Blue Roof Design

Stephenson House

Surface Water Disposal Strategy

Revision 03

August 2018

Carl Harrop
FCPIHE FSoPHE MCIBSE IEng

Stephenson House

Surface Water Disposal Strategy

1. Introduction

This study has been commissioned by GLP in order review the strategy for the disposal of surface water from the redeveloped of Stephenson House.

This current document, Revision 03, uses the revised roofscape following client and letting agent comments and more detailed design by the Architects.

Extensive work has been undertaken to develop a scheme which provides significant attenuation of rainwater, but designs-out the need for pumping rainwater from a central storage stank at Lower Ground Floor Level. The pumping of rainwater for the lifetime of the building is not considered a sustainable approach.

This report also briefly reviews the information provided within the earlier SUDS (SUstainable Drainage Systems) report produced by others and issued as part of the planning application and the responses received from the statutory sewerage undertaker (Thames Water) and the Lead Local Flood Authority (Camden Council).

Since this original scheme, the design has been developed to remove the requirement for pumping rainwater by employing a combination of rooftop attenuation techniques (blue and green roofs). This report is now intended to support the final approval by the Lead Local Flood Authority (Camden Council) and as required by the planning Conditions, the additional explicit approval of Thames Water.

Earlier approval, through the statutory approval process is understood to have been given by Thames Water via Camden and Thames have stated verbally that they would expect the finalised approach to be via Camden. It is anticipated therefore that after the significant work and conversations with all parties that the approach outlined in the report will prove acceptable.

2. Executive Summary

There is the requirement for the flows from the development to be significantly restricted resulting in the need to temporarily hold water within the building. The outline proposal given within the original SuDS report (by others) was to use storage tanks at Lower Ground Floor with a discharge restricted to an agreed rate by pumps.

On submission of the SuDS report for planning however, Camden (Lead Local Flood Authority) advised an action to "provide details on feasibility for SuDS higher up in the SuDS hierarchy". The approach has therefore been reconsidered to achieve a gravity outflow from the building.

Our proposal is for all rainwater to be routed from the building via gravity. To achieve this, a series of blue and green roof areas will be provided to control and slow the flow of rainwater collected.

By choosing a method higher up in the SuDS hierarchy it has not possible to achieve the ideal and very strict flow rate of 5 l/s from the development, however, a considerable reduction of over 50% of the existing flow can be achieved.

We believe we have, through the effective combination of blue and green roof techniques, achieved a significant reduction in the peak storm flows from the site. Additionally, the use of green roof areas will result in a reduction in the overall volume of storm water discharged to the public sewerage system.

We would therefore seek final approval of our proposals for the surface water system from the development which will see a reduction in the surface water flow rate from the building of over 50% from 52 l/s to 25.5 l/s.

3. Overview of Potential Benefits

The benefits of blue and green roofs are now becoming far more well know, however, the following highlights some of those particularly relevant to this development

When compared to a traditional rainwater collection system and central attenuation reservoir located underground or at ground level it is believed that attenuation at roof level can potentially offer the following benefits.

- An above ground tank uses expensive floor area, yet it will probably only be fully utilized several times in the entire lifespan of the building. Storage at roof level however maintains or improves the ability for the area to still be fully utilized for plant space or a valuable roof terrace or external office break out space.
- Underground tanks may require pumped discharges which are subject to failure and are not a sustainable solution.
- Tanks situated below ground level may expose the building to sewer surcharge
- A zero gradient blue roof allows greater flexibility in outlet positioning.
- When compared to a traditional system for the building it is believed that it could yield the following savings
  - A reduction of rainwater outlets and downpipes together with the associated underground drainage works
  - The removal / reduction in size of the central storage tank and control device
  - The removal of screed or tapered insulation associated with 1:60 falls afforded to normal 'flat' roofs.
- When used in conjunction with green roof areas, as in this development, then these benefits are further enhanced by all those that go with green roofs such as a reduction in surface water volume discharged to the sewer. Also green roofs are seen to improve water quality, mitigate the urban heat island, reduce air pollution, sequester carbon and increase urban biodiversity by providing habitat for wildlife.

4. Loadings

The loadings from a basic blue roof can often fall within the standard tolerances meaning no upgrade of the design is necessary. However, as with all flat roofs, the maximum loadings will need to consider the potential for snow build up and the potential for blockage or failure of the rainwater system leading to overflow.

The loadings for the Stephenson House project have been considered, evaluated and approved by the project Structural Engineer. For information however, below is some typical loading data.

The following outline figures will assist in giving some background and context to the likely loads;

- General maximum operating depth = 0.75 kN/m^2
- Heavy duty void former = 0.09kN/m^2
- Additional possible water depth in event of blockage (will depend on roof detailing tbc) = 0.58 kN/m^2 approx
- Structural designs will normally already have a factor for snow loading, typically in the region of 0.60 kN/m^2 and should have an allowance for blockage of rainwater outlets causing accidental flooding
- A Blue Roof at zero gradient does not require a screed to be laid to falls. Such screeds can impose loads of between 1.2 and 4.8 kN/m2 and hence this allowance can be removed

It can be seen therefore, typically, the additional loads imposed by Blue Roofs will be relatively small and structural requirements are unlikely to differ significantly from a conventional flat roof.

Void formers can be specified with sufficient strength to allow the roof to be used for a roof terrace with raised planters, plant and equipment zones.

5. Exceedance Strategy

A completed blue roof installation may well be invisible and require far less maintenance than a system incorporating pumps, but failure through design or maintenance still has the potential to cause significant damage to the building below and hence the design should be undertaken in detail across the whole design team.

Probably the most important factor is a well-considered overspill strategy. The engineer and architect are working together to map the safe route of water should there be a blockage or storm event that exceeds the storm condition.

Generally, the strategy for exceedance paths will be via chutes or discreet overflow weirs through the parapets. In some instances, secondary pipe systems may be employed where this strategy can not be achieved (i.e. against a party wall)

The outlets will be in a position that is readily accessible to allow safe inspection and maintenance.

6. Design Parameters

Building rainwater disposal systems are generally designed in accordance with BS EN 12056. The following key information is applicable to this building in terms of the rainwater disposal systems;

- Assumed building life = 40 years
- Design storm duration = 2 minutes
- Design rainfall intensity = 221 mm/hr @ risk cat 2 (Atrium Roof)
- Design rainfall intensity = 87 mm/hr @ risk cat 1 (Flat Roofs)

In terms of the attenuation systems, the following parameters have been employed;

- Return Period = 100 years
- Climate Change allowance = 30%
- Base existing flow comparison = 50mm/hr
- Design Storm duration = 6 hours

7. Analysis

General

In preparing our calculations we have our used software specially developed for the design of Blue Roofs. This allows a choice of flow restriction methods; in this instance we have assumed one of the commercially available rainwater outlets with integral flow control device will be used. The storage volumes have been cross checked with Microdrainage calculations and these are appended to this report.

The basis for our calculations is that the attenuation system will be capable of containing the rainwater resulting from a storm with a return period of 100 years. A climate change allowance of 30% has also been added to this figure and the performance checked against a 6 hour storm duration.

The calculation uses the FSR data which is felt to be applicable for the short duration storms and small areas, applicable to a building scale SUDS system.

The estimated existing flow from the site using an intensity of 50mm/hr is **52 litres per second.**

There are certain parts of the building where it is not practical to employ attenuation, such as some of the very small terrace areas and the façade drainage channels adjacent to the public realm. We have therefore needed to allow some discharge direct to drain unattenuated.

However, the majority of the roofscape has been designed to include a combination of blue and green roof areas which has allowed us to achieve a significant decrease in peak flows from in excess of 52 litres per second to 25.5 litres per second.

The following section shows how this total allowance has been balanced across the different catchment areas.

8. Flow Summary

The table below summarises the assessed flows from each catchment area. This demonstrates a reduction in excess of 50% surface water run off (based upon a based condition measured at 50mm / hr and a proposed condition using 87mm / hr).

With consideration that this is an existing building being redeveloped and there is no increase in impermeable area, we believe this is a good balance in reducing peak flow rates without creating a legacy of increased carbon production.

AREA	FLOW RATE (l/s)	COMMULATIVE FLOW RATE FROM BUILDING (l/s)
LEVEL 8	2.0	2.0
LEVEL 7 TERRACE	2.4	4.4
LEVEL 6 TERRACE	7.3	11.7
ATRIUM ROOF	Cascade to Level 1	11.7
LEVEL 4	Cascade to Level 1	11.7
LEVEL 3	Cascade to Level 1	11.7
LEVEL 2	Cascade to Level 1	117
LEVEL 1	6.5	18.2
FACDE LINEAR DRAINS	7.3	25.5
	TOTAL	**25.5**

The façade drains at Ground level were introduced to the design after the initial rainwater disposal proposals were developed. It has therefore been necessary to allocate a specific flow rate to them. This will need to be achieved by the limiting of the outlet size or an inline downstream flow control mechanism to prevent the maximum design flow rates been exceeded.

9. Operation and Maintenance

Maintenance

The purpose of a SuDS Maintenance Plan is to ensure that those involved in the maintenance and ongoing operation of the SuDS system understand its functionality and maintenance requirements in supporting the long-term performance to the criteria to which it was designed.

The completed SuDS Maintenance Plan should cover the following;

- A description of the site, describing how the drainage system works and what it is trying to achieve. It should also explain the biodiversity aspects of a scheme as these can easily be compromised by inappropriate maintenance.
- A plan that identifies runoff sub-catchments, SuDS components, critical water levels, control structures, flow routes (including exceedance routing) and outfalls.
- A plan for the safe and sustainable removal and disposal of silt and waste periodically arising from the drainage system.
- A maintenance schedule of work, listing the tasks to be undertaken and the frequency at which they should be performed so that an acceptable long-term performance standard is secured. The schedule should be a living document as it may change, where inspections advise changes to the scheme maintenance requirements.
- Contact sheet and emergency action plan for dealing with incidents or pollution accidents.

Although detailed operating and maintenance plans will be developed as the design progresses, the following reviews some of the primary operating and maintenance functions for the different SuDS components proposed within this report.

Blue Roof Areas
The following elements will form the basis of the management plan;

- Regularly inspect to ensure that there have been no changes to the use of the roof area that reduce the storage volume available or impede the (potentially subsurface) flow of water.
- Regularly inspect waterproofing membrane for mechanical damage
- Periodic inspections & removal of debris or other items that represent blockage risks particularly in vicinity of the outlet

- After significant storm events, visually inspect the roof to confirm that the orifice of the outlet is not blocked

<u>*Green Roof Areas*</u>

General maintenance is normally carried out annually during springtime. However, certain tasks which will be dependent upon the location of the roof, such as the removal of weeds, seedlings and accumulated leaf litter may also need to be done during other times of the year. Much of the green roof areas proposed for this project are planters within accessible areas so will be regularly tended.

Health and safety is a prime concern and although the outline designs currently indicate all planted roofs are safely accessible this must be monitored as the design develops.

Debris and silt will be prevented from entering the water storage zone by the use of geotextile membranes. All rainwater outlets will be installed so as to be readily accessible for routine inspection and maintenance.

<u>Carbon and Embodied Energy</u>

As discussed elsewhere in this report, it is felt that a solution that involves pumping the rainwater into the sewer for the lifespan of the building is not a sustainable proposal for the following reasons;

- Higher embodied energy / carbon in the construction
- Higher maintenance demands with the associated carbon impact
- Higher risk of property damage in the event of a power failure
- Ongoing running costs and carbon burden of the permanent use of the building even when not in use.

We have assessed the impact of running a pump to discharge the rainwater as follows.

- Average rainy days for London = 106 / year
- Average pump run time = 2120 hours / year

Assuming that the pump will be on part load for 50% of this 2120 hours, and allowing a 5kW inverter driven pump;

- 5kW x 0.5 x 2120 = 5,300 kWh / year

Scottish Power in London have a current standard tariff for electricity at 12.3 p/kWh. Annual Running costs would therefore equate to;

- 5,300 x 0.123 = £ 651.90 + maintenance /service costs.

The current kWh to carbon conversion factor (ref: Carbon Trust – conversion factors – energy and carbon conversions 2016 update) is 0.41205 kgCO2e per unit of grid electricity;

- 5,300 kWh x 0.41205 = 2,183.86 kgCO2e of carbon generated / year

This is just for the pump and does not included the impact of the increased maintenance required for pumps or their replacement.

Appendix 1

Review of Individual Roof Areas

As the building design has developed and the client has provided feedback as to the use of the completed building, the roofscape has changed from the earlier designs. There has been a reduction in the amount of green roofscape that is readily available for calculated attenuation of stormwater.

For this reason, the rainwater design has developed. Whilst it still includes the benefits associated with green roofs, for the large proportion this is now excluded from the attenuation calculations and the buildings blue roof attenuation is now concentrated at levels 8 and 1.

The table below provides a summary of the green roof areas, together with the average soil depths.

	m² of soil at different depths (mm)				
	100	200	300	400	500
L1		74.4	57.3		
L2			26.4		
L3		47.1	29.2		
L4		43.9	38.4	7.5	6.2
L6			21.9		
L7					

The following reviews the approach for each roof area.

Main Roof (L8)

It has been assumed in our calculation that there is a 95% void availability, with some 9th floor roof areas cascading to this 8th floor roof.

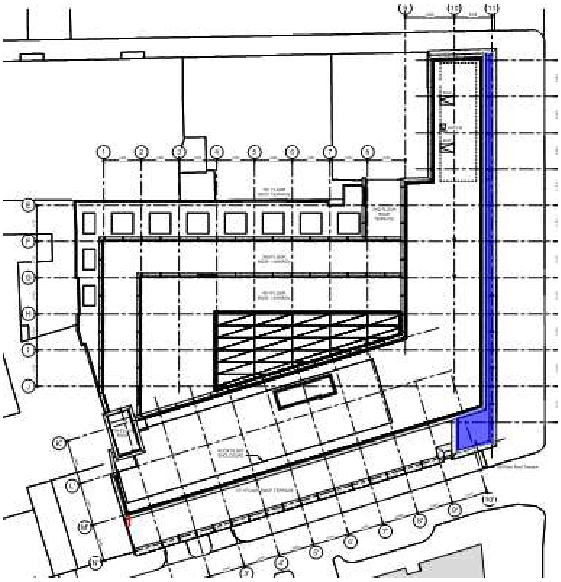
The roof is to be provided with a granular topping and the available void has been assumed to start only above the top level of granular material.

Design Water Depth and Overspill Strategy

The calculated design water depth in the 100 year (+30% CC) is 71mm. Overspill points are to be through the parapets to the lower terrace on the perimeter of the building.

- Approximate Area = 1530m2
- Approximate Blue roof Area = 1280m2
- Restricted Flow Rate = 2 l/s
- Estimated Storage Volume Provided = 84m3
- Estimated Maximum Water Depth = 78mm

7th Floor Terrace



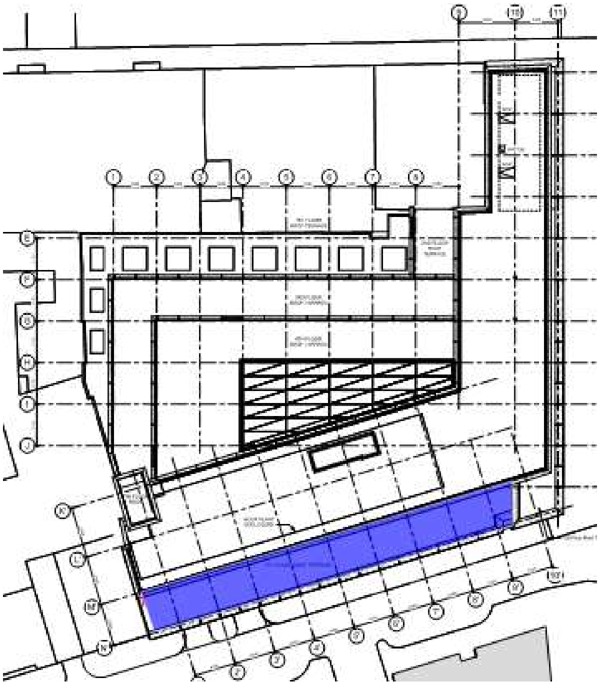
The green rood portion of this roof has been removed and therefore the rainwater discharges traditionally to the gravity system.

Design Water Depth and Overspill Strategy

Overspill points are to be provided through the parapet. These will be sized to cater from potential overspill from the main roof.

- Approximate Area = 101m2
  - 101m2 x 87mm per hr / 3600 = **2.4 l/s**

6th Floor Terrace



This roof area has two distinct zones. The planted zone has the ability to hold water for attenuation, whilst the zone closest to the level threshold into the building is of insufficient depth to facilitate this.

Attenuation will be provided within the green roof areas by means of the time taken for water to percolate through the growing media. The proposed average soil depth is 3000mm.

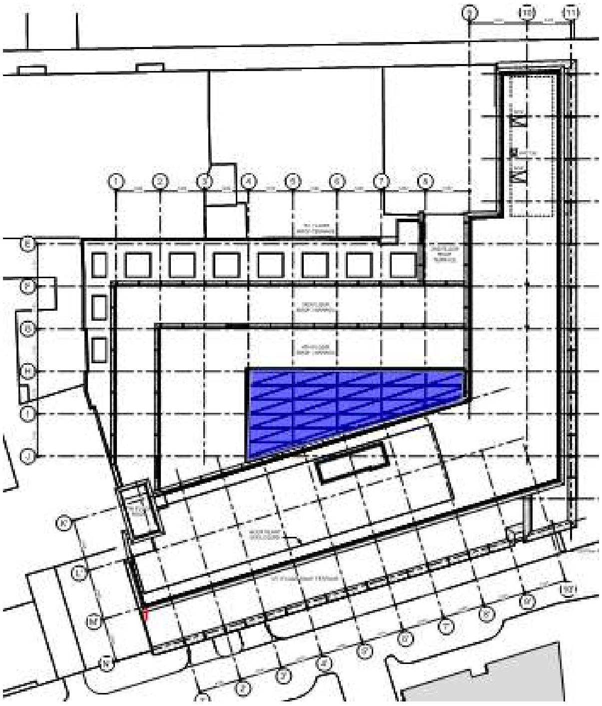
Design Water Depth and Overspill Strategy

Water will be held within the green roof media.

Overflow capacity will be required via overflow chutes through the parapet walls

- Approximate Area = 332m2
- Assumed standard roof area = 310m2
  - 145m2 x 87mm per hr / 3600 = **7.2 l/s**
- Assumed Green roof Area = 22m2
  - 22m2 x 87mm per hr / 3600 = 0.5 l/s
  - Assuming a growing medium depth of 300mm yielding a minimum peak flow reduction of 75%
  - 0.5 l/s x 0.25 = **0.12 l/s**

Atrium Roof



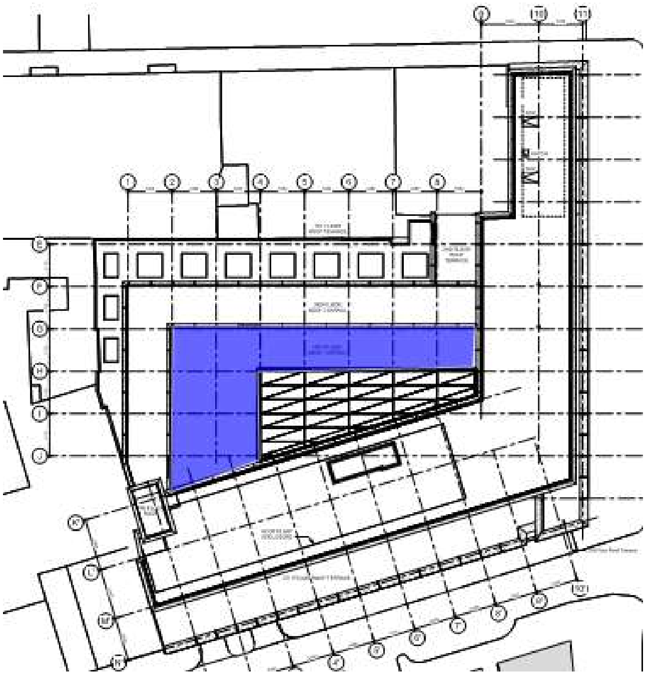
This glazed roof has no potential for attenuation. The roof will be provided with a continuous perimeter gutter. External rainwater pipes will collect the water and route it to the Level 4 roof from where it will cascade and become part of the attenuated flow at Level 1.

Design Water Depth and Overspill Strategy

This gutter has been sized at BS12056 category 2 and the overspill strategy is onto the lower surrounding roof area. This higher risk category used making any overspill unlikely.

- Approximate Area = 280m2
    - 280m2 x 220mm per hr / 3600 = **<u>17.1 l/s</u>**

4th Floor Terrace



Although almost 100m2 of green roof, at variable depths, has been retained in the design this is insufficient to provide the level of attenuation required to achieve the 50% reduction in flows required for the building.

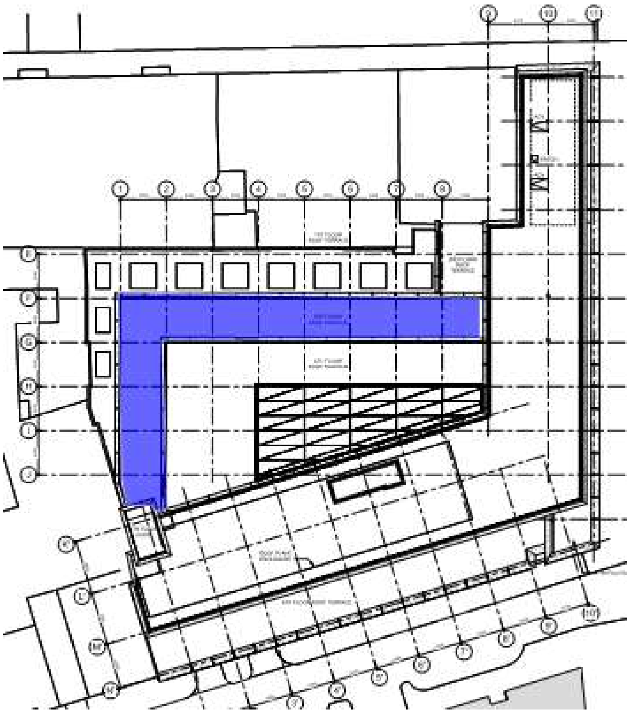
The benefits of green roofs remain, however, in terms of attenuation calculation the entire flow is cascaded to Level 1 where the flow will be attenuated.

Design Water Depth and Overspill Strategy

Exceedance paths to be via open chutes through the parapets to the roof below

- Approximate Area = 456m2 to cascade to the Level 1 Blue Roof

3rd Floor Terrace



Although over 76m2 of green roof, at variable depths, has been retained in the design this is insufficient to provide the level of attenuation required to achieve the 50% reduction in flows required for the building.

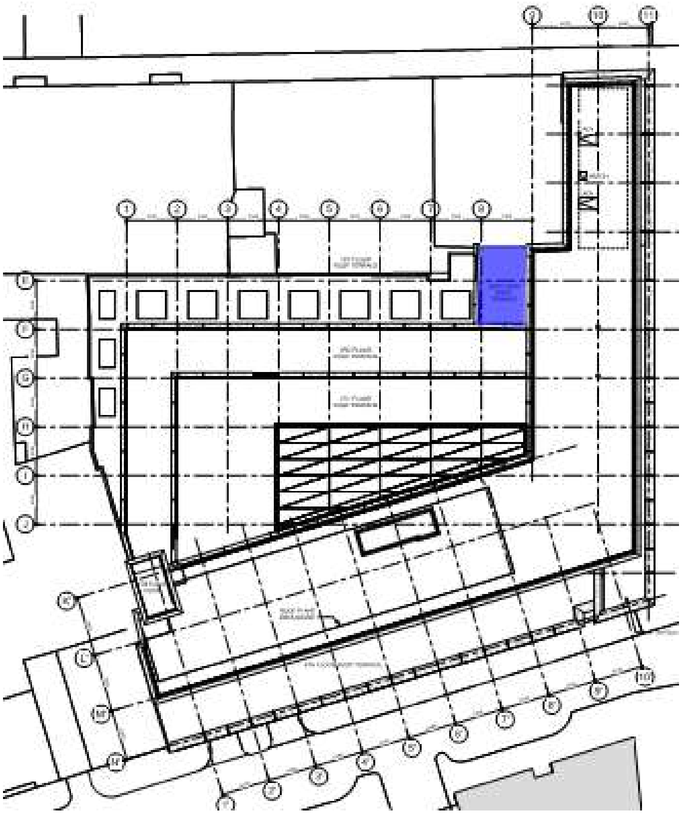
The benefits of green roofs remain, however, in terms of attenuation calculation the entire flow is cascaded to Level 1 where the flow will be attenuated. Overspill provision will be provided via the chutes through the parapets serving the exposed hopper and downpipes.

Design Water Depth and Overspill Strategy

Exceedance paths to be via open chutes through the parapets to the roof below

- Approximate Area = 418m2 to cascade to the Level 1 Blue Roof

2nd Floor Roof Terrace



There is approximately 26m2 of green roof at this level, at variable depths, This is considered insufficient to provide the level of attenuation required to achieve the 50% reduction in flows required for the building.

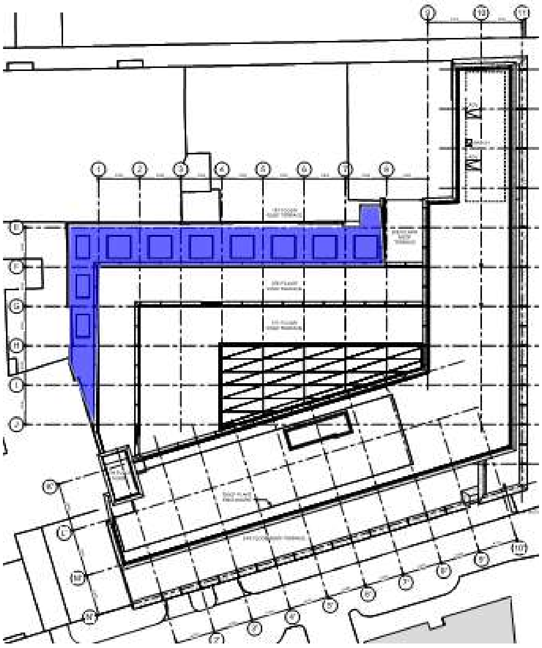
The benefits of green roofs remain, however, in terms of attenuation calculation the entire flow is cascaded to Level 1 where the flow will be attenuated. Overspill provision will be provided via the chutes through the parapets serving the exposed hopper and downpipes.

Design Water Depth and Overspill Strategy

Exceedance paths to be via open chutes through the parapets to the roof below

- Approximate Area = 60m2 to cascade to the Level 1 Blue Roof

1st Floor Roof Terrace



This roof has been detailed by the Architect / Landscape architect to be able to be the primary area for rooftop attenuation along with the Level 8 roof.

It is proposed to utilise a void former to hold water beneath the areas between rooflights. The areas will be provided with various green roof planters together with an pedestrian accessible topping to allow for maintenance access.

Design Water Depth and Overspill Strategy

Overspill provision to external elevations is limited and hence a secondary pipe system may also be considered.

- Approximate Area = 311m2
- Roof available for attenuation = 210m2
- Additional contributing areas
    - (Atrium Roof) = 242m2
    - Level 4 = 456 m2
    - Level 3 = 418m2
    - Level 2 = 60m2
- Therefore, total area contributing to Level 1 attenuation zone = 1433m2

- Restricted Flow Rate = 6.5 l/s
- Estimated Storage Volume Provided = 52m3
- Estimated Maximum Water Depth = 276mm

Appendix 2

Blue Roof Calculation Summary

Roof 1 = Level 1

Roof 2 = Level 8

Project: Stephenson House			
Client: GLP			
Designer: Carl Harrop	Ref:		Date: 14/08/2018
Rainfall: London			
FSR: r: 0.42 M5-60: 20 mm			
FEH: Parameters Not Set			
Method	FSR	FSR	
Return Period	100 years	100 years	
Percentage Increase	30	30	
Roof	**Roof 1**	**Roof 2**	
Blue Roof Area (m²)	210	1280	
Percentage Multiplier	100	100	
Additional Area (m²)	1223	250	
Percentage Multiplier	100	100	
Total Area (m²)	1433	1530	
Outlet Location			
Slope (1 in)			
Length (m)			
Width (m)			
Gutter Width (m)			
Gutter Depth (mm)			
Depression Depth (mm)			
Storage void ratio (%)	90	85	
Drop to orifice (m)	0	0	
Results			
Critical Storm Duration	56 min	3.2 hrs	
Critical Rainfall (mm/h)	55.3	21.9	
Time to Half Empty	1.11 hrs	5.86 hrs	
Storage Depth (mm)	276	78	
Max. Outflow Rate (l/s)	6.5	2	
Storage Volume (m³)	52.163	84.353	
Orifice Diameter (mm)	siphonic	siphonic	
	Pass	**Pass**	

Appendix 3

Overview of Blue Roof Principles

There is no fixed definition for a Blue Roof. At the more elaborate end of the spectrum, they share similar characteristics with an Intensive Green Roof system but with deeper substrate, containing more organic matter and retaining more water, thus allowing establishment of a marshy habitat.

Blue Roofs in this guise can significantly improve thermal performance of a building, acting as a thermal store, reducing fluctuations in temperature and providing a cooling effect in summer, with additional insulation in winter; particularly beneficial in mitigating Urban Heat Island effect. Incorporation of an attenuation zone results in a reduction in the rate of run-off slowing rainfall to entry into watercourses and sewers.

Systems which release the majority of the volume of the design storm within 24-48 hours are however more common and will be the only ones considered in this report.

Any system which purposely retains water on the roof to minimise the impact upon downstream infrastructure can be classified a blue roof. These can broadly be considered under the following categories;

- Exposed

  Where the water is retained directly on top of the roof finish. A layer of aggregate may be used which will help aesthetically.

- Enclosed

  Where the water is stored within a void formed beneath paving for example or within similar void former

- Combined

  Where a void former is used to create a calculable void beneath a green roof for example.

Appendix 4

Project Examples

The following are some of the projects where rooftop rainwater attenuation has been successfully incorporated.

Project Name	Date Installed	Comments
Mixed Use Devt. Greenwich Reach	2012	Mixed use
Blackburn Youth Zone	2012	Education
Bristol University	2014	Education - Auditorium
Unite Stratford	2014	Education
Rooftop MUGA at MUFC Supporters Trust Hotel	2015	Commercial
New rooftop MUGA at Media City	2015	Commercial
Creek Road, Greenwich	2016	Residential
Taylor Wimpy Homes Kew Podium	2016	Residential
Project Dylon, Sydenham, Kent	2017	Residential
White Collar Factory, London	2016	Mixed including IT & Software
Seacole House, London	2016	Transformer building for London financial quarter
Euston HS2 , Camden	In Design	Transport / Commercial / Retail

Appendix 5

Rainwater Harvesting Review

<u>Background</u>

As discussed elsewhere in this report, the most sustainable approach for this building is considered to be the implementation of maximum rooftop attenuation using a gravity connection to the sewer. In such a system rainwater harvesting would not be appropriate.

The use of extensive green roof areas would lead to the discolouration of the collected water. Additionally, the local attenuation of rain at individual roofs will make combining the rainwater to a central position difficult without re-introducing a pumped discharge of excess water.