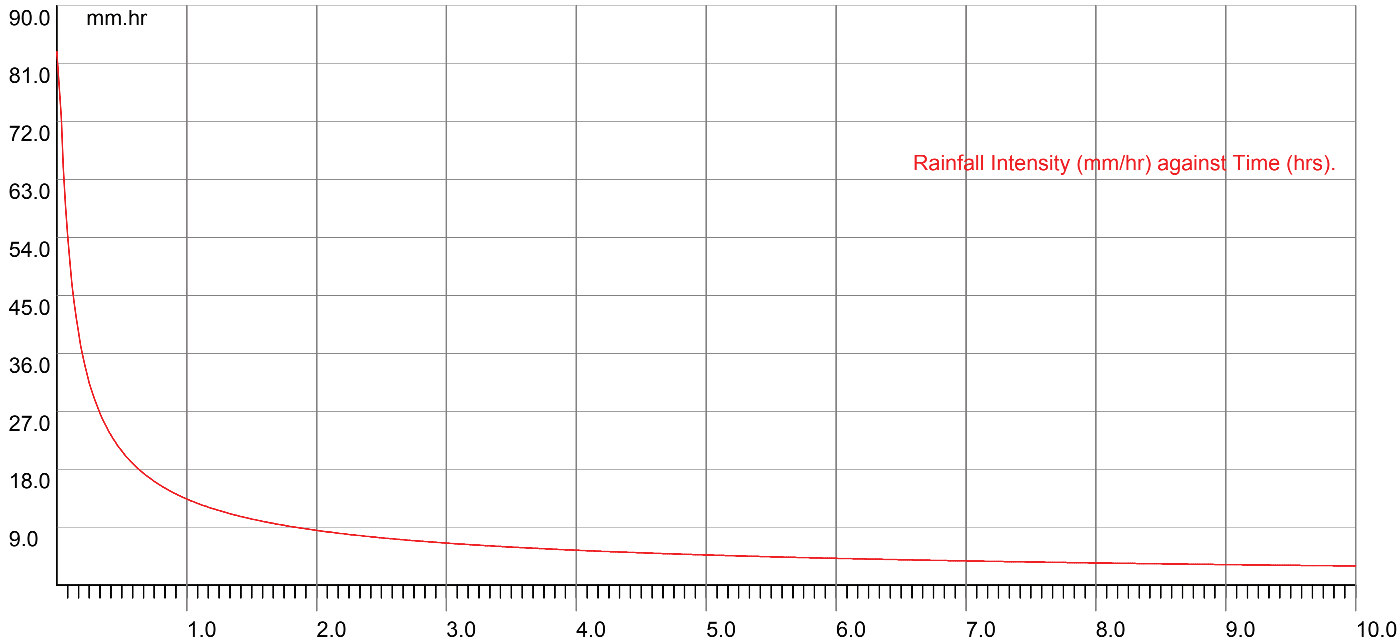
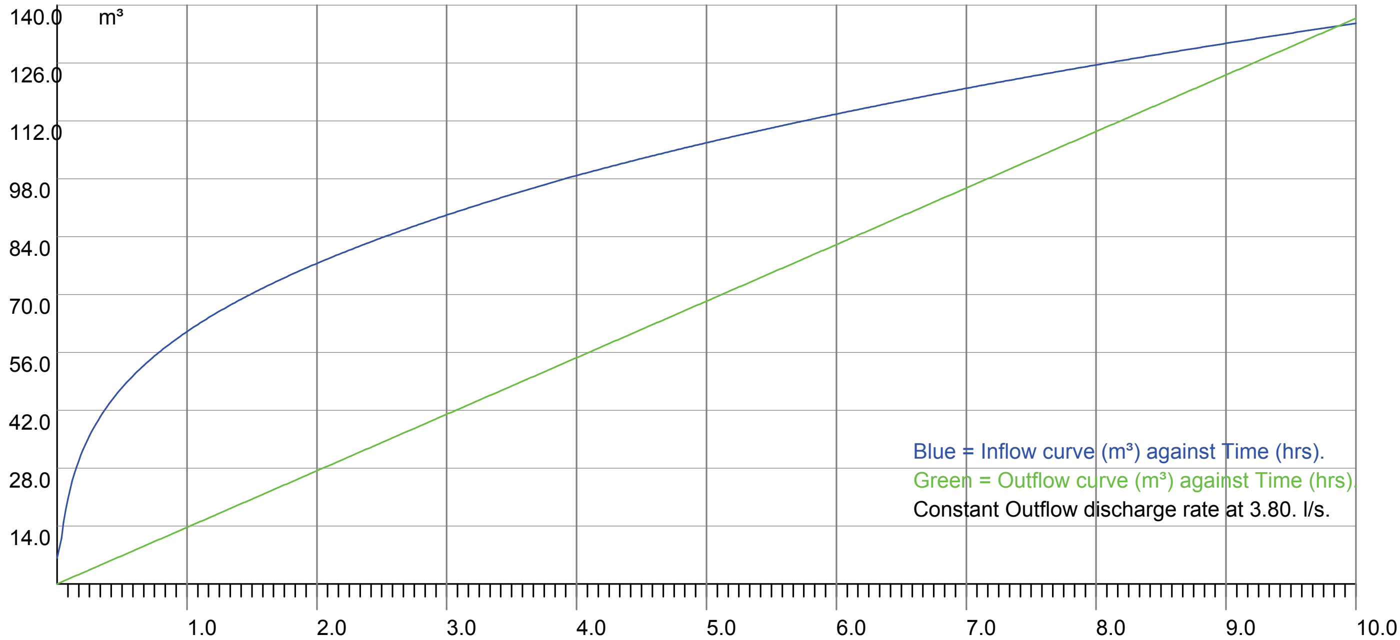
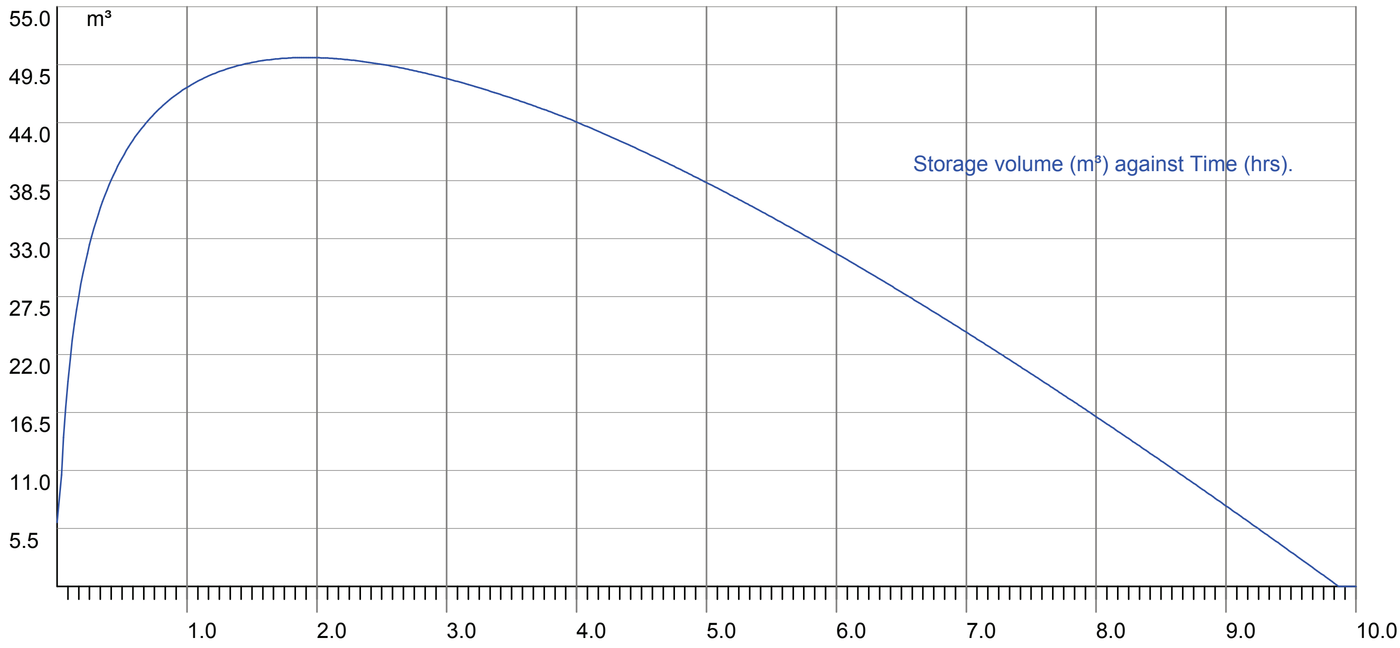
Title Peak flow storage calcs for WHALLEY







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Explanatory notes for Peak Flow Storage

1) This system uses the rainfall intensity/ duration curve calculated using either the Wallingford or FEH method as selected.
2) The outflow is regarded as constant for the duration of the storm; i.e. no allowance is made for the changing head behind the flow restrictor.*
3) The balance is calculated from the inflow minus the outflow.
4) The storage volume is the maximum value of the balance curve.
5) This method was described by Davis (1963) - see Butler & Davies, 2nd edition, p294
6) References to 'storm duration' relate only to the hydrograph method (qv).
7) There are always 600 steps in the calculation process, thus a 'run' time of 10 hours will be sampled every minute,

Explanatory notes for Hydrograph Storage

1) The user has the choice of Summer or Winter curves
2) The mean intensity varies with the duration of the storm curve
3) There are always 120 steps in the calculation process, irrespective of storm duration.
4) The outflow is regarded as constant for the duration of the storm; i.e. no allowance is made for the changing head behind the flow restrictor.*
5) The balance is calculated from the inflow minus the outflow.
6) The storage volume is the sum of the balance values for each step.
7) Varying durations should be tried to find the maximum storage value - this can be narrowed down very closely.

*Modelling using the flow characteristics of the restrictor is available using Vortex Control modelling function.
Please be aware that this function needs the full design data file to function.

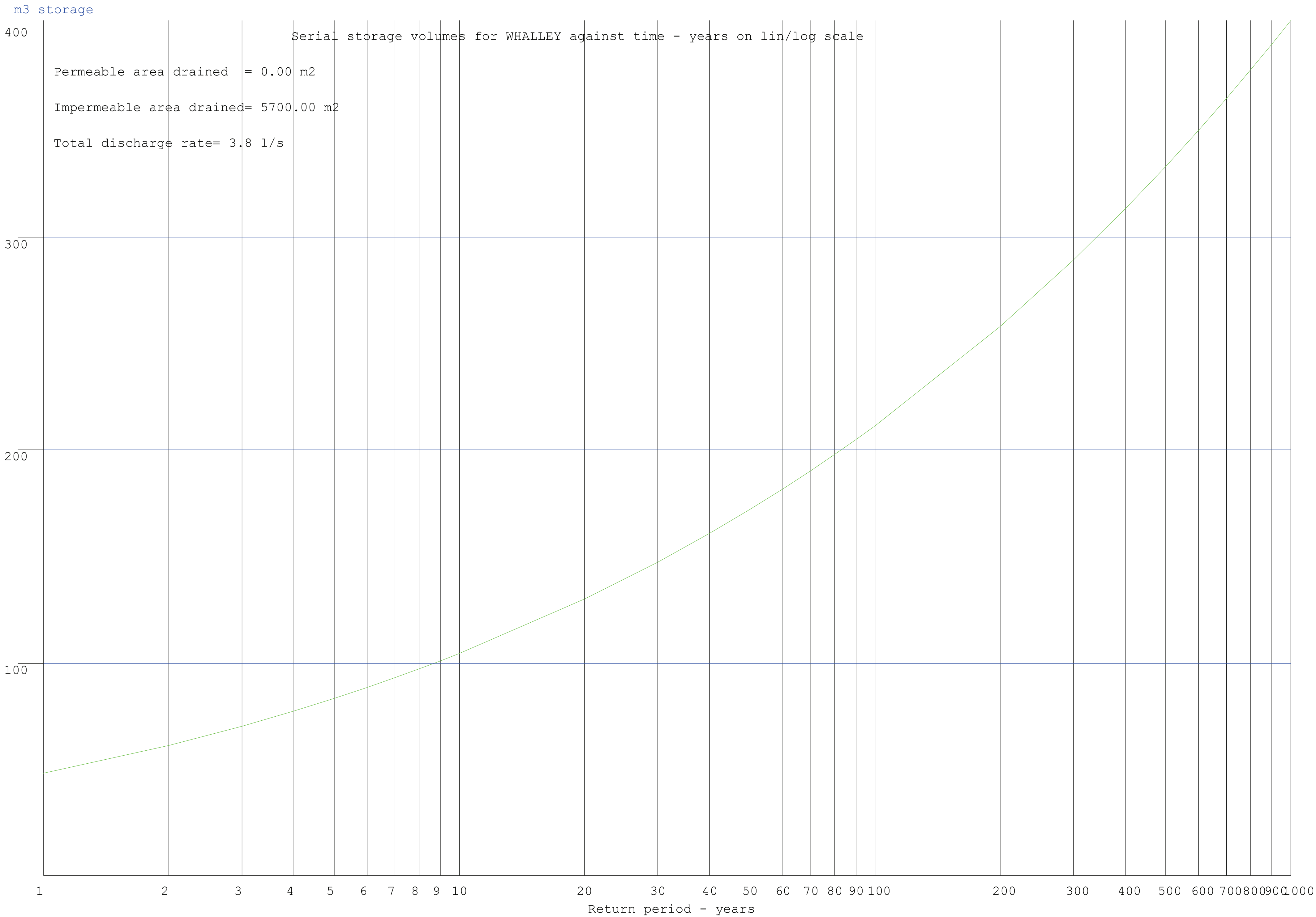
Why do the two methods give different results?

The rainfall characteristics for each method are very different.

The Peak flow (using the Intensity/Duration/Frequency curve) does not model the actual rainfall. This curve is joined points which represent the mean intensity of a storm at a given duration i.e. a value of 19.5 mm/hr for a 60 minute storm indicates that over the sixty minute period, the mean intensity was 19.5 mm/hr. The calculation method samples the IDF curve for a given location and frequency (Return Period) and calculates the storage for that rate and duration less the outflow volume. The maximum value is displayed as the 'worst case' storage.

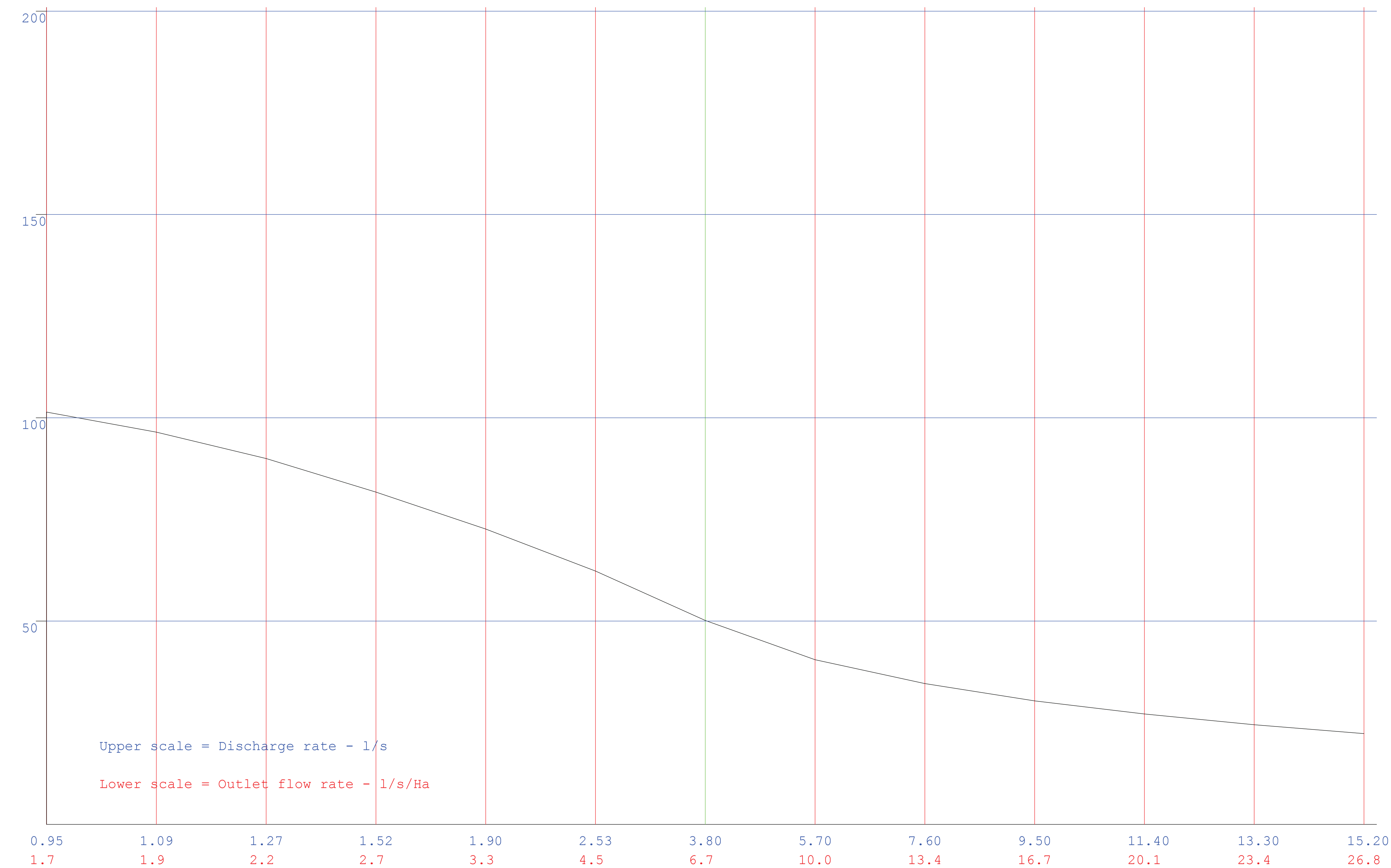
The hydrograph method uses a standard curve for either Winter or Summer storms. Traditionally these are symmetrical about the central peak. UK rainfall does not fit into this convenient curve, so the calculations are dealing with a stylised set of data. The mean intensity for the storm is calculated from the IDF curve and applied to the curve data, calculating the storage for that step less the outflow volume. The final storage volume is the sum of the storage for all the steps.

It can be seen that these two methods are very different, and the user may have the choice of which result to use. This is not an exact science, though is often treated as such by those that do not understand the principles of the calculations.


m3 storage
Serial storage volumes for WHALLEY against time - years on lin/log scale
Permeable area drained = 0.00 m2
Impermeable area drained= 5700.00 m2
Total discharge rate= 3.8 l/s
400
300
200
100
1
2
3
4
5
6
7
8
9
10
20
30
40
50
60
70
80
90
100
200
300
400
500
600
700
800
900
1000
Return period - years

Storage volumes for WHALLEY against varying discharge rates

Design discharge rate= 3.8



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Project Land North of Barrow Brook Business Park

Title Peak flow storage calcs for WHALLEY

Data:-

FSR Hydrology:-

Location	= WHALLEY	Grid reference	= SD7335
M5-60 (mm)	= 18.8	r	= 0.30
Soil index	= 0.45	SAAR (mm/yr)	= 1060
Return period	= 30	WRAP	= 4
UCWI	= 107.9		

Clayey, or loamy over clayey soils with an impermeable layer at shallow depth.

User Runoff factor factors =

Factor for Impervious areas = 80%
Factor for Pervious areas = 47%

Design data:-

Imperv. area	= 5700 m²	Pervious area	= 0 m²
Total area (TA)	= 5700 m²	Equiv area	= 4674 m² (TA x RF).
Discharge to drain	= 7.51 l/s	Areal reduction factor	= 1.000
Additional flow	= 0.00 l/s		

Calculated data:-

Time to max	= 123.0 mins	Storage volume	= 113.8 m³
Rainfall at max	= 18.10 mm/hr	Discharge rate per Ha	= 13.18 l/s/Ha

Adjustments to result for climate change:-

Volume + 10% for normal discharge (W5-074) -	Storage volume = 125.1 m³
Volume + 20% for discharge into river flows (DEFRA)-	Storage volume = 136.5 m³
Volume + 30% for EA residential requirements -	Storage volume = 147.9 m³
Volume + 50% for other residential requirements -	Storage volume = 170.6 m³

Rainfall intensities calculated using the Wallingford Procedure

Storage lengths for initial calculation (x 1.1, 1.2, 1.3 or 1.5 as above if required) :-

Diam	Len	Diam	Len	Ovoid	Len	Box culvert	Len
100	14486.0	1125	114.5	400 x 600	632.0	500 x 500	455.0
150	6438.2	1200	100.6	600 x 900	275.2	500 x 750	303.3
225	2861.4	1275	89.1	800 x 1200	154.8	500 x 1000	227.5
300	1609.6	1350	79.5			750 x 1000	151.7
375	1030.1	1425	71.3			750 x 1200	126.4
450	715.4	1500	64.4			750 x 1500	101.1
525	525.6	1575	58.4			1000 x 1000	113.8
600	402.4	1650	53.2			1000 x 1200	94.8
675	317.9	1725	48.7			1000 x 1500	75.8
750	257.5	1800	44.7			1000 x 1800	63.2
825	212.8	1875	41.2			1000 x 2000	56.9
900	178.8	1950	38.1			1500 x 1500	50.6
975	152.4	2025	35.3			1500 x 1800	42.1
1050	131.4	2100	32.8			1500 x 2000	37.9

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By	Checked	Approved

Project Land North of Barrow Brook Business Park

Title Peak flow storage calcs for WHALLEY

Data:-

Time (mins)	Rain mm/hr	Inflow (m3)	Outflow (m3)	Balance (m3)
10	78.0	59.622	4.506	55.116
20	55.0	84.326	9.012	75.314
30	44.0	100.585	13.518	87.067
40	37.0	113.020	18.024	94.996
50	32.0	123.203	22.530	100.673
60	29.0	131.882	27.036	104.846
70	26.0	139.474	31.542	107.932
80	24.0	146.238	36.048	110.190
90	22.0	152.348	40.554	111.794
100	21.0	157.924	45.060	112.864
110	20.0	163.057	49.566	113.491
120	18.0	167.814	54.072	113.742
130	17.0	172.246	58.578	113.668
140	17.0	176.395	63.084	113.311
150	16.0	180.296	67.590	112.706
160	15.0	183.976	72.096	111.880
170	15.0	187.457	76.602	110.855
180	14.0	190.760	81.108	109.652
190	13.0	193.901	85.614	108.287
200	13.0	196.893	90.120	106.773
210	13.0	199.751	94.626	105.125
220	12.0	202.483	99.132	103.351
230	12.0	205.100	103.638	101.462
240	11.0	207.687	108.144	99.543
250	11.0	210.239	112.650	97.589
260	11.0	212.713	117.156	95.557
270	10.0	215.117	121.662	93.455
280	10.0	217.454	126.168	91.286
290	10.0	219.728	130.674	89.054
300	10.0	221.944	135.180	86.764
310	10.0	224.104	139.686	84.418
320	9.0	226.213	144.192	82.021
330	9.0	228.271	148.698	79.573
340	9.0	230.284	153.204	77.080
350	9.0	232.251	157.710	74.541
360	9.0	234.177	162.216	71.961
370	8.0	236.062	166.722	69.340
380	8.0	237.910	171.228	66.682
390	8.0	239.720	175.734	63.986
400	8.0	241.496	180.240	61.256
410	8.0	243.239	184.746	58.493
420	8.0	244.950	189.252	55.698
430	8.0	246.630	193.758	52.872
440	7.0	248.280	198.264	50.016
450	7.0	249.903	202.770	47.133
460	7.0	251.498	207.276	44.222
470	7.0	253.068	211.782	41.286
480	7.0	254.612	216.288	38.324
490	7.0	256.132	220.794	35.338
500	7.0	257.629	225.300	32.329
510	7.0	259.103	229.806	29.297
520	7.0	260.556	234.312	26.244
530	7.0	261.987	238.818	23.169
540	6.0	263.398	243.324	20.074
550	6.0	264.790	247.830	16.960
560	6.0	266.162	252.336	13.826
570	6.0	267.516	256.842	10.674
580	6.0	268.852	261.348	7.504
590	6.0	270.171	265.854	4.317
600	6.0	271.473	270.360	1.113

Storage volume (m^3) = 113.8 m^3

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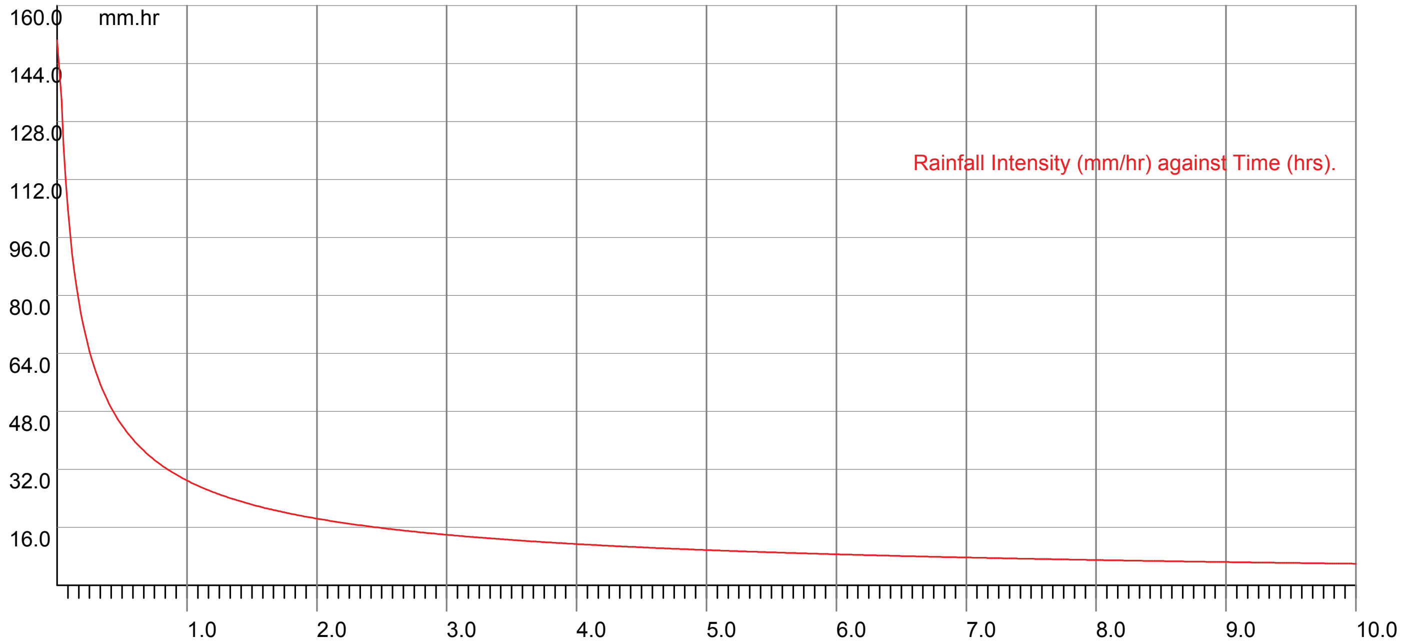
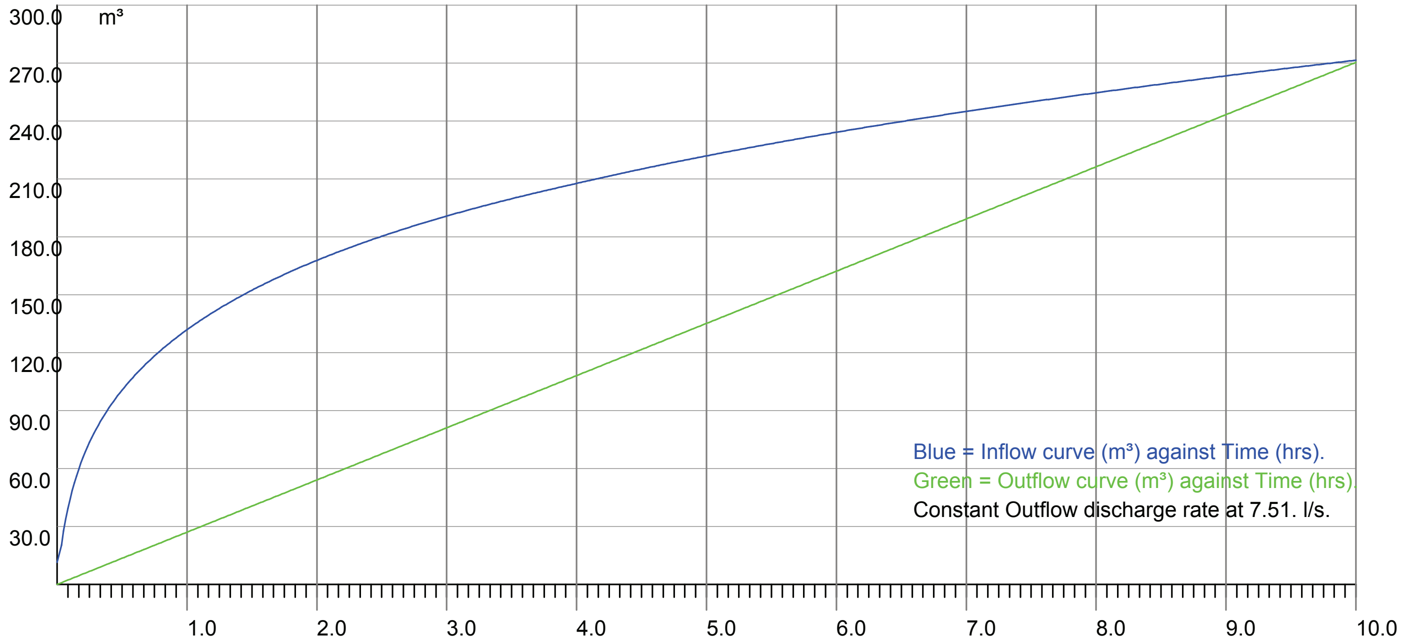
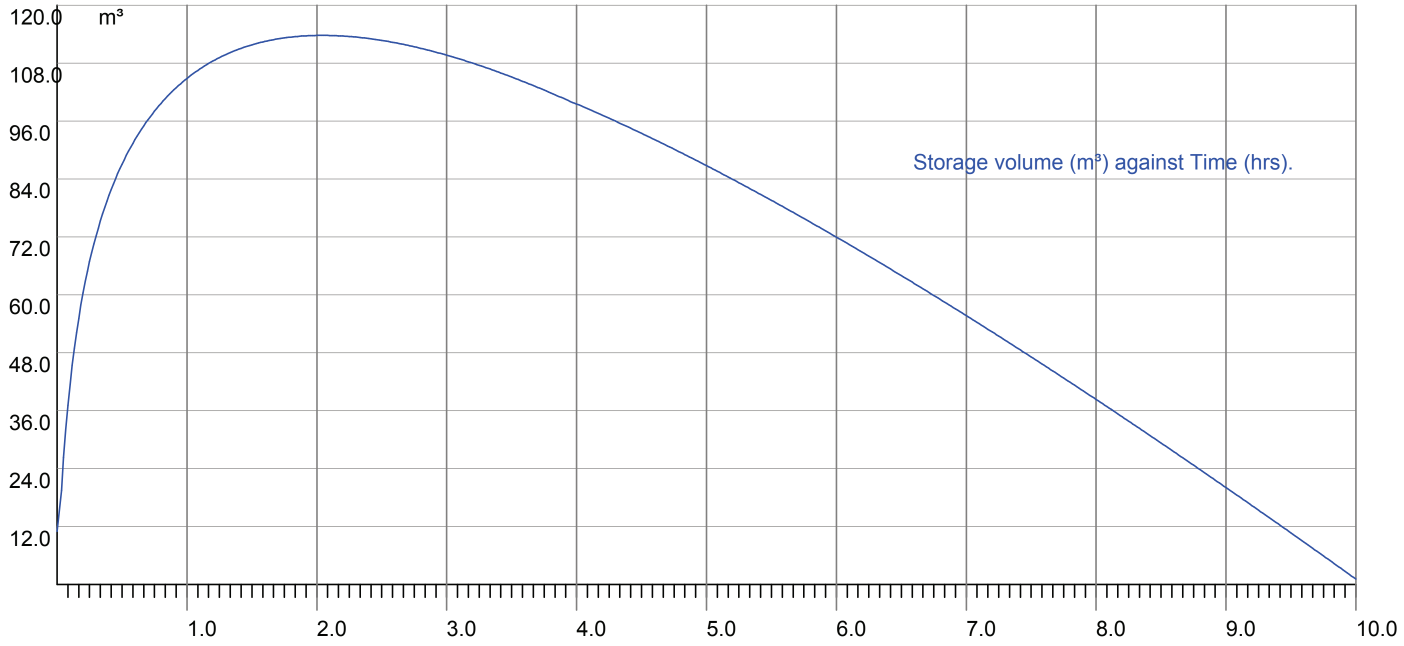
			Sheet no. 3		
			Date 25/06/12		
	Project Land North of Barrow Brook Business Park		By	Checked	Approved
	Title Peak flow storage calcs for WHALLEY				







Explanatory notes for Peak Flow Storage

1) This system uses the rainfall intensity/ duration curve calculated using either the Wallingford or FEH method as selected.
2) The outflow is regarded as constant for the duration of the storm; i.e. no allowance is made for the changing head behind the flow restrictor.*
3) The balance is calculated from the inflow minus the outflow.
4) The storage volume is the maximum value of the balance curve.
5) This method was described by Davis (1963) - see Butler & Davies, 2nd edition, p294
6) References to 'storm duration' relate only to the hydrograph method (qv).
7) There are always 600 steps in the calculation process, thus a 'run' time of 10 hours will be sampled every minute,

Explanatory notes for Hydrograph Storage

1) The user has the choice of Summer or Winter curves
2) The mean intensity varies with the duration of the storm curve
3) There are always 120 steps in the calculation process, irrespective of storm duration.
4) The outflow is regarded as constant for the duration of the storm; i.e. no allowance is made for the changing head behind the flow restrictor.*
5) The balance is calculated from the inflow minus the outflow.
6) The storage volume is the sum of the balance values for each step.
7) Varying durations should be tried to find the maximum storage value - this can be narrowed down very closely.

*Modelling using the flow characteristics of the restrictor is available using Vortex Control modelling function.
Please be aware that this function needs the full design data file to function.

Why do the two methods give different results?

The rainfall characteristics for each method are very different.

The Peak flow (using the Intensity/Duration/Frequency curve) does not model the actual rainfall. This curve is joined points which represent the mean intensity of a storm at a given duration i.e. a value of 19.5 mm/hr for a 60 minute storm indicates that over the sixty minute period, the mean intensity was 19.5 mm/hr. The calculation method samples the IDF curve for a given location and frequency (Return Period) and calculates the storage for that rate and duration less the outflow volume. The maximum value is displayed as the 'worst case' storage.

The hydrograph method uses a standard curve for either Winter or Summer storms. Traditionally these are symmetrical about the central peak. UK rainfall does not fit into this convenient curve, so the calculations are dealing with a stylised set of data. The mean intensity for the storm is calculated from the IDF curve and applied to the curve data, calculating the storage for that step less the outflow volume. The final storage volume is the sum of the storage for all the steps.

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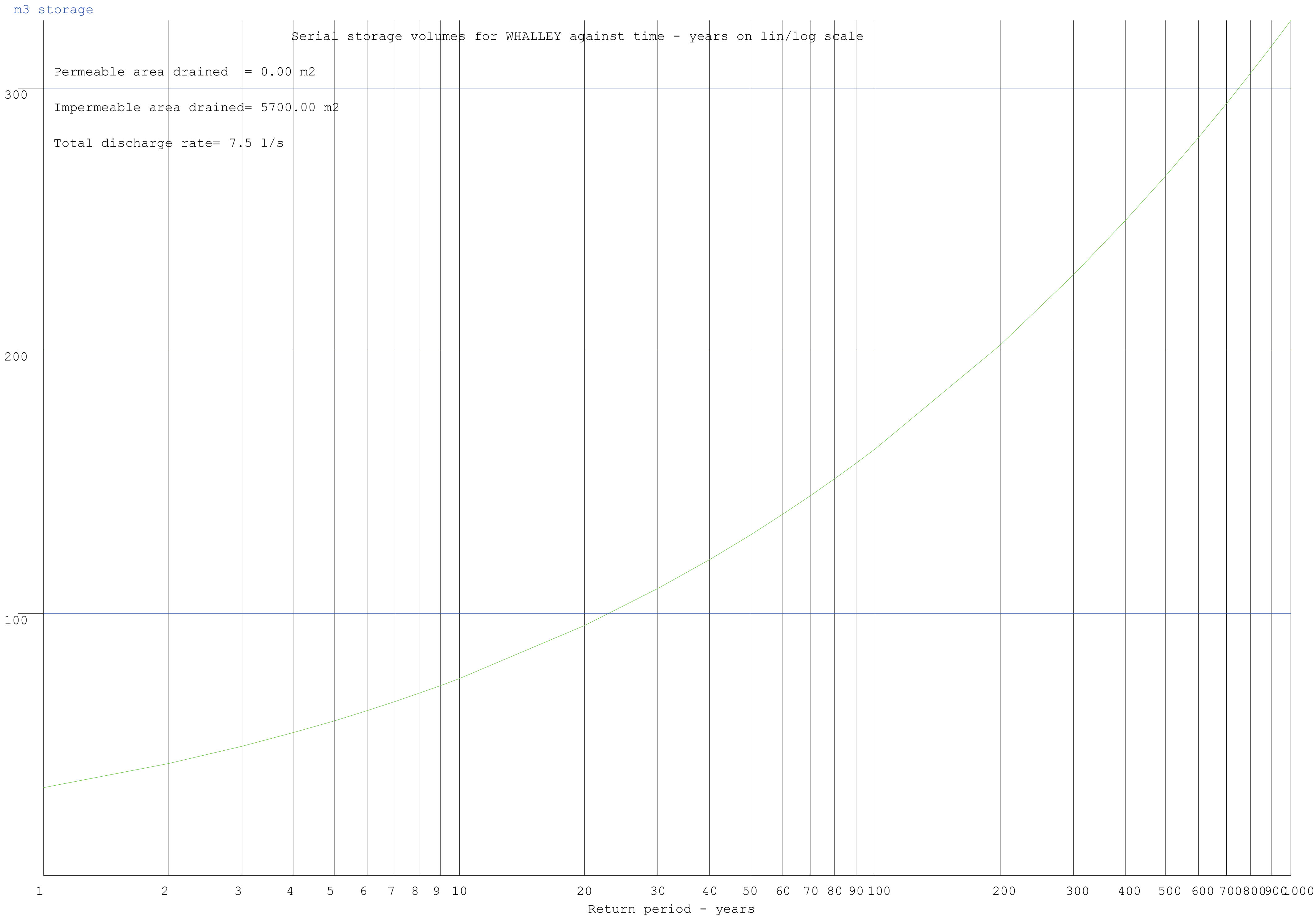
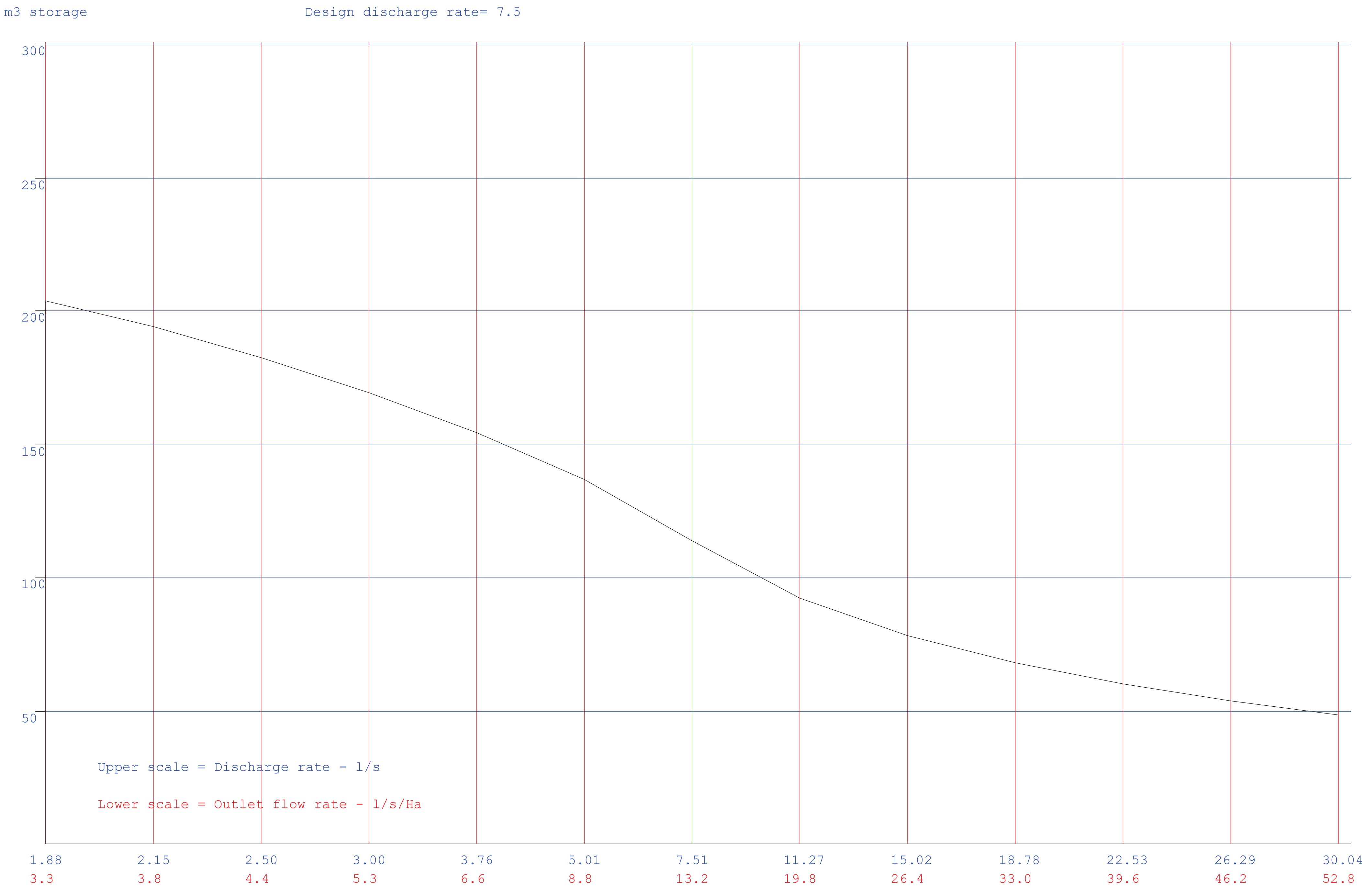

m3 storage
Serial storage volumes for WHALLEY against time - years on lin/log scale
Permeable area drained = 0.00 m2
Impermeable area drained= 5700.00 m2
Total discharge rate= 7.5 l/s
300
200
100
1
2
3
4
5
6
7
8
9
10
20
30
40
50
60
70
80
90
100
200
300
400
500
600
700
800
900
1000
Return period - years

Storage volumes for WHALLEY against varying discharge rates

Design discharge rate= 7.5



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			Sheet no. 1		
			Date 25/06/12		
	Project Land North of Barrow Brook Business Park		By	Checked	Approved
	Title Peak flow storage calcs for WHALLEY 100yr				

Data:-

FSR Hydrology:-

Location = WHALLEY
M5-60 (mm) = 18.8
Soil index = 0.45
Return period = 100
UCWI = 107.9

Grid reference = SD7335
r = 0.30
SAAR (mm/yr) = 1060
WRAP = 4

Clayey, or loamy over clayey soils with an impermeable layer at shallow depth.

User Runoff factor factors =

Factor for Impervious areas = 80%
Factor for Pervious areas = 47%

Design data:-

Imperv. area = 5700 m²
Total area (TA) = 5700 m²
Discharge to drain = 9.39 l/s
Additional flow = 0.00 l/s

Pervious area = 0 m²
Equiv area = 4674 m² (TA x RF).
Areal reduction factor = 1.000

Calculated data:-

Time to max = 127.0 mins
Rainfall at max = 23.27 mm/hr

Storage volume = 153.1 m³
Discharge rate per Ha = 16.47 l/s/Ha

Adjustments to result for climate change:-

Volume + 10% for normal discharge (W5-074) - Storage volume = 168.4 m³
Volume + 20% for discharge into river flows (DEFRA) - Storage volume = 183.7 m³
Volume + 30% for EA residential requirements - Storage volume = 199.0 m³
Volume + 50% for other residential requirements - Storage volume = 229.6 m³

Rainfall intensities calculated using the Wallingford Procedure

Storage lengths for initial calculation (x 1.1, 1.2, 1.3 or 1.5 as above if required) :-

Diam	Len	Diam	Len
100	19491.4	1125	154.0
150	8662.8	1200	135.4
225	3850.1	1275	119.9
300	2165.7	1350	106.9
375	1386.1	1425	96.0
450	962.5	1500	86.6
525	707.2	1575	78.6
600	541.4	1650	71.6
675	427.8	1725	65.5
750	346.5	1800	60.2
825	286.4	1875	55.4
900	240.6	1950	51.3
975	205.0	2025	47.5
1050	176.8	2100	44.2

Ovoid	Len
400 x 600	850.3
600 x 900	370.2
800 x 1200	208.2

Box culvert	Len
500 x 500	612.2
500 x 750	408.1
500 x 1000	306.1
750 x 1000	204.1
750 x 1200	170.1
750 x 1500	136.0
1000 x 1000	153.1
1000 x 1200	127.5
1000 x 1500	102.0
1000 x 1800	85.0
1000 x 2000	76.5
1500 x 1500	68.0
1500 x 1800	56.7
1500 x 2000	51.0

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Project Land North of Barrow Brook Business Park

Title Peak flow storage calcs for WHALLEY 100yr

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Data:-

Time (mins)	Rain mm/hr	Inflow (m3)	Outflow (m3)	Balance (m3)
10	100.0	76.196	5.634	70.562
20	72.0	109.336	11.268	98.068
30	58.0	131.201	16.902	114.299
40	49.0	147.939	22.536	125.403
50	43.0	161.619	28.170	133.449
60	38.0	173.239	33.804	139.435
70	34.0	183.361	39.438	143.923
80	32.0	192.335	45.072	147.263
90	29.0	200.397	50.706	149.691
100	27.0	207.713	56.340	151.373
110	26.0	214.406	61.974	152.432
120	24.0	220.569	67.608	152.961
130	23.0	226.275	73.242	153.033
140	22.0	231.581	78.876	152.705
150	21.0	236.534	84.510	152.024
160	20.0	241.173	90.144	151.029
170	19.0	245.530	95.778	149.752
180	18.0	249.634	101.412	148.222
190	18.0	253.506	107.046	146.460
200	17.0	257.168	112.680	144.488
210	16.0	260.636	118.314	142.322
220	16.0	263.926	123.948	139.978
230	15.0	267.052	129.582	137.470
240	15.0	270.189	135.216	134.973
250	14.0	273.318	140.850	132.468
260	14.0	276.350	146.484	129.866
270	14.0	279.290	152.118	127.172
280	13.0	282.144	157.752	124.392
290	13.0	284.919	163.386	121.533
300	13.0	287.618	169.020	118.598
310	12.0	290.247	174.654	115.593
320	12.0	292.810	180.288	112.522
330	12.0	295.309	185.922	109.387
340	12.0	297.749	191.556	106.193
350	11.0	300.132	197.190	102.942
360	11.0	302.461	202.824	99.637
370	11.0	304.740	208.458	96.282
380	11.0	306.970	214.092	92.878
390	10.0	309.154	219.726	89.428
400	10.0	311.293	225.360	85.933
410	10.0	313.390	230.994	82.396
420	10.0	315.447	236.628	78.819
430	10.0	317.465	242.262	75.203
440	10.0	319.446	247.896	71.550
450	9.0	321.391	253.530	67.861
460	9.0	323.302	259.164	64.138
470	9.0	325.180	264.798	60.382
480	9.0	327.027	270.432	56.595
490	9.0	328.842	276.066	52.776
500	9.0	330.629	281.700	48.929
510	9.0	332.387	287.334	45.053
520	8.0	334.118	292.968	41.150
530	8.0	335.822	298.602	37.220
540	8.0	337.500	304.236	33.264
550	8.0	339.154	309.870	29.284
560	8.0	340.784	315.504	25.280
570	8.0	342.391	321.138	21.253
580	8.0	343.975	326.772	17.203
590	8.0	345.538	332.406	13.132
600	8.0	347.079	338.040	9.039

Storage volume (m^3) = 153.1 m^3

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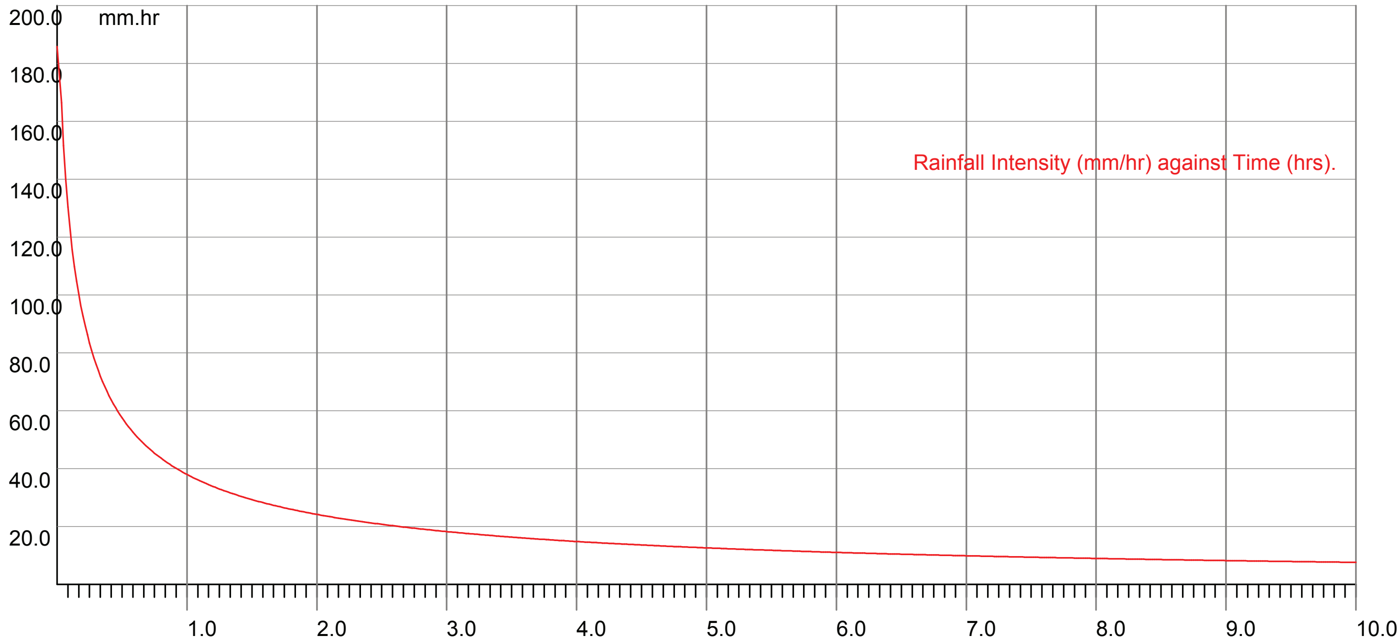
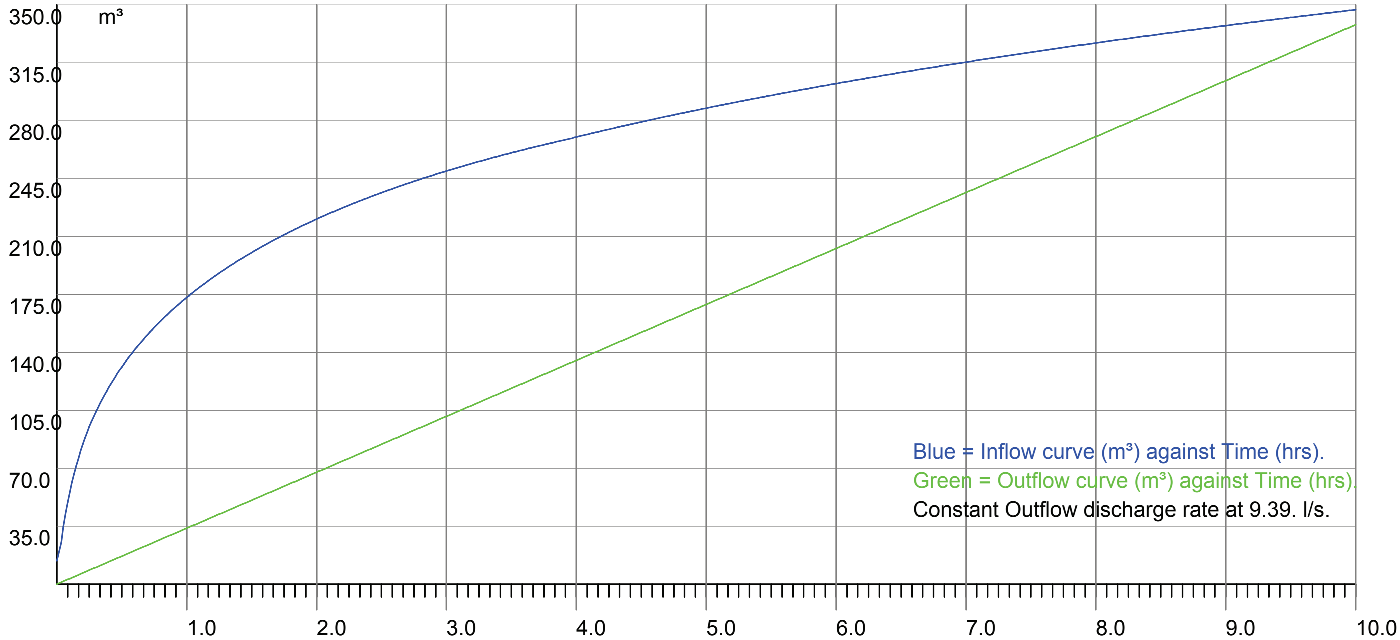
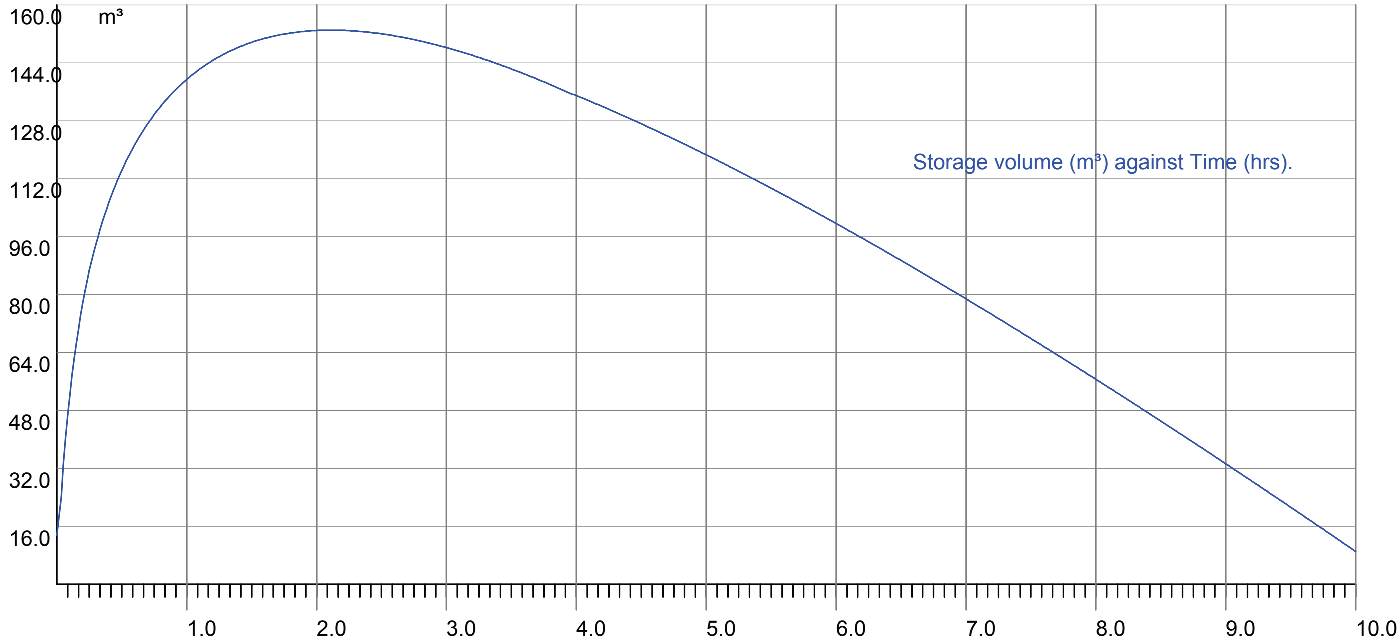
Project Land North of Barrow Brook Business Park

Title Peak flow storage calcs for WHALLEY 100yr







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Explanatory notes for Peak Flow Storage

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2) The outflow is regarded as constant for the duration of the storm; i.e. no allowance is made for the changing head behind the flow restrictor.*
3) The balance is calculated from the inflow minus the outflow.
4) The storage volume is the maximum value of the balance curve.
5) This method was described by Davis (1963) - see Butler & Davies, 2nd edition, p294
6) References to 'storm duration' relate only to the hydrograph method (qv).
7) There are always 600 steps in the calculation process, thus a 'run' time of 10 hours will be sampled every minute,

Explanatory notes for Hydrograph Storage

1) The user has the choice of Summer or Winter curves
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The rainfall characteristics for each method are very different.

The Peak flow (using the Intensity/Duration/Frequency curve) does not model the actual rainfall. This curve is joined points which represent the mean intensity of a storm at a given duration i.e. a value of 19.5 mm/hr for a 60 minute storm indicates that over the sixty minute period, the mean intensity was 19.5 mm/hr. The calculation method samples the IDF curve for a given location and frequency (Return Period) and calculates the storage for that rate and duration less the outflow volume. The maximum value is displayed as the 'worst case' storage.

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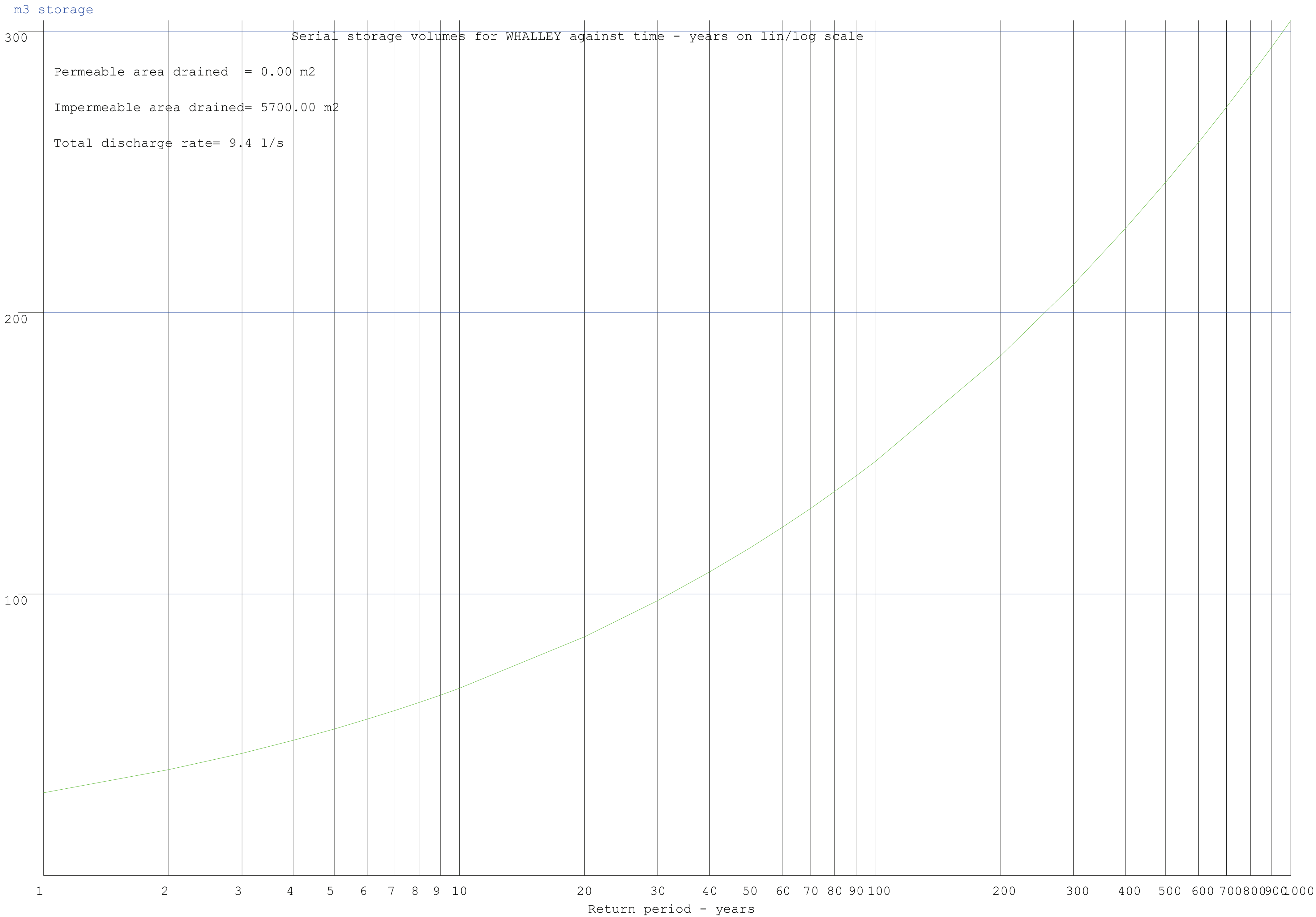
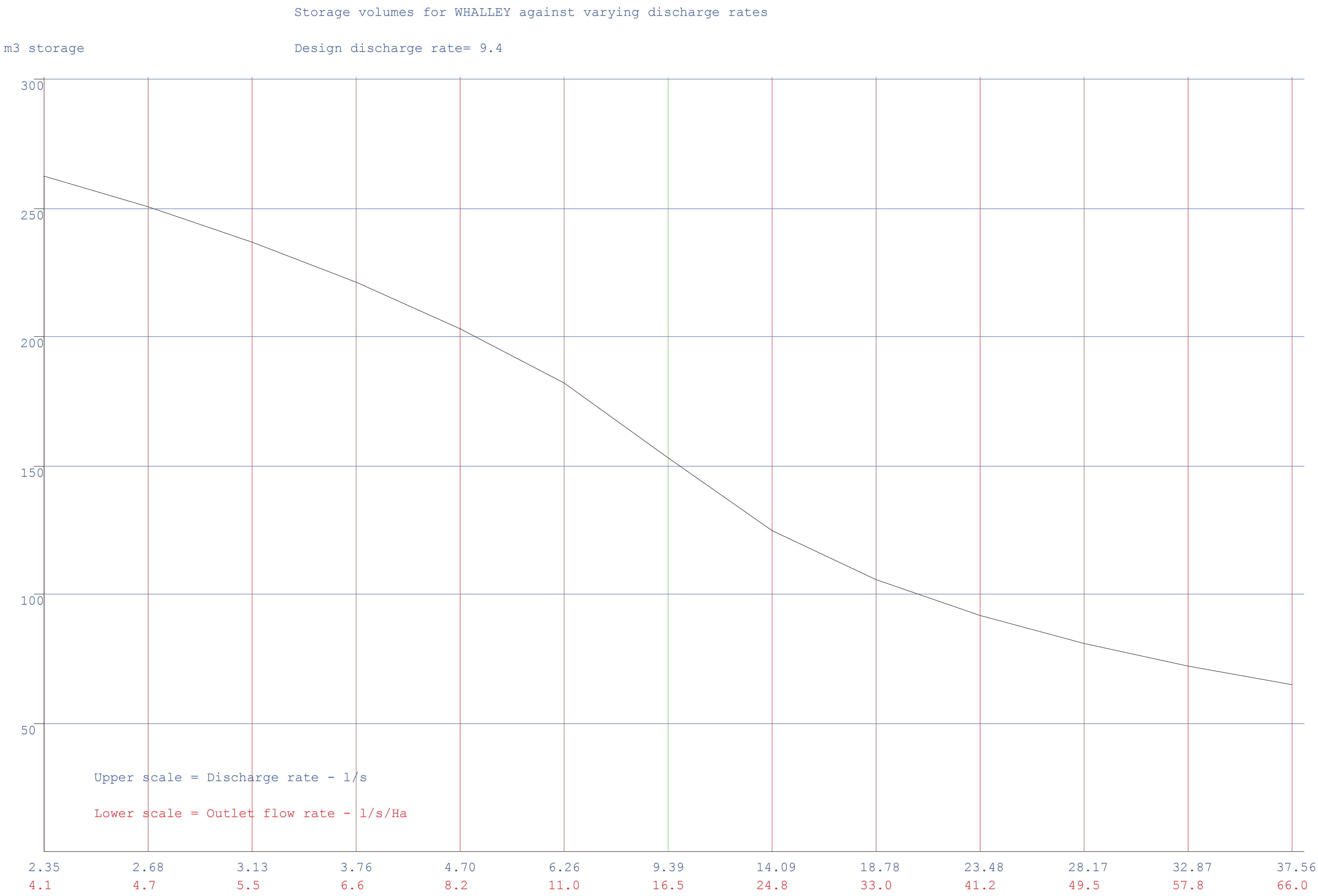

m3 storage
Serial storage volumes for WHALLEY against time - years on lin/log scale
Permeable area drained = 0.00 m2
Impermeable area drained= 5700.00 m2
Total discharge rate= 9.4 l/s
300
200
100
1
2
3
4
5
6
7
8
9
10
20
30
40
50
60
70
80
90
100
200
300
400
500
600
700
800
900
1000
Return period - years


Storage volumes for WHALLEY against varying discharge rates
m3 storage
Design discharge rate= 9.4
300
250
200
150
100
50
Upper scale = Discharge rate - l/s
Lower scale = Outlet flow rate - l/s/Ha
2.35 2.68 3.13 3.76 4.70 6.26 9.39 14.09 18.78 23.48 28.17 32.87 37.56
4.1 4.7 5.5 6.6 8.2 11.0 16.5 24.8 33.0 41.2 49.5 57.8 66.0