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Sustainable Urban Drainage (SUDS) Strategy

for
New Residential Development
at
28 Redington Road
Hampstead
London NW3

Revision	Description	By	Approved	Date
01	Issued for Planning	M O'Regan BSc CEng MI Struct E	M Wakely BSc CEng MIStruct FICE	August 2017

1.0 Executive Summary

The proposed redevelopment of 28 Redington Road, London NW3 provides an opportunity to incorporate Sustainable Urban Drainage Systems SUDS to this existing developed site and to reduce demands on the combined surface water and sewerage network by applying the London Plan drainage hierarchy.

28 Redington Road is an existing residential with an impermeable area of 0.08 ha. The proposed development does not increase the impermeable area.

Calculations show the present site generates a peak surface run-off rate of 24 l/s for a 1 in 100 year storm event which discharges into the public sewer.

It is proposed that we limit the flow rate for a maximum discharge rate of 5.0 l/s for all events up to and including 1 in 100 years plus a 30% allowance for climate change. This will satisfy the requirements of the London Plan as:

- It reduces the peak surface flows from the site by 79% which vastly exceeds the 50% targets (SPG CL3.4.8)
- It limits the run off rate to no more than three times the calculated greenfield rate (London Plan Cl 3.4.10)

We will use a proprietary cellular attenuation tank. The system is designed to provide storage during intense storm conditions. When the amount of rainfall exceeds the 5 l/s maximum permitted rate of discharge, stormwater will temporarily back up within the void and discharge over an elongated period of time. This will significantly reduce the peak run-off rates that presently discharge from the site into the public sewer.

The SUDS measures that will be incorporated include:

- Stormwater attenuation using a proprietary cellular attenuation tank. The system is designed to provide storage during intense storm conditions. When the amount of rainfall exceeds the 5 l/s maximum permitted rate of discharge, stormwater will temporarily back up within the void and discharge over an elongated period of time. This will significantly reduce the peak run-off rates that presently discharge from the site into the public sewer. The tank has been sized for a 1 in 100 year storm event with a 30% allowance for climate change.

- Water efficient fixtures and fittings will be installed wherever possible

2.0 Introduction

This report outlines the proposed planning stage SUDS strategy that is being developed for the proposed redevelopment of the residential property at 28 Redington Road, London NW3 7RB.

This report has been prepared by Ross and Partners on the instructions of the property owner, Linton Group. No professional liability or warranty is extended to other parties by Ross and Partners as a result of this specification being used by others without the written permission of Ross and Partners.

Ross and Partners are working within a design team of co-consultants to develop the project. The proposals are based upon drawings prepared by Jo Cowen Architects.

The proposed below ground drainage will be designed in accordance with the Building Regulations Part H, and the London Plan.

3.0 Site Description and Location

The site is located at 28 Redington Road, London NW3 7RB. The site is presently occupied by an existing residential property.

The site is relatively flat with a maximum level of 105m OD and a minimum level of circa 98m OD. Slopes within the plot do not exceed 4°.

The site is located within Flood Risk Zone 1 which means it is assessed as having a less than 1 in 1000 annual probability of river or sea flooding.

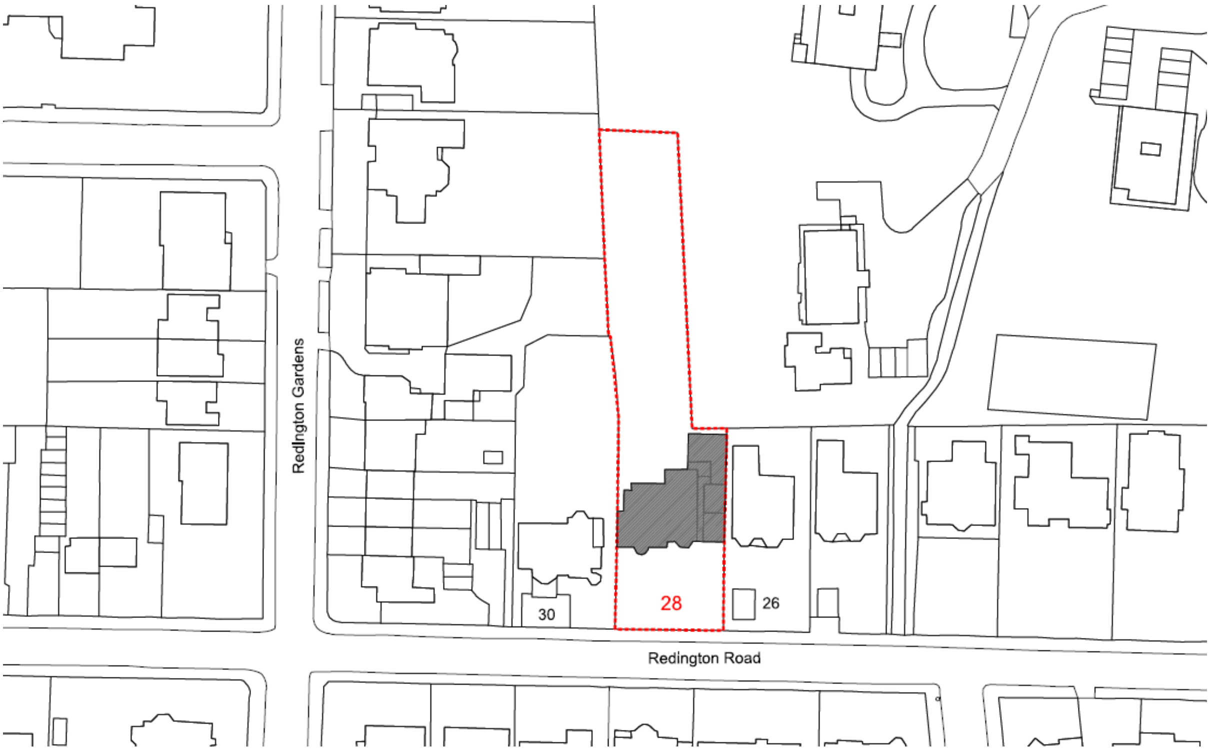


Figure 1 Site Location Map

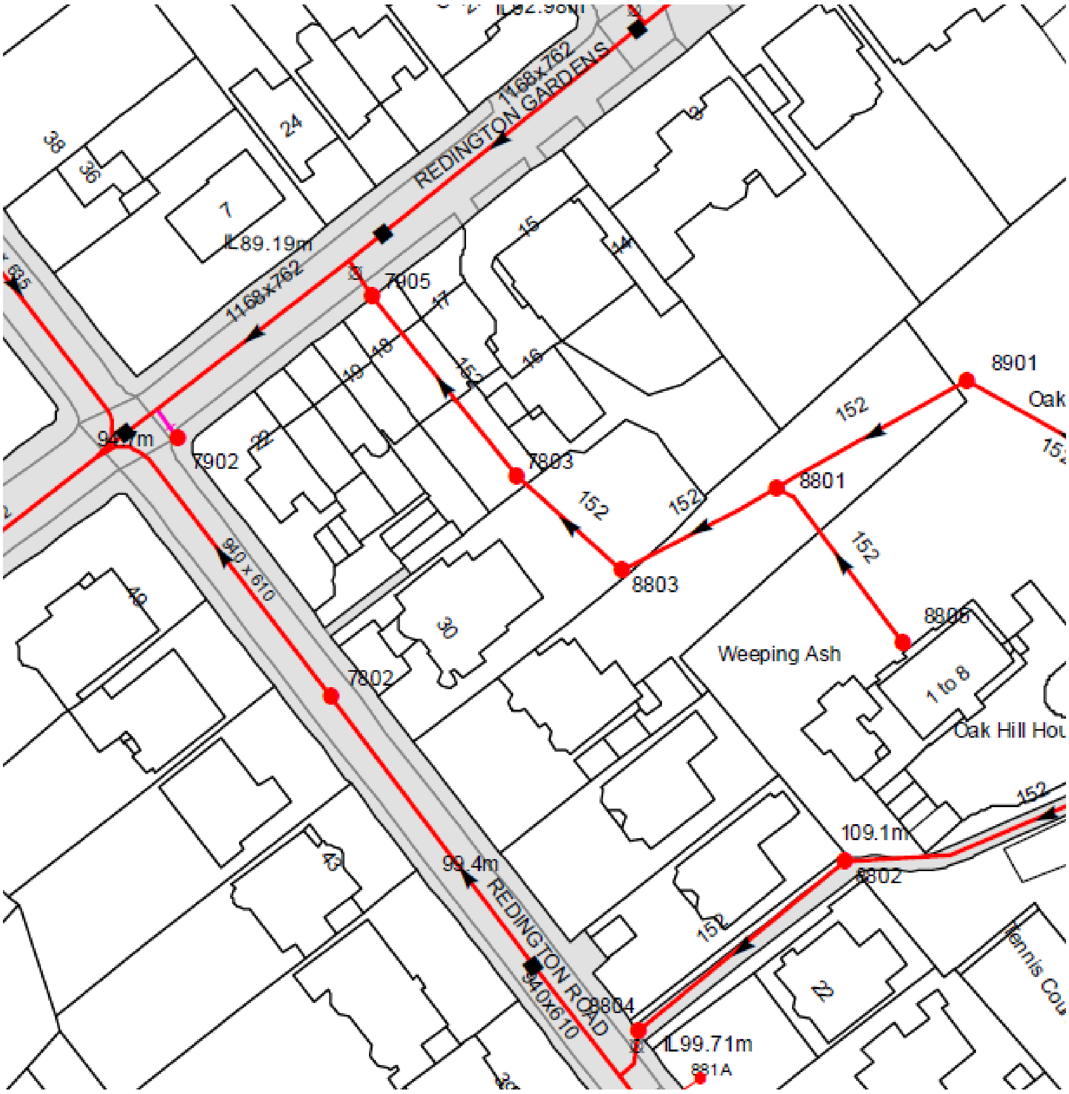
Site Data

Site name	28 Redington Road, London NW3 7RB
Site Description	Existing developed residential site
Proposed development	Construction of new residential property
National Grid reference	TQ 257858
Approximate site area	1866 m^2
Approximate area of undeveloped site that is impermeable and positively drained	806 m^2
Approximate area of developed site that will be impermeable and positively drained	806 m^2
Existing Site Discharge	An 150mm diameter cast iron drain which exits the front of the site into the combined sewer in Redington Road.
Sewer Network	Combined Sewer within Redington Road
Site Geology	Bagshot Formation over Claygate Member over London Clay
Water table	Water monitoring recorded groundwater levels at an average horizon of 95.3m OD.
Site Contaminated	The site has no reported contamination history.
Infiltration Potential	Very limited. The site has a low infiltration rate
Flood Risk	The site is located within Flood Risk Zone 1 which means it is assessed as having a less than 1 in 1000 annual probability of river or sea flooding.

4.0 Existing Site Drainage

The site is 100m long by 20m wide. The rear of the plot, which accounts to approximately 57% of the area, comprises of soft landscaping. The remaining 43% comprises of the existing building and hard landscaping that is impermeable.

Surface water falling on impermeable areas is collected via gulleys and rainwater pipes and conveyed via a gravity drainage system through the front of the site where it is discharged into the public sewer.



There is a 940 x 610 sewer in Redington Road. There is also a Thames Water Sewer crossing the rear landscaped areas. This conveys waste water from the neighbouring properties at Oakhill Lodge and Oak Hill House.

5.0 Surface Water Flow

Our calculations are based upon the method from the Institute of Hydrology Report 124 in accordance with CIRIA C697 - The SUDS Manual

5.1 Existing pre-developed site

Catchment area	=	1866 m^2	
Existing Impermeable Area	=	806 m^2	
Existing permeable Area	=	1060 m^2	

Greenfield run off estimation[1]	=	0.40 l/s	1 in 1 year
	=	1.00 l/s	1 in 30 years
	=	1.40 l/s	1 in 100 years

5.2 Existing Run off

The existing run off rate is calculated for various storm events using the modified rational method where:

Q =2.78 A*i*

Where A = Catchment Area and i = rainfall intensity

Q = 2.78 x 0.08 x 34	=	7.56	l/s	1 in 1 year
Q = 2.78 x 0.08x 82	=	18.23	l/s	1 in 30 year
Q = 2.78 x 0.08 x107	=	23.79	l/s	1 in 100 year

5.3 Proposed Site

Catchment area	=	1866 m^2
Proposed Impermeable Area	=	806 m^2
Proposed permeable Area	=	1060 m^2

5.4 Proposed Run off

The proposed run off rate is calculated for various storm events (1 in 1 year, 1 in 30 year and 1 in 100year) using the modified rational method and includes a 30% allowance for climate change.

This gives run off rates of:

Q = 2.78 x 0.08 x 42.2	=	9.40	l/s	1 in 1 year + 30% cc
Q = 2.78 x 0.08 x 103.1	=	22.93	l/s	1 in 30 year + 30% cc
Q = 2.78 x 0.08 x 139	=	30.91	l/s	1 in 100 year + 30% cc

[1] Greenfield Estimation calculated using the FEH method on the UK Sustainable drainage website

6.0 Permitted Surface Water Discharge Rates

The design for surface water discharge from the site will comply with the London Plan Policy 5.13 and the Mayor's Sustainable Design and Construction Supplementary Planning Guidance April 2014

London Plan Policy 5.13 and Sustainable Design and Construction Supplementary Planning Guidance 2014 (SPG)

This sets out Sustainable Drainage aspirations for developments and requires developers to aim for greenfield runoff rate from their developments. Greenfield runoff rates are defined as the runoff rates from a site, in its natural state, prior to any development. Typically this is between 2 l/s/ha and 8 l/s/ha

SPG Cl 3.4.8
This clause sets minimum expectation targets of 50% attenuation of peak surface water flows of the site prior to redevelopment Cl 3.4.8.

This equates to 50% x 23.79 l/s = 11.90 l/s

On previously developed sites run off rates should not be more than three times the calculated greenfield rate Cl 3.4.10.

This equates to 3 x 1.4 = 4.20 l/s**

On small scale developments, where the calculated greenfield run off is extremely low and the final outfall pipe required to achieve this would be prone to blockage, it is recommended the minimum designed discharge rate is 5l/s. Cl 3.4.9

** this is less than the minimum recommended discharge rate of 5 l/s to maintain the self-cleansing velocity of the out flow system. Pipework with flow rates less than 5 l/s are prone to blockage.[2]

We shall limit the flow rate for a maximum discharge rate of 5.0 l/s for all events up to and including 1 in 100 years plus a 30% allowance for climate change. This will satisfy the requirements of the London Plan SPG Cl 3.4.8.

[2] SPG cl 3.4.9 and HR Wallingford

7.0 Surface Water Attenuation

In order to limit the peak flow rate to 5.0l/s for all storm events up to and including 1 in 100 years + 30% climate change allowance, an attenuation tank will be provided.

The volume of storage required is 30.6m³ and reflects the worst calculated event of a 120min event.

Attenuation will be provided using a proprietary cellular tank located at the front of the property.

Please note this volume of storage represents an increase upon the original proposal prepared by Mott MacDonald; as it was felt prudent to reduce the peak discharge flow rate.

8.0 SUDS Proposals and Opportunities

The following drainage hierarchy outlined in the London Plan has been considered. Developments should aim to ensure that surface water is managed as close as possible in line with the following drainage hierarchy.

Control of run-off at Source

The majority of the site will remain soft landscaped as formal gardens with natural infiltration. The ground will be slightly re-profiled to ensure that in heavy rainfall events water will be retained on site and not discharge onto neighbouring properties.

Store rainwater for later use

Rainwater harvesting requires underground tanks that store filtered rainwater. The water is then re-used via pumps for flushing of toilets. Given the tanks could be full at any given time, the tanks will not have any storage capacity for an 1 in 100 year storm event and cannot be include in the attenuation design.

This will not be used.

Use infiltration techniques such as porous surfaces in non-clay areas

The impermeable areas are restricted to the footprint of the building and the entrance drive only. Infiltration techniques are not feasible for this runoff at this site; permeability tests derived a coefficient of permeability K = 4.3×10^{-10} (m/s). So infiltration rates are unsuitable on this site.

Attenuate rainwater in ponds or open water features for gradual release

On such a narrow site it is not possible to have a pond or open water feature due to the nature of the built up area.

Attenuate rainwater by storing in tanks or sealed water features for gradual release

Stormwater attenuation will be provided to reduce the rate of discharge from the site to a maximum of 5.0 l/s.

We will use a proprietary cellular attenuation tank system below the paving to provide storage of surface water run-off.

The system is designed to provide storage during intense storm conditions. When the amount of rainfall exceeds the 5 l/s maximum permitted rate of discharge, stormwater will temporarily back up within the void and discharge over an elongated period of time. This will significantly reduce the peak run-off rates that presently discharge from the site into the public sewer.

Calculations indicate a tank storage volume of 30.0 m^3 is required for a maximum out flow rate of 5.0 l/s for storm events up to and including 1 in 100 year plus 30% climate change allowance.

Discharge rainwater direct to a watercourse

This strategy is not feasible.
There is no watercourse near the site and hence this strategy is not viable in this location.

Discharge rainwater to a surface water sewer/drain

This strategy is not feasible.
There is no surface water sewer/drain near the site premises. Hence this strategy is not viable in this location.

Discharge rainwater to the combined sewer

This strategy objective has been achieved.

It is understood there is an existing 150mm diameter outlet from the site into the combined sewer system. It is proposed the site foul and surface water drainage are kept separate and are discharged separately via the final manholes nearest the boundary before discharging into the combined public sewer. A non-return valve will be installed to avoid the risk of backflow in the event of public sewer surcharge due to storm conditions.

9.0 SUDS Technical Standards

In consideration of the DEFRA Non-Statutory Standards for Sustainable Drainage Systems 2015.

Peak Flow

> ***S3*** *For developments which were previously developed, the peak runoff rate from the development to any drain, sewer or surface water body for the 1 in 1 year rainfall event and the 1 in 100 year rainfall event must be as close as reasonably practicable to the greenfield runoff rate from the development for the same rainfall event, but should never exceed the rate of discharge from the development prior to redevelopment for that event.*

It is proposed to control the surface water run-off to 5 l/s. This will provide the lowest practical control rate without significantly increasing the risk of blockages in the system.

Volume Control

> ***S6*** *Where it is not reasonably practicable to constrain the volume of runoff to any drain, sewer or surface water body, the runoff volume must be discharged at a rate that does not adversely affect flood risk.*

Attenuation storage will be provided for surface water events up to and including 1 in 100 year plus 30% climate change. This will reduce the rate of run off discharging into the public sewer system.

Flood Risk within the Development

> ***S7*** *The drainage system must be designed so that, unless an area is designated to hold and/or convey water as part of the design, flooding does not occur on any part of the site for a 1 in 30 year rainfall event.*
>
> ***S8*** *The drainage system must be designed so that, unless an area is designated to hold and/or convey water as part of the design, flooding does not occur during a 1 in 100 year rainfall event in any part of: a building (including a basement); or in any utility plant susceptible to water (e.g. pumping station or electricity substation) within the development.*
>
> ***S9*** *The design of the site must ensure that, so far as is reasonably practicable, flows resulting from rainfall in excess of a 1 in 100 year rainfall event are managed in exceedance routes that minimise the risks to people and property.*

Attenuation storage will be provided for surface water events up to and including 1 in 100 year plus 30% climate change. This storage is calculated for the entire impermeable area and should therefore ensure no flooding occurs on site.

External site levels will be arranged to convey water away from buildings.

Structural Integrity

> ***S10*** *Components must be designed to ensure structural integrity of the drainage system and any adjacent structures or infrastructure under anticipated loading conditions over the design life of the development taking into account the requirement for reasonable levels of maintenance.*
>
> ***S11*** *The materials, including products, components, fittings or naturally occurring materials, which are specified by the designer, must be of a suitable nature and quality for their intended use.*

The system and product selection is based upon proprietary systems specifically developed for this type of use.

Designing for Maintenance considerations

> ***S12*** *Pumping should only be used to facilitate drainage for those parts of the site where it is not reasonably practicable to drain water by gravity.*

Pumps will be deployed within basement areas for the lifting of foul and surface water.

Construction

> ***S13*** *The mode of construction of any communication with an existing sewer or drainage system must be such that the making of the communication would not be prejudicial to the structural integrity and functionality of the sewerage or drainage system.*
>
> ***S14*** *Damage to the drainage system resulting from associated construction activities must be minimised and must be rectified before the drainage system is considered to be completed.*

The existing 150mm dia outfall drain will be retained and reused as part of this development. It will be reinforced with a resin impregnated liner to improve it's longevity.

10.0 Conclusion

28 Redington Road is an existing residential property that occupies a long, narrow footprint. Most of the plot has soft landscaping.

It is proposed the property will be replaced with a new building. The impermeable area of 0.08ha will not increase as a result of the new development.

The redevelopment provides an opportunity to introduce sustainable urban drainage systems. The ground conditions do not favour infiltration systems. So an attenuation tank will be provided to store rainwater for gradual release into the sewer network. This will relieve some of the peak burden on the sewer network.

Calculations show the present site generates a peak surface run-off rate of 23.79 l/s for the 1 in 100 year storm event and that discharges into the public sewer.

It is proposed that we limit the flow rate for a maximum discharge rate of 5.0 l/s for all events up to and including 1 in 100 years plus a 30% allowance for climate change. This will satisfy the requirements of the London Plan.

We will use a proprietary cellular attenuation tank. The system is designed to provide storage during intense storm conditions. When the amount of rainfall exceeds the 5 l/s maximum permitted rate of discharge, stormwater will temporarily back up within the void and discharge over an elongated period of time. This will significantly reduce the peak run-off rates that presently discharge from the site into the public sewer.

Calculations indicate a tank storage volume of 31m³ is required for a maximum out flow rate of 5.0 l/s for storm events up to and including 1 in 100 year plus 30% climate change allowance.

Appendix A

Run Off Calculations

Project: 28 REDINGTON ROAD		Mott MacDonald	
Calculations for: SURFACE WATER DRAINAGE	Dvn/dept	Job no/file no	
	Calculated by: [signature]	Date: 22/4/16	Sheet no
	Checked by	Date	1 of 3

AIM

TO CALCULATE THE EXISTING AND PROPOSED RAINFALL INTENSITY, PEAK DISCHARGE RATES, SURFACE WATER VOLUME AND REQUIRED ATTENUATION VOLUME FOR A NUMBER OF RETURN PERIODS

REFERENCES

1. MICRODRAINAGE
2. MODIFIED RATIONAL METHOD

CALCULATIONS

RAINFALL INTENSITY

USING MICRODRAINAGE THE RAINFALL INTENSITY FOR A NUMBER OF RETURN PERIODS CAN BE OBTAINED.

FOR EACH RETURN PERIOD A 15 MIN WINTER STORM DURATION WAS MODELLED TO DETERMINE THE PEAK RAINFALL INTENSITY.

AN INCREASE OF 30% HAS BEEN ALLOWED FOR DURING THE 1:100 YEAR EVENT FOR CLIMATE CHANGE.

RETURN PERIOD	RAINFALL INTENSITY (mmh^{-1})
1	34
30	82
100	107
100+30%	139

PEAK DISCHARGE RATE

THE PEAK DISCHARGE RATE PER RETURN PERIOD CAN BE CALCULATED USING THE MODIFIED RATIONAL METHOD.

$Q = 2.78\,CiA$ WHERE
Q = PEAK FLOW RATE (ls^{-1})
C = RUNOFF COEFFICIENT
i = RAINFALL INTENSITY (mmh^{-1})
A = IMPERMEABLE AREA (Ha)

Project		
28 REDINGTON ROAD		Mott MacDonald
Calculations for: SURFACE WATER DRAINAGE	Dvn/dept	Job no/file no
	Calculated by	Date 22/4/16
	Checked by	Date
		Sheet no 2 of 3

C = 1 (WORST CASE)

i = AS CALCULATED ABOVE

A = 800m² = 0.08Ha (THIS IS THE SAME FOR EXISTING AND PROPOSED)

RETURN PERIOD	PEAK DISCHARGE RATE (ls^{-1})
1	7.55
30	18.20
100	23.75
100+30%	30.86

TOTAL VOLUME OF SURFACE WATER

AS THE EXISTING SITE IS POSITIVELY DRAINED AND THE PROPOSED SITE IS POSITIVELY DRAINED IT IS ASSUMED THAT 100% OF THE SURFACE WATER WHICH FALLS ON THE IMPERMEABLE AREAS OF THE SITE DISCHARGES VIA THE OUTFALL.

THE VOLUME OF WATER HAS BEEN CALCULATED FOR A 6 HOUR PERIOD BASED ON THE RAINFALL INTENSITY FOR A 6 HOUR EVENT (CALCULATED WITH MICRODRAINAGE) AND THE AREA OF 800m²

RETURN PERIOD	6 HOUR RAINFALL ($mm \cdot h^{-1}$)	DISCHARGE VOLUME (m^3)
1	3.72	17.86
30	8.17	39.22
100	10.58	50.78
100+30%	13.75	66.00

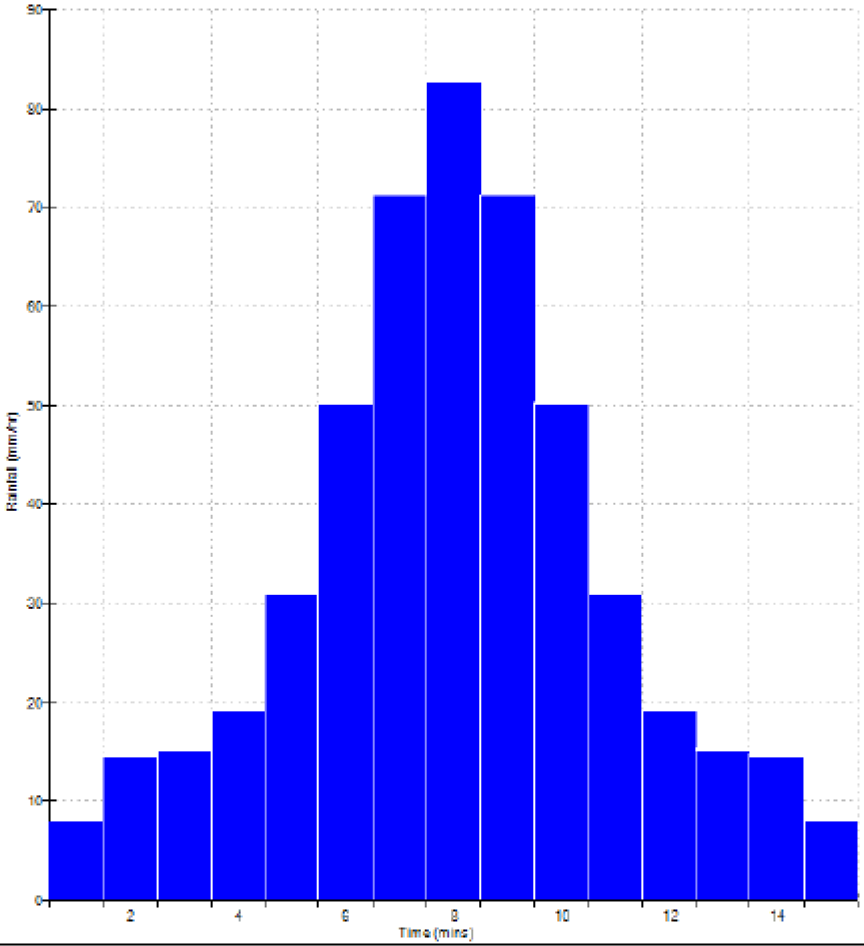
Mott MacDonald		Page 1
1st Floor Spring Ban... 33 Stamford Street Altrincham WA14 1ES		Micro Drainage
Date 22/04/2016 15:03 File	Designed by sim64626 Checked by	
Micro Drainage	Network 2013.1.1	

Rainfall profile

Storm duration (mins) 15

FSR Data
Region England and Wales

M5-60 (mm)	21.000
Ratio R	0.428
Peak Intensity (mm/hr)	82.705
Ave. Intensity (mm/hr)	33.349
Return Period (years)	1



Mott MacDonald		Page 1
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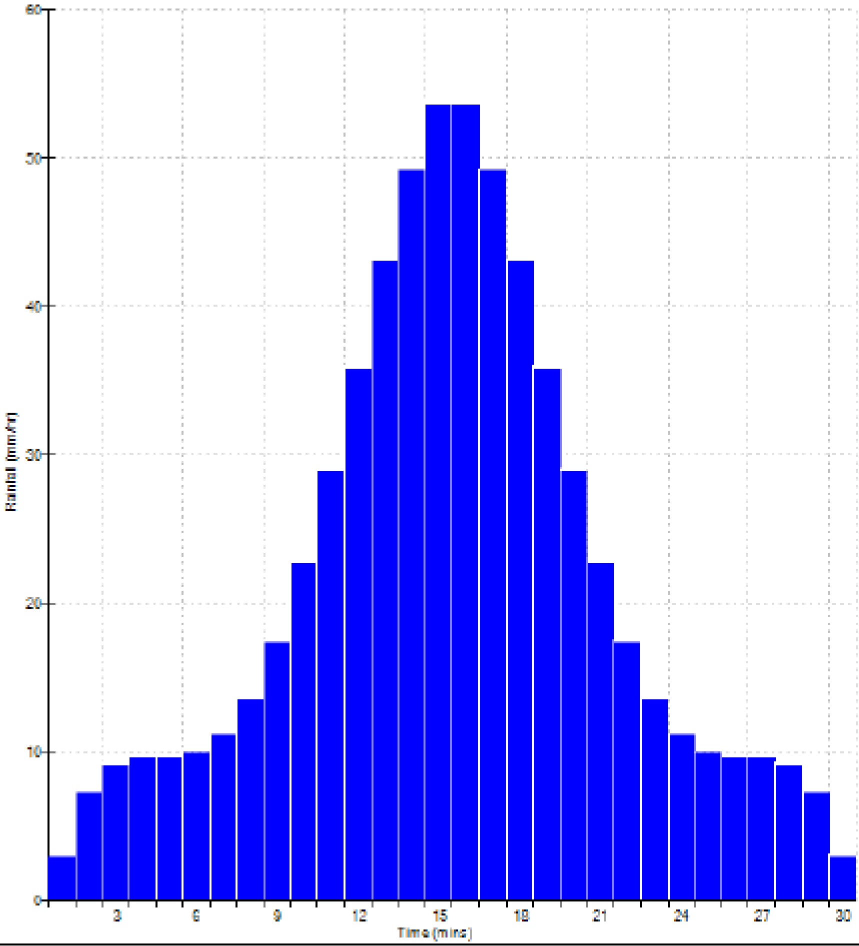
Date 22/04/2016 15:04 File	Designed by sim64626 Checked by	
Micro Drainage	Network 2013.1.1	

Rainfall profile

Storm duration (mins) 30

FSR Data	
Region	England and Wales
M5-60(mm)	21.000
Ratio R	0.428
Peak Intensity (mm/hr)	53.575
Ave. Intensity (mm/hr)	21.603
Return Period (years)	1



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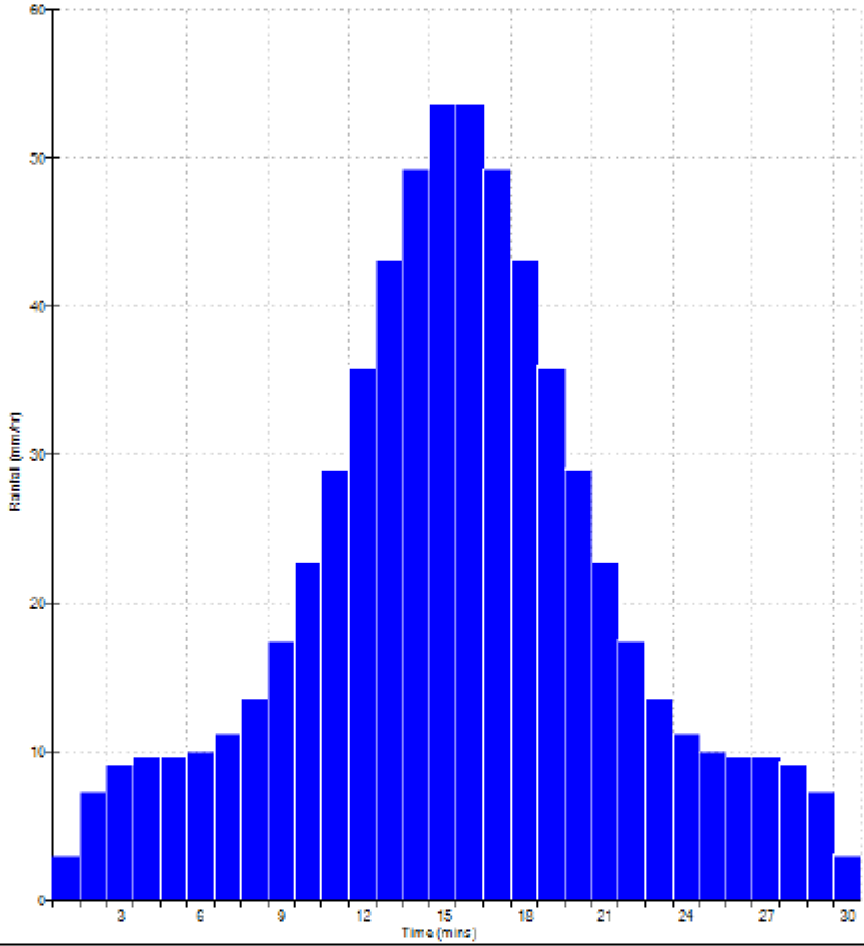
Micro Drainage	Network 2013.1.1	

Rainfall profile

Storm duration (mins) 30

FSR Data	
Region	England and Wales
M5-60 (mm)	21.000
Ratio R	0.428
Peak Intensity (mm/hr)	53.575
Ave. Intensity (mm/hr)	21.603
Return Period (years)	1



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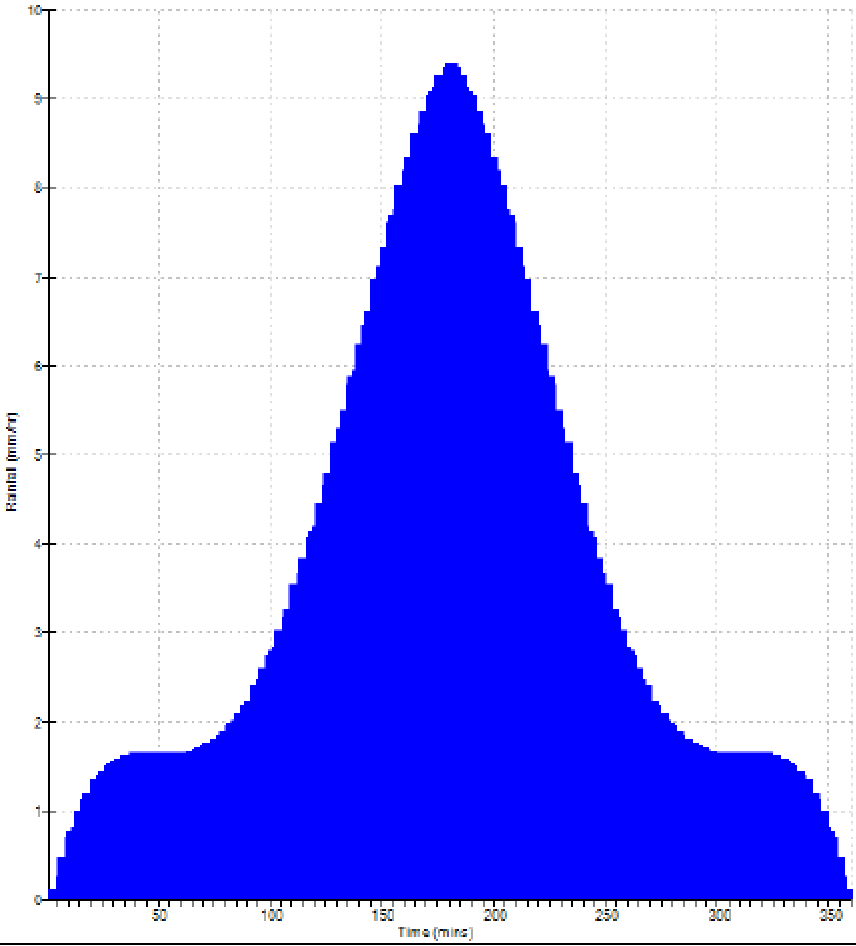
Date 22/04/2016 15:41 File	Designed by sim64626 Checked by	
Micro Drainage	Network 2013.1.1	

Rainfall profile

Storm duration (mins) 360

FSR Data	
Region	England and Wales
M5-60 (mm)	21.000
Ratio R	0.428
Peak Intensity (mm/hr)	9.404
Ave. Intensity (mm/hr)	3.718
Return Period (years)	1

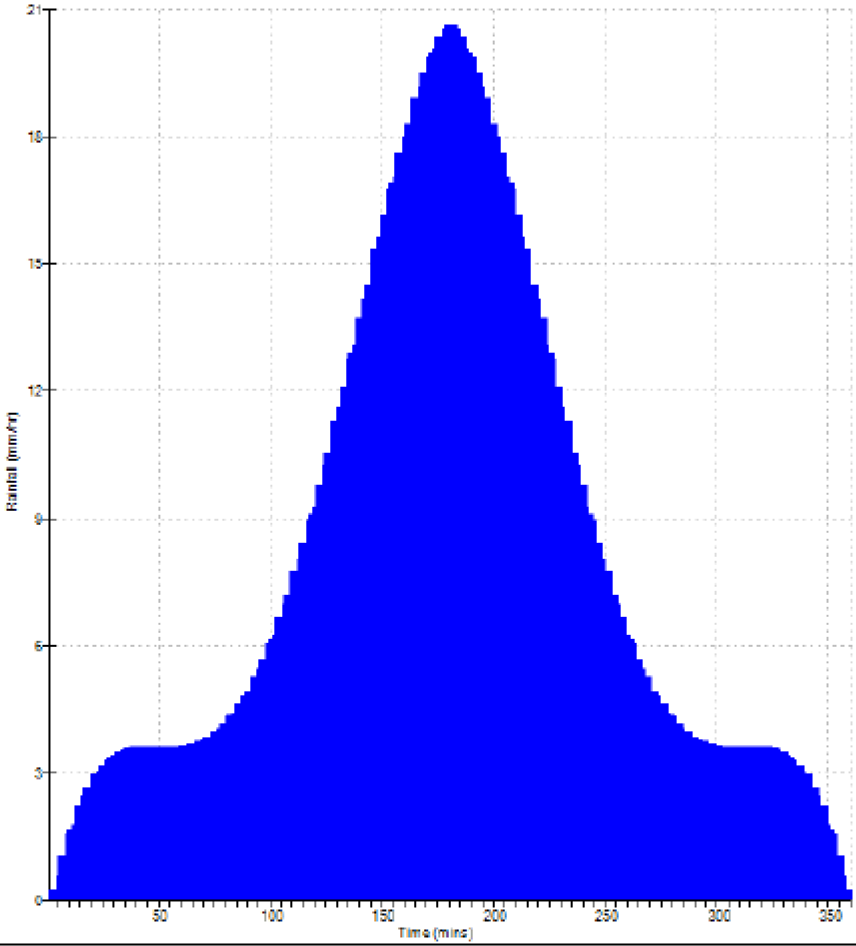


Mott MacDonald		Page 1
1st Floor Spring Ban... 33 Stamford Street Altrincham WA14 1ES		
Date 22/04/2016 15:43 File	Designed by sim64626 Checked by	
Micro Drainage	Network 2013.1.1	

Rainfall profile

Storm duration (mins) 360

FSR Data	
Region	England and Wales
M5-60 (mm)	21.000
Ratio R	0.428
Peak Intensity (mm/hr)	20.655
Ave. Intensity (mm/hr)	8.167
Return Period (years)	30

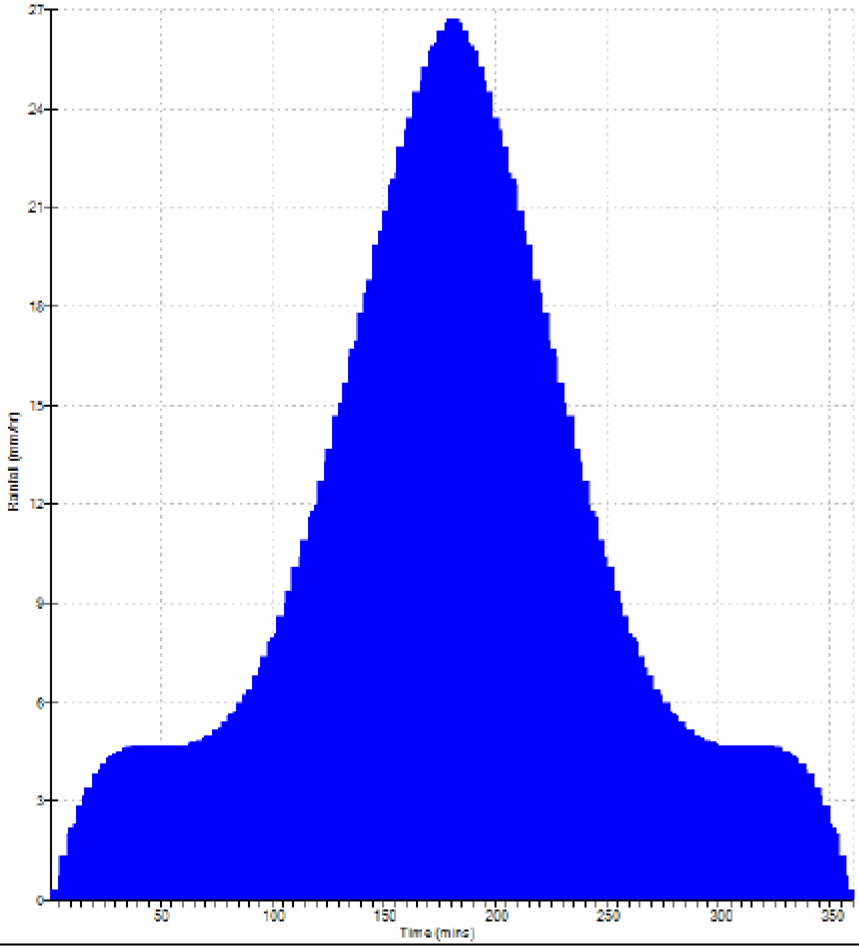


Mott MacDonald		Page 1
1st Floor Spring Ban... 33 Stamford Street Altrincham WA14 1ES		
Date 22/04/2016 15:44 File	Designed by sim64626 Checked by	
Micro Drainage	Network 2013.1.1	

Rainfall profile

Storm duration (mins) 360

FSR Data	
Region	England and Wales
M5-60 (mm)	21.000
Ratio R	0.428
Peak Intensity (mm/hr)	26.756
Ave. Intensity (mm/hr)	10.579
Return Period (years)	100



ATTENUATION DESIGN

In accordance with CIRIA publication C753 - The SUDS Manual

Pre post runoff method

Site characteristics

Location; London

Hydrological region; 6

Soil type (Wallingford Procedure W.R.A.P map); 3

Standard percentage runoff; SPR = **0.37**

Average annual rainfall; SAAR = **600** mm

5 year return period rainfall of 60 minute duration; M5_60min = **20.0** mm

Ratio 60-minute to 2 day rainfalls of 5 year return; r = **0.44**

Rainfall intensity increase due to global warming; $p_{climate}$ = **30%**

Routing coefficient; c_r = **1.00**

Volumetric runoff coefficient; c_v = **0.75**

Catchment details

Subcatchment	Name	Area (ha)	PIMP (%);	Impermeable. area (ha)
1;	site;	0.18;	43.0;	0.08;
	Total	0.18;	43.0;	0.08;

Greenfield runoff rates

Catchment area; AREA = **50.00** hectare

Greenfield runoff rate (50 hectare site); $\bar{Q}_{rural} = 0.00108m^3/s \times (AREA/1km^2)^{0.89} \times (SAAR/1mm)^{1.17} \times SPR^{2.17}$ = **119.9** l / s

Greenfield runoff rate; $\bar{Q} = \bar{Q}_{rural} / AREA \times A$ = **0.4** l / s

Greenfield runoff rate per unit area; $\bar{Q}_A = \bar{Q} / A$ = **2.4** l / s / hectare

Estimated site discharges

FSR growth rate (1 year); FSR_{1yr} = **0.85**

Discharge (1 year); $Q_{1yr} = \bar{Q} \times FSR_{1yr}$ = **0.4** l/s

FSR growth rate (30 year); FSR_{30yr} = **2.30**

Discharge (30 year); $Q_{30yr} = \bar{Q} \times FSR_{30yr}$ = **1.0** l/s

FSR growth rate (100 year); FSR_{100yr} = **3.19**

Discharge (100 year); $Q_{100yr} = \bar{Q} \times FSR_{100yr}$ = **1.4** l/s

Table equations

Peak flow; $Q_{post\_imp} = c_r \times I_{max} \times A_{imp}$

Runoff volume; $V_{post\_imp} = Q_{post\_imp} \times D / c_r$

Post development runoff; $\bar{Q}_{post} = Q_{post\_imp} + Q_{post\_open}$

Permitted discharge; $O_{exist} = Q \times D$

Post development runoff volume; $I_{post} = Q_{post\_open} \times D + V_{post\_imp}$

Storage volume required; $S_{post} = I_{post} - O_{exist}$

Required storage for period of 1 year

Discharge per hectare; $Q_{1yr\_area} = Q_{1yr} / A$ = **2.0** l/s/hectare

Greenfield runoff rate post development; $Q_{1yr\_post\_open} = Q_{1yr\_area} \times A_{imp} =$ **0.2** l/s

Duration (min)	1 year rainfall (mm)	Rainfall intensity (mm/hr)	Peak flow (m^3/s)	Runoff volume (m^3)	Post dev. runoff (m^3/s)	Permit dischrge (m^3)	Post dev. runoff vol (m^3)	Storage vol. reqd (m^3)
5	6.1	73.6	0.02	3.7	0.02	0.11	3.70	3.59
10	8.6	51.7	0.01	5.1	0.01	0.22	5.23	5.01
15	10.5	42.2	0.01	6.3	0.01	0.33	6.42	6.09
30	13.7	27.4	0.01	8.2	0.01	0.66	8.44	7.78
60	17.3	17.3	0.00	10.3	0.00	1.32	10.85	9.53
120	21.2	10.6	0.00	12.6	0.00	2.64	13.74	11.09
240	25.1	6.3	0.00	14.9	0.00	5.28	17.21	11.92
360	27.8	4.6	0.00	16.6	0.00	7.93	19.98	12.05
600	31.3	3.1	0.00	18.6	0.00	13.21	24.32	11.11
1440	39.1	1.6	0.00	23.3	0.00	31.71	36.94	5.24

Attenuation storage required

Vol. increase due to head-discharge relationship; $p_{hydro} =$ **1.00**

Maximum attenuation storage required; $V_{req\_max} = V_{max\_1yr} \times p_{hydro} =$ **12.1** m^3

Required storage for period of 30 year

Discharge per hectare; $Q_{30yr\_area} = Q_{30yr} / A =$ **5.5** l/s/hectare

Greenfield runoff rate post development; $Q_{30yr\_post\_open} = Q_{30yr\_area} \times A_{imp} =$ **0.4** l/s

Duration (min)	30 year rainfall (mm)	Rainfall intensity (mm/hr)	Peak flow (m^3/s)	Runoff volume (m^3)	Post dev. runoff (m^3/s)	Permit dischrge (m^3)	Post dev. runoff vol (m^3)	Storage vol. reqd (m^3)
5	15.0	179.8	0.04	8.9	0.04	0.30	9.05	8.75
10	21.2	127.2	0.03	12.6	0.03	0.60	12.88	12.28
15	25.8	103.1	0.02	15.3	0.02	0.89	15.73	14.83
30	32.7	65.4	0.01	19.5	0.01	1.79	20.25	18.46
60	39.8	39.8	0.01	23.7	0.01	3.57	25.21	21.64
120	46.8	23.4	0.01	27.9	0.01	7.15	30.94	23.79
240	53.8	13.4	0.00	32.0	0.00	14.30	38.16	23.86
360	58.4	9.7	0.00	34.8	0.00	21.45	43.98	22.53
600	64.0	6.4	0.00	38.1	0.00	35.75	53.45	17.70
1440	75.9	3.2	0.00	45.2	0.00	85.80	82.08	-3.72

Attenuation storage required

Vol. increase due to head-discharge relationship; $p_{hydro} =$ **1.00**

Maximum attenuation storage required; $V_{req\_max} = V_{max\_30yr} \times p_{hydro} =$ **23.9** m^3

Required storage for period of 100 year

Discharge per hectare; $Q_{100yr\_area} = Q_{100yr} / A =$ **7.7** l/s/hectare

Greenfield runoff rate post development; $Q_{100yr\_post\_open} = Q_{100yr\_area} \times A_{imp} =$ **0.6** l/s

Duration (min)	100 year rainfall (mm)	Rainfall intensity (mm/hr)	Peak flow (m^3/s)	Runoff volume (m^3)	Post dev. runoff (m^3/s)	Permit dischrge (m^3)	Post dev. runoff vol (m^3)	Storage vol. reqd (m^3)
5	19.2	230.5	0.05	11.4	0.05	0.41	11.62	11.20
10	27.5	165.2	0.04	16.4	0.04	0.83	16.75	15.92
15	33.7	134.8	0.03	20.1	0.03	1.24	20.60	19.36
30	43.0	86.0	0.02	25.6	0.02	2.48	26.67	24.19
60	52.1	52.1	0.01	31.0	0.01	4.96	33.12	28.16
120	60.9	30.4	0.01	36.2	0.01	9.92	40.50	30.59
240	69.6	17.4	0.00	41.4	0.00	19.83	49.94	30.11
360	75.3	12.5	0.00	44.8	0.00	29.75	57.60	27.85
600	82.1	8.2	0.00	48.9	0.00	49.58	70.17	20.59
1440	96.1	4.0	0.00	57.2	0.00	119.00	108.41	-10.59

Attenuation storage required

Vol. increase due to head-discharge relationship; p_{hydro} = **1.00**

Maximum attenuation storage required; $V_{req\_max} = V_{max\_100yr} \times p_{hydro}$ = **30.6** m^3

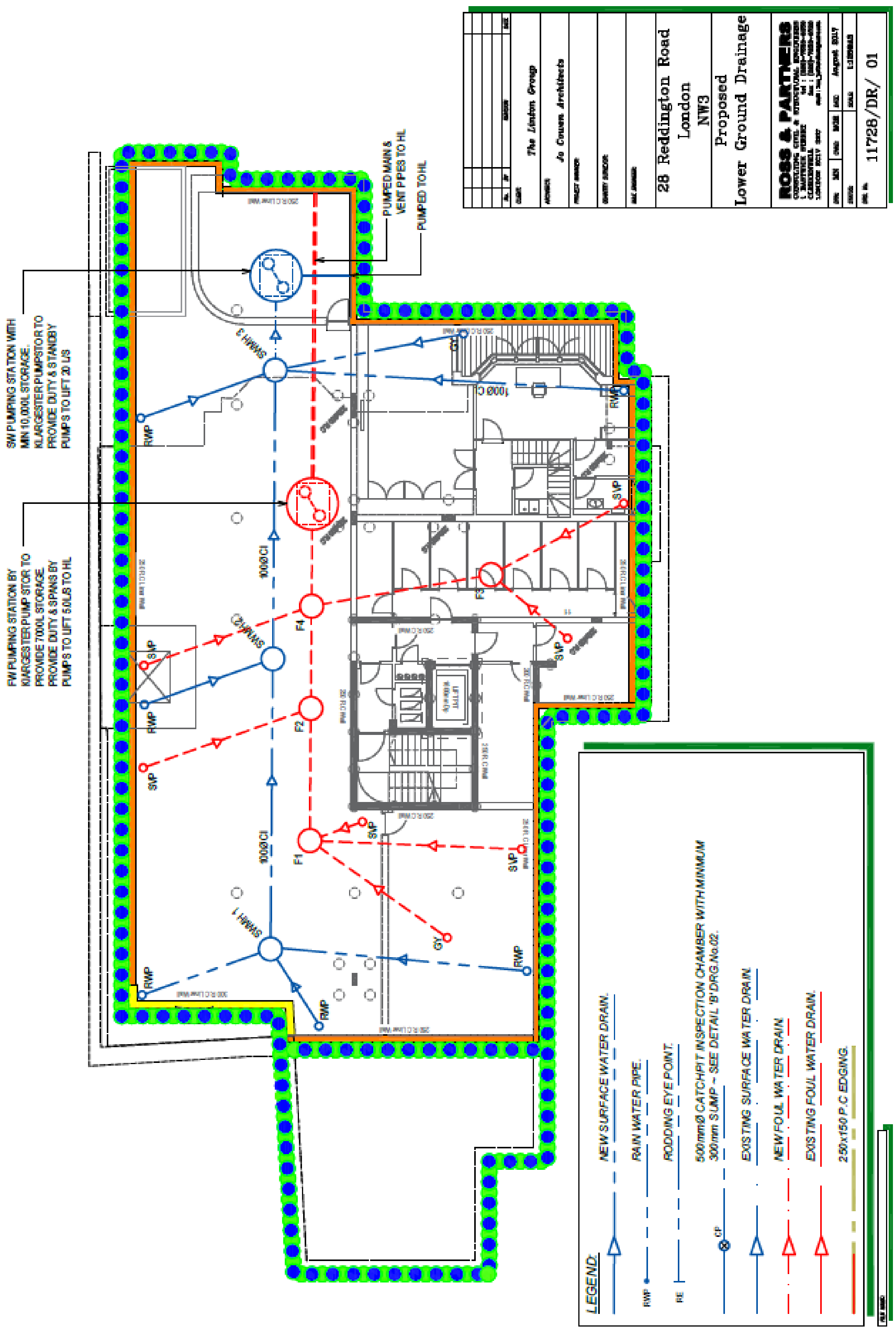
Interception storage

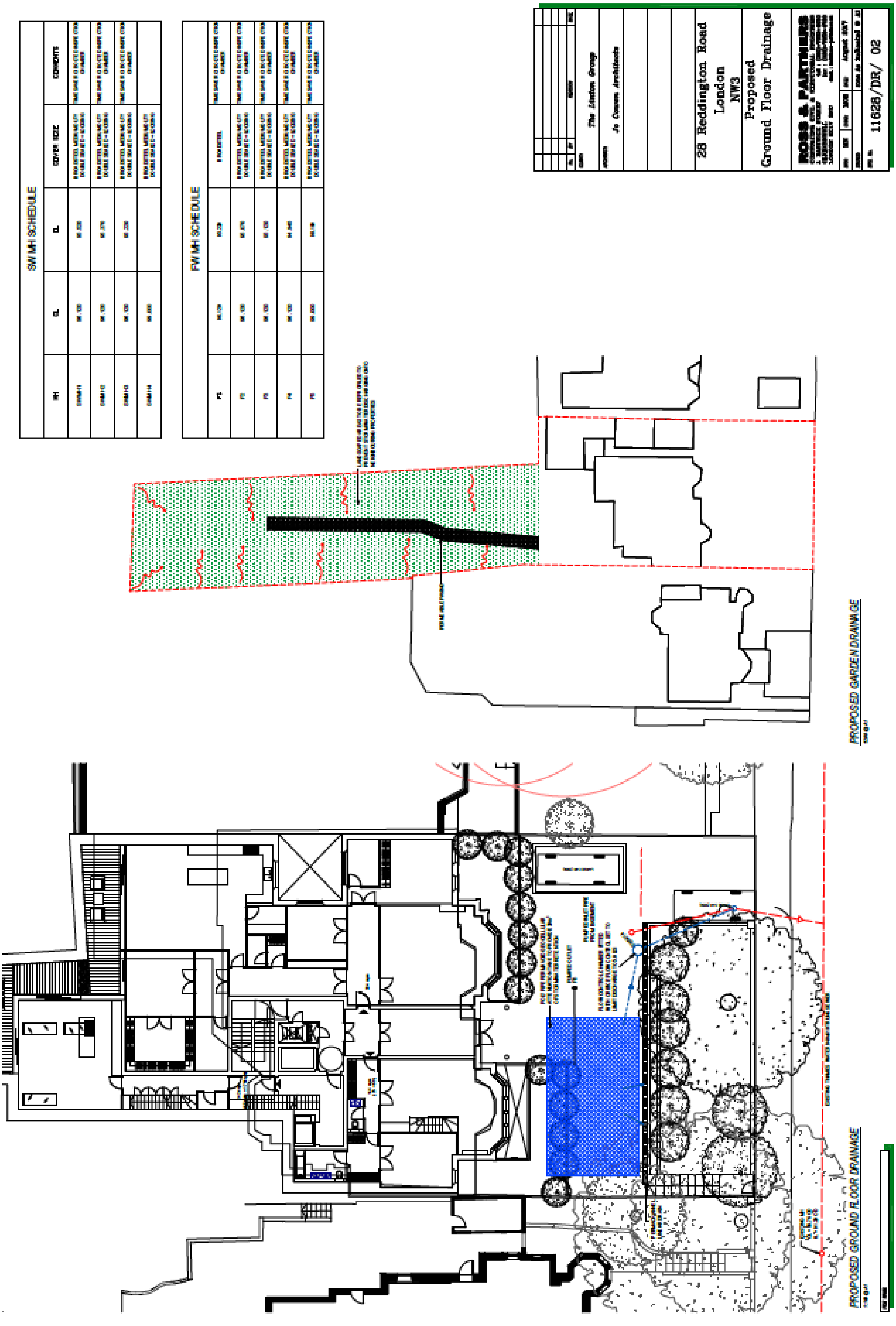
Interception rainfall depth; d_{int} = **5** mm

Volume of interception storage required; $V_{int\_req} = 0.8 \times A_{imp} \times d_{int}$ = **3.10** m^3

Appendix B

Proposed Drainage Layouts


SW PUMPING STATION WITH MIN 10,000L STORAGE. KLARGESTER PUMPSTOR TO PROVIDE DUTY & STANDBY PUMPS TO LIFT 20 L/S
FW PUMPING STATION BY KLARGESTER PUMP STOR TO PROVIDE 7000L STORAGE. PROVIDE DUTY & SPANS BY PUMPS TO LIFT 5.0L/S TO HL
PUMPED MAINS & VENT PIPES TO HL
PUMPED TO HL
RWP
SVP
F1
F2
F3
F4
GY
100Ø CI
LEGEND:
NEW SURFACE WATER DRAIN.
RAIN WATER PIPE.
RODDING EYE POINT.
500mmØ CATCHPIT INSPECTION CHAMBER WITH MINIMUM 300mm SUMP – SEE DETAIL 'B' DRG.No.02.
EXISTING SURFACE WATER DRAIN.
NEW FOUL WATER DRAIN.
EXISTING FOUL WATER DRAIN.
250x150 P.C EDGING.
The Linton Group
Jo Cowen Architects
28 Reddington Road
London
NW3
Proposed
Lower Ground Drainage
ROSS & PARTNERS
August 2017
11728/DR/ 01


SW MH SCHEDULE
FW MH SCHEDULE
The Linden Group
Jo Cowen Architects
28 Reddington Road
London
NW3
Proposed
Ground Floor Drainage
11628/DR/ 02
PROPOSED GARDEN DRAINAGE
PROPOSED GROUND FLOOR DRAINAGE