Review of drainage and flooding implications of basement extensions in RBKC

Revision 2.0
March 2014

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Reference	EPG/RBKC/2014/001/2.0	**Revision**	2.0	**Issue Date**	March 2014

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Appendix A Storage and interception capacity of soil construction above a basement roof

KEY FINDINGS

1. There are no significant concerns over basement extensions and sustainable drainage.

2. Runoff from the roof of a basement with 1m of soil over it, is not likely to occur for most frequent rainfall events. This is one of the fundamental requirements of a sustainable drainage system in accordance with the SuDS Manual (known as interception).

3. It is easy to provide the roof with an effective sustainable drainage system that can manage more extreme events in accordance with SuDS Manual and the current draft of the National Standards for Sustainable Drainage Systems.

4. Provision of a pumped outfall from the basement will provide adequate mitigation against flooding from sewers into basements.

5. The design of basements should take account of other forms of flooding such as from over topping of river walls. This can be achieved for example by maintaining threshold levels at a level that minimizes the risk of flood water entry.

6. The proposed RBKC policy to limit basements to 50% of a garden area is far too generic and does not take into consideration the particulars of the specific development such as existing groundwater levels, the permeability of the ground, SuDS measures incorporated into the design, etc.

7. The existing requirement to limit basements to 85% of the garden area is more than sufficient to allow reasonable SuDS provision and aquifer recharge on most sites.

8. There is no valid reason why basement construction should be limited to a blanket 50% of a garden area on the basis of drainage or flood risk. Any assessment should be on a site specific basis and include consideration of the proposed SuDS.

1. INTRODUCTION

1.1 Purpose

Royal Borough of Kensington and Chelsea (RBKC) has prepared a Basements Publication Policy for consultation (the Policy). The Authors have been appointed by Cranbrook Basements Limited to comment on the references made in the Policy to drainage and flooding issues. The RBKC policy indicates that there are concerns that basement development of greater than 50% of the garden area may lead to reduced surface water infiltration, increased surface water run-off and hence increased flooding risk.

The purpose of this report is to determine whether the statements made in the Policy are supported by robust evidence. Where this is not the case alternative evidence is provided to show that the statements are not reasonable.

The report includes:

- An assessment of the geology, groundwater levels and likely infiltration rates within the RBKC area, and the impact these have on drainage and flooding. This considers the permeability of the ground and the likely runoff from gardens in 1 in 10/20/100 year storm events in typical geological conditions in RBKC;
- A drainage impact assessment of the effects of constructing basements to various proportions of garden space;
- An assessment of the performance of typical basement construction when compared to green roofs which are promoted by the Environment Agency as a source control technique as part of sustainable drainage;
- A comparison of runoff from the top of the basement construction with the runoff from permitted developments in rear gardens that do not require attenuation;
- A demonstration of how good drainage design can easily mitigate the potential impact of basement construction on surface water runoff from a site.
- Consideration of the impact of infiltration of runoff from the top of the basement close to basement foundations (the 5m rule from Building Regulations) and how this can be dealt with by good geotechnical design/analysis.

1.2 Authors

Steve Wilson is a Chartered Civil Engineer with over 30 years of experience in geotechnical and environmental engineering. He is a UK Registered Ground Engineering Advisor and has wide experience of geotechnical and drainage design and construction. Steve is the Technical Director or EPG Limited.

He has expertise in flood risk assessment and the design of sustainable drainage systems (SuDS). He has contributed to much of the leading research into SuDS over the past 14 years including CIRIA, Environment Agency and Interpave guidance on SuDS, green roofs and permeable pavements. He has prepared evidence to support legislation relating to permeable driveways and he is currently part of a team working to update the SuDS Manual and National Standards for SuDS. Steve was responsible for the design of the sustainable drainage to the equestrian venue at the London 2012 Olympics, which involved considering runoff from an elevated temporary platform that supported the equestrian arena. Steve is also employed as an expert witness in cases relating to SuDS.

Anthony McCloy is a Chartered Civil & Environmental Engineer and managing director of McCloy Consulting Limited. He has 15 years technical experience in the areas of hydrology, hydraulics, flood risk assessment and drainage, particularly in relation to hydraulic modelling and design of SuDS.

Anthony has been involved at all stages of the development process; from initial site selection, outline and detailed design, though to performance assessment and site inspection. As a leading specialist in the field of sustainable drainage, Anthony has been a key tutor for the (CIRIA) National SUDS training workshops held yearly throughout UK and Ireland since 2006. He has been involved in development of SuDS planning guidance for Local Authorities in the greater London area and is a member of the Project Advisory Group for the CIRIA SuDS Manual update.

Andy O Dea has more than 20 years of experience as a project manager and geotechnical/geoenvironmental engineer in sustainable land development and infrastructure projects across the UK and internationally with major UK and international consultancies. He is a Chartered Environmentalist and has managed and delivered many specialist geoenvironmental and geotechnical projects and large and complicated multidisciplinary land development schemes. Andy has extensive experience of contamination risk assessment, waste management, ground gas risk assessment, sustainability assessment, earthworks specification and control, geotechnical design and environmental impact assessment.

He has published many technical articles and papers and contributed to industry best-practice guidance including membership of the steering group for CIRIA Report C681, Unexploded Ordnance (UXO) – A guide for the Construction Industry.

Nick Langdon is both a Chartered Civil Engineer and Chartered Environmentalist with 35 years of experience as a geotechnical and geoenvironmental specialist. He is a Fellow of the Institution of Civil Engineers and a Director of CGL.

He is the author of more than twenty publications in geotechnical and geoenvironmental subjects and co-author of the ICE Design and Practice Guide on Contaminated land investigation, assessment and remediation. He was also on the steering committee on the authoritative CIRIA C583 Engineering in the Lambeth Group, 2004. For eleven years he was a senior lecturer in geotechnics and engineering geology studies at the University of Portsmouth during which time he directed research involving the assessment of permeability of London Clay as a landfill lining material.

1.3 Statements in RBKC Basements Publication Planning Policy

The RBKC Basements Publication Planning Policy makes a number of statements regarding flood risk and sustainable drainage. These are summarised below:

34.3.50 – "*There are also concerns over the sustainable drainage*…."

34.3.55 – "*Retaining at least half of each garden will enable natural landscape and character to be maintained, give flexibility in future planting (including major trees), support biodiversity and allow water to drain through to the 'Upper Aquifer*[7]" Footnote 7 to this sentence states "*Due to the impermeable London Clay which lies beneath the gravel terraces there is a local perched water table which is fed by precipitation within the Thames Valley. This is known as London's Upper Aquifer*."

34.3.56 – "*Keeping the unexcavated area of a garden in a single area and adjacent to similar areas in other plots allows better drainage*….."

34.3.67 – "*Policy CE2 of the Core Strategy requires surface water run-off to be managed as close to its source as possible. A minimum of 1m of suitably drained permeable soil above any part of a basement within a garden provides for both reducing the amount and speed of water run-off to the drainage system and the long term future of shrub and other garden planting. Other SUDS measures may also be required*."

34.3.71 – "*Given their nature, basements are more susceptible to flooding, both from surface water and sewage, than conventional extensions, and applicants are advised to see Policy CE2. Fitting basements with a positive pumped device (or equivalent reflecting technological advances) will ensure that they are protected from sewer flooding. Fitting only a 'non return valve' is not acceptable as this is not effective in directing the flow of sewage away from the building.*"

Policy C7, (i) – "*include a sustainable urban drainage scheme (SUDs), including a minimum of one metre of permeable soil above any part of the basement beneath a garden. Where the character of the gardens within an urban block is small paved courtyards SUDs may be provided in other ways*."

2. GROUND CONDITIONS IN RBKC

2.1 Geology

The geology of London and the Thames Basin lies within a chalk basin. The strata overlying the Chalk comprise Thanet Sands at depth overlain by the Lambeth Group which are generally a mixture of sand and clay. Above this is London Clay which in Kensington and Chelsea is approximately 50m deep generally. The London Clay outcrops at the surface around Notting Hill and to the north of the RBKC area (Figure 1).

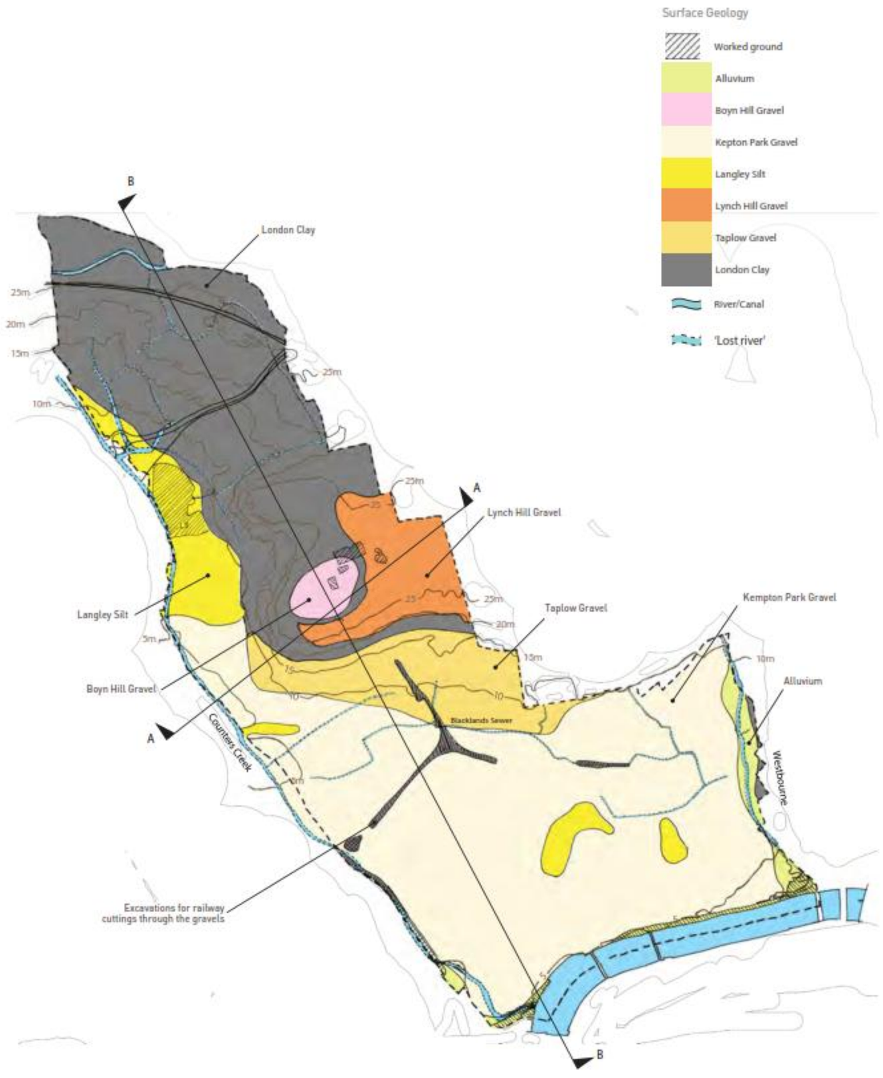

Figure 1 Geology of Royal Borough of Kensington and Chelsea (Alan Baxter[1])

[1] Alan Baxter, *Royal Borough of Kensington and Chelsea Residential Basement Study Report*. March 2013.

Deposits of sands and gravels which can be up to 10m thick lie above the London Clay. These were deposited during and at the end of the last ice age when the route of the River Thames assumed its current position. The process of eroding its valley has created a series of individual sand and gravel terraces (the Kempton Park and Taplow Gravel Formations and the Lynch Hill and Boyne Hill Gravel Members).

In places there are deposits of Langley Silt (sometimes called brickearth) which is a mixture of silts, clays and sands. Typically this overlies the sands and gravels. As might be gauged from the alternative name these formed the basic material for London stock bricks. The Langley Silt has been excavated in many areas and the resulting brick pits or fields pits were at times backfilled, sometimes with poor quality material. Also, in some locations the sands and gravels may also have been excavated for use in construction.

On top of these natural deposits there is often a layer of fill or made ground which results from human occupation over the centuries. This can be up to between 4m and 6m thick in localised areas but typically is no more than 1 to 2m in RBKC.

In summary the geology of the borough can be simplified as follows. In the most northern areas the London Clay outcrops and is not covered by drift deposits. Near Notting Hill the permeable river terrace gravels comprising the Boyn Hill Gravel and Lynch Hill Gravel overlie the impermeable London Clay. To the west of Notting Hill the Langley Silt overlies the London Clay in the Counters Creek basin. Most of the southern part of the Borough is covered by the permeable river terrace gravels, comprising Kempton Park or Taplow Gravel which can be up to 10m thick, although locally these may be overlain with relatively impermeable Langley Silt. Below these gravels lies the impermeable London Clay.

Adjacent to the Thames, and its tributaries the Westbourne and Counters Creek there are more recent alluvial deposits at or close to the surface.

The map showing different soils types from the Wallingford Procedure[2] reflects the geology of RBKC. The map (Figure 2) indicates in the north there is poor infiltration (soil type 4) which corresponds to the outcrop of London Clay. In the south of catchment reasonable infiltration is indicated (soil type 2) which corresponds to the area where gravels are present.

[2] DEFRA/Environment Agency, *Preliminary rainfall runoff management for developments*. R&D Technical Report W5-074A/TR1. Appendix - Figures 4 and 5, September 2005.

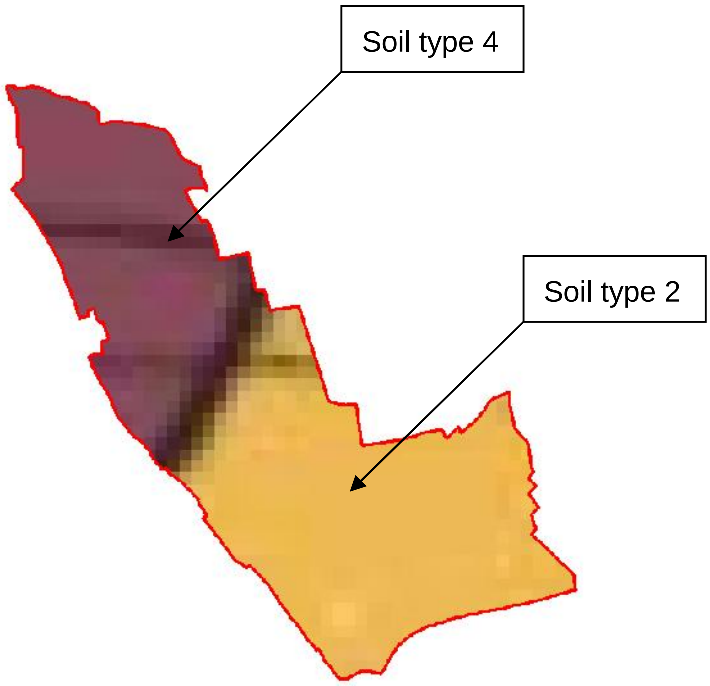

Figure 2 Soil types from the Wallingford Procedure

Soil Type 4 has a standard percentage runoff (SPR) value of 0.47 and soil Type 2 has an SPR value of 0.3[3]. These values are used in drainage design and assessment of runoff from undeveloped sites or areas such as gardens, parks or landscaping.

2.2 Groundwater

The principle aquifer within the London Basin lies deep below ground within the Thanet Sands and Chalk. It is fed from the chalk outcrops to the north and south of the Thames Valley. The impermeable London Clay acts as an aquiclude beneath the gravel terraces giving rise to local perched water (at times quite isolated and small bodies) which is fed by precipitation within the Thames Valley. This is a secondary aquifer and because of the relatively flat surface of the London Clay water tends to flow slowly across the surface of within the first metre or so of the overlying sands and gravels.

Despite London's development altering what were natural open ditches which flowed into tributaries of the River Thames; Counters Creek and the River Westbourne these water levels do not vary significantly as water flows southwards in the Borough to the Thames. Occasionally some more robust flows have historically eroded shallow channels in the surface of the clay which tend to be filled with sand and gravel. These can have an influence on local ground water levels and ground water flows.

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[3] Environment Agency R&D Technical Report W5-074A/TR1, *Preliminary Rainfall Runoff Management for Developments*, September 2005

The combination of the topography and geology around Notting Hill in places causes unusually high ground water flows which can be problematic for subterranean construction, unless this is recognised and clearly understood by those designing and constructing basements. This will also have an impact on drainage design around and over basements.

2.3 Infiltration rates

Permeability or infiltration rates for all London soils are well documented in a variety of publications. For the purposes of summary the BGS Technical Report WN/97/27[4] provides a source of appropriately wide ranging data. The SuDS Manual also provides typical infiltration rates for various soil types. The values from both sources are summarised in Table 1.

Table 1 Typical infiltration rate

Strata name	Characteristic infiltration rate m/s	
	BGS	**SuDS Manual**
Langley Silt (Brickearth)	2 to 9 x 10^{-8}	2 x 10^{-5} to 2 x 10^{-7} (silt loam)
Alluvium Clayey sand Peat	 1 x 10^{-6} 1 x 10^{-9}	Variable
River Terrace Gravel Boyn Hill, Kempton Park, Taplow, Lynch Hill	1 x 10^{-3} to 1 x 10^{-5}	3 x 10^{-2} to 3 x 10^{-5}
London Clay	3 x 10^{-9} to 3 x 10^{-11}	< 3 x 10^{-8}

These ranges themselves are taken from a large number of references (both peer reviewed publications and commercial testing).

Thus there are a wide range of soil types present across the area and infiltration rates will vary from site to site. Therefore any assessment of the impact of basement construction on drainage and infiltration of rainwater into the ground to recharge the shallow aquifer should be made on a site by site basis.

[4] British Geological Survey, WN97/27 *The Engineering Geology of the London Area* A Forster BGS 1997

3. HYDROLOGY OF RBKC

3.1 Rainfall

Rainfall experienced in the catchment can be considered in two forms,

- Design rainfall for a specified return period and rainfall duration.
- Time series rainfall data – historic records of rainfall occurring over a specified period (generally full year data sets).

Single event / Design Rainfall data

The catchment specific rainfall statistics have been extracted from the Flood Estimation Handbook Rainfall data and are summarised in Table 2

Table 2 Rainfall statistics for RBKC.

	Return period rainfall depth (mm)[1]				
Storm duration (minutes)	**1**	**10**	**20**	**100**	**200**
15	7.95	18.35	23.6	42.33	54.44
60	12.74	27.06	33.94	57.45	72.06
120	16.13	32.86	40.7	66.92	82.91
180	18.51	36.81	45.27	73.18	89.99
240	20.42	39.9	48.81	77.96	95.38
300	22.03	42.47	51.75	81.89	99.79
360[2]	**23.43**	**44.7**	**54.28**	**85.25**	**103.54**
720	29.66	54.27	65.1	99.31	119.12
1440	35.23	61.83	73.25	108.54	128.58

Notes:
1. Rainfall statistics are based upon Rainfall POT (Peaks Over Threshold) analysis
2. The 6 hour duration is used for the basis of volume analysis.

Long term / Time series rainfall data

Typically in the London area the majority of rainfall events are less than 25mm and a significant proportion (up to 90%) will be lower than 12mm[5]. Furthermore 50% of rainfall occurs during events where less than 4 to 5mm of rain falls.

Effects of rainfall

Traditional drainage systems are designed to deal with both day to day rainfall and also rainfall up to a specific return period, which is specified as 1 in 30 year protection by the Sewers For Adoption Manual[6]. SuDS systems are designed to the same requirement, ie to keep water in the drainage system up to the 1 in 30 year event. There is also often a requirement for SuDS to maintain the rate of discharge from a site to that which would occur from a green field site for a return period of 1 in 100 years plus an allowance for climate change.

Most sewers can deal with modest rainfall intensities however they are particularly susceptible to intense short duration storms that fill the conveyance pipes to capacity or block the inlet gratings with debris.

On areas which have a permeable surface (parks, gardens etc), the first 4 to 5mm of rainfall does not cause runoff, instead soaking into the topsoil profile and being lost to evaporation and evapotranspiration.

3.2 Runoff destination from rear gardens

If soils below a garden are permeable sand and gravel there may not be any runoff except in quite extreme events. Most rainfall soaks into the ground and recharges the shallow aquifer. The less permeable the soil the smaller the rainfall depth that is necessary to cause surface runoff (or ponding), depending on the topography.

Many gardens include hard areas such as patios, sheds, etc and it is not unusual for whole gardens to be covered in such surfacing. Runoff from these areas cannot infiltrate directly into the ground. It will either drain to the edge where it soaks into the ground or it will be provided with a drainage system that drains into the house drainage system. The house drainage system will then flow into a surface water or a combined sewer.

[5] Lloyd's (2010). *East London Extreme Rainfall, Importance of granular data*. Lloyd's emerging risks team report.
[6] *Sewers for Adoption* 7th Edition - A Design & Construction Guide for Developer.

3.3 Garden runoff rates

Rates of runoff from gardens will vary depending on a number of factors, which are broadly characterised as follows:

- Soil type (ability of the underlying soil to infiltrate)
- Slope
- Vegetation or other surfacing.

Garden areas have been obtained by measuring typical dimensions of gardens in three different streets in RBKC (measured from Ordnance Survey Maps). The dimensions used in the assessment are summarised in Table 3.

Table 3 Typical garden dimensions and runoff volumes

Location	Typical width of garden (m)	Typical area (m^2)	Return period	Runoff from garden, Soil type 2 (m^3)	Runoff from garden, Soil type 4 (m^3)
Holland Park	15	180	1	0.50	1.23
			10	0.96	2.35
			20	1.19	2.91
			100	1.89	4.63
			200	2.22	5.44
Oxford Gardens	11	143	1	0.40	0.98
			10	0.76	1.87
			20	0.94	2.31
			100	1.50	3.68
			200	1.76	4.32
Lamont Road	5	42.5	1	0.12	0.29
			10	0.23	0.56
			20	0.28	0.69
			100	0.45	1.09
			200	0.52	1.29

3.4 Runoff from permitted development with normal roofs

Permitted development is defined in Statutory Instruments 2008, No. 2362 Town and Country Planning, England. The Town and Country Planning (General Permitted Development) (Amendment) (No. 2) (England) Order 2008.

Permitted development for residential properties essentially allows a single storey extension or conservatory to be built up to 3m from the back wall of a terraced house to the width of curtilage. There is no requirement to provide any form of sustainable drainage and the roof runoff will most commonly be drained via a downpipe that is connected to the drainage for the house.

The volume of runoff from these permitted developments is summarised in Table 4. The calculations assume assumed a runoff coefficient, Cv, of 0.95 for the roof. The volumes shown are combined roof and garden area runoff (from the area not covered by roof).

Table 4 Typical permitted development dimensions and runoff volumes

Location	Typical garden area (m^2)	Typical permitted development area (m^2)	Return period	Runoff from permitted development, Soil type 2 (m^3)	Runoff from permitted development, Soil type 4 (m^3)
Holland Park	15	45	1	1.38	1.93
			10	2.29	2.84
			20	2.71	3.28
			100	4.21	5.04
			200	5.15	6.19
Oxford Gardens	11	33	1	1.04	1.49
			10	1.71	2.16
			20	2.02	2.48
			100	3.14	3.81
			200	3.83	4.68
Lamont Road	5	15	1	0.41	0.52
			10	0.71	0.83
			20	0.85	0.97
			100	1.33	1.50
			200	1.62	1.83

3.5 Runoff from patios

Inspection of aerial photos of the area covered by RBKC shows that many back gardens are covered by a significant area of hard surfacing (in some instances there appears to be full coverage). The estimated runoff from patios is summarised in Table 5. The calculations assume that the runoff coefficient from the patio areas, Cv, is 0.8. The volumes shown are for the paved areas only and do not include roofed and grassed areas.

Table 5 Runoff from hard surfacing in gardens (eg patios or flagged areas)

Location	Typical garden area (m^2)	Return period	25% hard surfacing (m^3)	50% hard surfacing (m^3)	75% hard surfacing (m^3)
Holland Park	180	1	0.84	1.69	2.53
		10	1.61	3.22	4.83
		20	1.95	3.91	5.86
		100	3.07	6.14	9.21
		200	3.73	7.45	11.18
Oxford Gardens	143	1	0.67	1.34	2.01
		10	1.28	2.56	3.84
		20	1.55	3.10	4.66
		100	2.44	4.88	7.31
		200	2.96	5.92	8.88
Lamont Road	42.5	1	0.20	0.40	0.60
		10	0.38	0.76	1.14
		20	0.46	0.92	1.38
		100	0.72	1.45	2.17
		200	0.88	1.76	2.64

3.6 Flooding

The Alan Baxter report[7] for RBKC indicates that parts of RBKC located close to the River Thames are at risk from flooding due to overtopping of river walls if there was either a failure of the Thames Barrier during a flood event or if the event exceeded the capacity of the barrier. Flooding could also occur if there is a breach in the river walls. These areas are a small proportion of RBKC and are adjacent to the Thames. There is also a risk of surface water flooding due to sewer capacity being exceeded or due to overland flows during periods of heavy rainfall. The Alan Baxter report provides recommendations for the design of basements in recognition of these risks (eg setting basement thresholds at a height that will minimise the risk of flood water ingress). This requirement is site specific and it would apply regardless of the area of the basement and is not a valid reason for restricting basements to 50% of the garden area.

3.1 Flooding into basement

Providing a suitable pumped device to remove foul flows from the basement will provide suitable mitigation against potential sewer flooding into the basement. The main cost in terms of this is emotional and disruption. In this respect there is no practical difference between a

[7] Alan Baxter, *Royal Borough of Kensington and Chelsea Residential Basement Study Report*. March 2013.

basement that is below 85% of a garden to one that is only 50%. The costs of any clean up will not increase significantly because of the size difference. There is therefore no reason to limit the size of basement extension on this basis. The potential adverse effects can again be easily mitigated against by simple flood resilient design (eg by keeping electrical systems high up walls).

4. BASEMENT EXTENSION CONSTRUCTION

4.1 Typical construction details

Basement extensions that extend under gardens are normally covered over so that the garden area is not lost. A large part of the basement roof will typically be covered by 1m of soil as shown in Figure 3.

Figure 3 Typical cross section of a basement extension

The basements are founded on a reinforced concrete base slab that is integral with the reinforced concrete walls. The whole construction is designed to be water proof to prevent groundwater penetration into the basement.

Normally the basement below the rear garden will be constructed in open cut and the excavation will be backfilled with imported fill material once the basement structure has been completed. This means that it is simple to specify the type of material that will be used to fill the ground below the new garden to achieve the necessary drainage characteristics to comply with any SuDS design for the basement.

Normally the maximum current extent of a basement would be 85% of the garden area and in reality the presence of trees can reduce this even further in a lot of cases, in order to avoid tree root protection zones.

4.2 Cover on roof

As discussed above the roof will have 1m of cover soil on it. This will have a garden over it or patio areas. The patio areas can easily be designed to be of permeable paving construction to allow rainfall to soak into the underlying soil. This type of construction is often used as part of sustainable drainage systems on podium decks above car parks in commercial and high rise residential buildings in London.

Again the cover soil can be easily specified to meet any drainage requirements.

4.3 Surface runoff from roof

Initially rainfall will soak into the 1m of soil above any basement roof. Even for thin extensive green roof construction (typically around 100mm thick substrate or less) calculations and monitoring have shown that runoff does not occur for events up to 12mm, in ideal conditions (ie it has been dry preceding the rainfall). This is the concept of interception in the SuDS Manual, which requires no runoff for the majority of rainfall events up to at least 5mm. Note that interception does not require runoff to be prevented for all rainfall events up to 5mm, only the majority. This recognises the fact that all drainage methods eventually become saturated and cause overland flow (as do gardens and similar areas). The roof construction over the basements is also a source control method which is another key principle of good SuDS design in accordance with Manual (ie rainfall is managed close to where it hits the ground).

Studies on extensive green roofs (with a very thin soil layer, often less than 150mm) have found an inverse relationship between the amount of rainfall and the percentage of rain retained, ie as rainfall volume increases the volume of runoff increases[8]. For small rainfall events (< 25.4 mm) 88% of rainfall was retained. During medium events (25.4 – 76.2 mm) more than 54% of rainfall was retained and for large events (> 76.2 mm) 48% was retained. These results were from extensive roof construction with a much thinner soil layer than proposed for basements in RBKC. The retained runoff will be far greater with 1m of soil over a basement roof.

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[8] Carter, T.L. Rasmussen, T.C. '*Hydrologic Behaviour of Vegetated Roofs*.' J. Am. Water Resources Association. **42**. 2006.

Some of the rainfall will not soak deep into the ground as it will be held at shallow depth and will be returned to the atmosphere via evapotranspiration including via plant roots if present. Therefore for the majority of rainfall events the basement roof will behave in a similar manner to any other garden area. The water that does seep deeper will simply flow sideways along the roof and down the walls to infiltrate into the ground. Thus there should be no net loss of recharge to the aquifer. There should also be no increase in surface runoff to sewers.

During prolonged periods of rainfall the soils above the roof may become saturated (especially in winter when the soil moisture deficit reduces). In such cases drainage can be provided where soil conditions are suitable to allow the excess water to infiltrate to the ground via a soakaway system. Where soils are less permeable (eg London Clay) the natural process would be for the water in these events to cause overland flow which would end up in the drainage system. Thus in these cases the drainage of the roof can be to the surface water or combined sewer. The design can allow for flows in the more extreme events to be restricted to greenfield runoff rates.

German guidance[9] indicates that in an area with annual rainfall depths of 650mm to 800mm depth the annual runoff from green roofs greater than 500mm thick is just 10% of rainfall.

Calculations to estimate the volume of water that could be stored in the soil layer are provided in Appendix A. These indicate that the soil layer could store up to 250mm of rainfall before the soil would become saturated and surface runoff occurs. This is similar in magnitude to the retention found by Stovin et al[10] (25% of the substrate depth). Some of this water (up to 40mm) would be removed by evapotranspiration and this is known as interception. The precise amount of evaporation will vary throughout the year as it would in a normal garden and can vary from 20mm/month in winter to in excess of 100mm/month in summer[11]. The remainder would either soak into permeable soils or require a drainage layer over the roof connected to the sewer. The drainage would be designed so that flows in it occur at a rate similar to that from a normal garden. A comparison of the total storage in the soil layer and the interception provided by the basement roof with the volume of runoff from gardens is provided in Figure 4.

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[9] Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau e.V. (FLL), *Guidelines for the Planning, Construction and Maintenance of Green Roofing*, 2008

[10] Stovin et al. The hydrological performance of a green roof test bed under UK climatic conditions. J Hydrol 2012, 414-415, 148-61.

[11] UK Climate Impact Programme (UKCIP), www.ukcip.org.uk

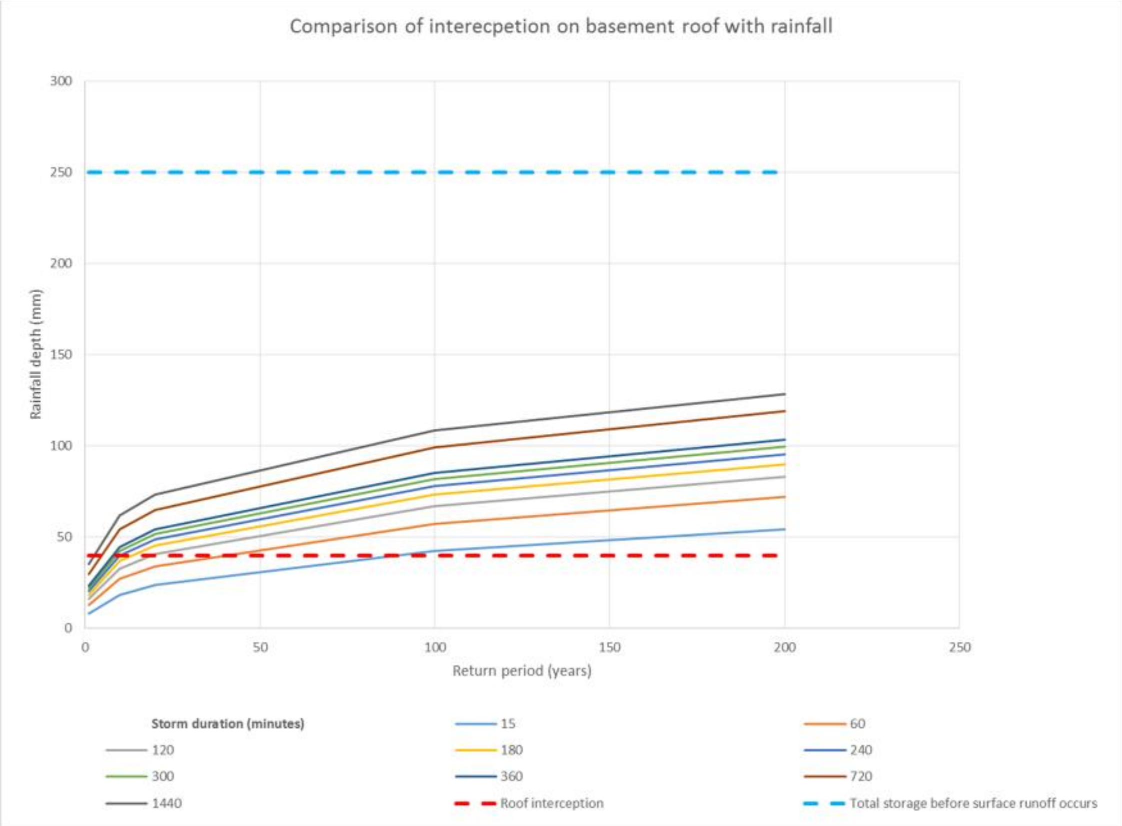


Figure 4 Comparison of interception on basement roof with rainfall

The comparison shows that even if the basement covered the whole footprint of a garden the interception provided by the overlying soils would be much greater than even the longest duration rainfall events for the frequent return period (1 in 1 year). The interception is sufficient to prevent runoff for less frequent short duration events (1 in 100 year, 15 minutes). Beyond that the water would be stored in the soil cover layer or drain to the surrounding soils or drainage system.

Beyond 40mm of rainfall the water would slowly soak down to the top of the roof and then drain to either side, down the outside of the walls and into the underlying soil if it is sufficiently permeable. Thus the presence of the basement is not having any significant impact on the surface water runoff from a garden or aquifer recharge in the area. In areas with low permeability soils (eg London Clay or Langely Silts) a drainage system to drain excess water would be provided. Once established a green roof can significantly reduce peak flow rates compared to a conventional roof[12]. It is likely that with 1m of soil the overall discharge rates

[12] The Green Roof Centre. www.thegreenroofcentre.co.uk

will be similar to a garden and in these areas aquifer recharge from a normal garden would be minimal.

In the worst case if the 1m of soil over the roof becomes saturated it will behave similar to a garden area (the runoff volumes from gardens are summarised in Table 3). Comparison of the runoff from a basement roof (Table3) with that from permitted developments (Table 4) and patios (Table 5) shows that the runoff will be less from the basement construction.

Thus for a basement below up to 85% of a garden there will be no adverse impact from the basement construction on flood risk in the catchment. It will behave better in terms of drainage than permitted developments such as extensions, conservatories and patios.

5. MITIGATION OF EFFECTS FROM BASEMENT CONSTRUCTION

5.1 Runoff

It is clear that there is likely to be minimal runoff from basement roofs where a 1m layer of cover soil is provided. This can be planted as a garden or covered by hard surfacing. If hard surfacing is required this should be designed as a permeable surface to allow water to soak through it into the underlying cover soil. The material can be specified to be good quality free draining soil sufficient to support plant growth if necessary and with sufficient void space and adsorptive capacity to achieve the requirements of the site drainage design.

The effect of the basement construction will be site specific. The proposed construction provides interception and source control in accordance with the SuDS Manual and will in many cases be a sufficient sustainable drainage system to minimise the effects of basement construction on runoff and flows from the site. Thus basement construction greater than 50% of a garden area should not have any adverse effect on flooding in nearby or downstream sewers, even if a significant number are constructed in one street.

In cases where the natural soil below a site is less permeable (London Clay or Langley Silts) a drainage connection to the sewer may be required but flows from the roof can be minimised and attenuated by the soil cover and appropriate design and specification of the drainage system. Where the soils are clay the provision of 1m of free draining topsoil is likely to allow more water to soak into the ground than the original less permeable soils below a thin layer of topsoil in a garden. Therefore the basement is likely to reduce surface water flows from these sites. The Alan Baxter report (clause 9.8.4) indicates that a proportion of rainfall should be allowed to soak into the underlying clay. This can be achieved by allowing a permeable blanket next to the slab and therefore there is no reason to limit basements to between 50% and 75% of the garden area as suggested in the Alan Baxter report. However care should be taken in the design to ensure that water levels do not rise too high adjacent to a basement within a clay “bathtub” as identified in the Alan Baxter report.

Where soils are permeable the water will drain through the uncovered surface in the same way as a garden and then down the backfill below the remaining garden into the underlying soils. To promote this recharge a layer of permeable gravel can be laid either under the basement raft (providing hydrostatic pressures are considered) or below the remaining garden to act as a soakaway and allowing water to infiltrate into the natural ground. This could easily be done as part of the basement construction with permeable soil or other construction provided vertically down the outside of the basement walls in specific locations (site specific design will be required and assessment of the likely water levels on the wall stability).

This will maintain the natural drainage characteristics of the site and maintain connectivity between the surface and the upper aquifer.

Design calculations for an infiltration system below the 15% remaining garden area have been undertaken using MicroDrainage. This software is widely used in the drainage industry. The infiltration design effectively follows the approach in CIRIA Report 156[13] for a plain infiltration system where water only flows out of the base and not the sides. A typical detail for such a system is provided in Figure 5.

Table 6 below indicates the storage volume requirements for an infiltration trench at the end of a basement extending up to 85% below a garden.

Table 6 Infiltration drainage requirements for a basement extending up 85% of a garden

Location	Typical garden area (m^2)	Typical garden width (m)	Return period	Infiltration trench dimensions required			
				Length (m)	Width (m)	Depth (m)	Volume (m3)
Holland Park	180	15	100 yr	15	1.5	0.679	4.6
			100 yr +30% CC	15	1.5	1.112	7.5
Oxford Gardens	143	11	100 yr	11	1.6	0.694	3.7
			100 yr +30% CC	11	1.6	1.135	6
Lamont Road	42.5	5	100 yr	5	1	0.784	1.1
			100 yr +30% CC	5	1	1.220	1.8

The design assumptions made are as follows;

- Return period -1 in 100 year, 1 in 100 year +30%;
- Infiltration rates - 0.036m/hr. This is the worst case for gravel in Table 1 of this report. Higher infiltration rates will result in smaller storage volumes;
- Factor of safety = 2;
- Infiltration assumed through the base only;
- 1m of soil over basement roof provides 20mm interception losses;
- Permeable backfill has 30% voids ratio.

The results show that water levels in the backfill will rise to a maxim of 1.2m in the most extreme event (1 in 100 year plus 30% addition for climate change). This will drain down

[13] CIRIA Report 156. *Infiltration drainage. A manual of good practice*. 1996.

quickly after the event (within 48 hours) and thus there should not be a permanent water level in the backfill.

The infiltration trench dimensions are essentially the dimensions of the permeable backfill below the remaining garden area, next to the basement. The backfill should be a free draining material such as Bardon SudsAgg or DrainAgg that also has sufficient void space to store water when necessary. It would also allow groundwater flow below the basement. These materials are commonly specified as the drainage layer below permeable pavements. The actual design of the drainage would be site specific and would take account of local ground and groundwater conditions and the foundation design. The storage could also be provided in the drainage layer over the roof of the basement. In all cases the basement waterproofing and structural design should take account of the presence of water on occasions in the backfill.

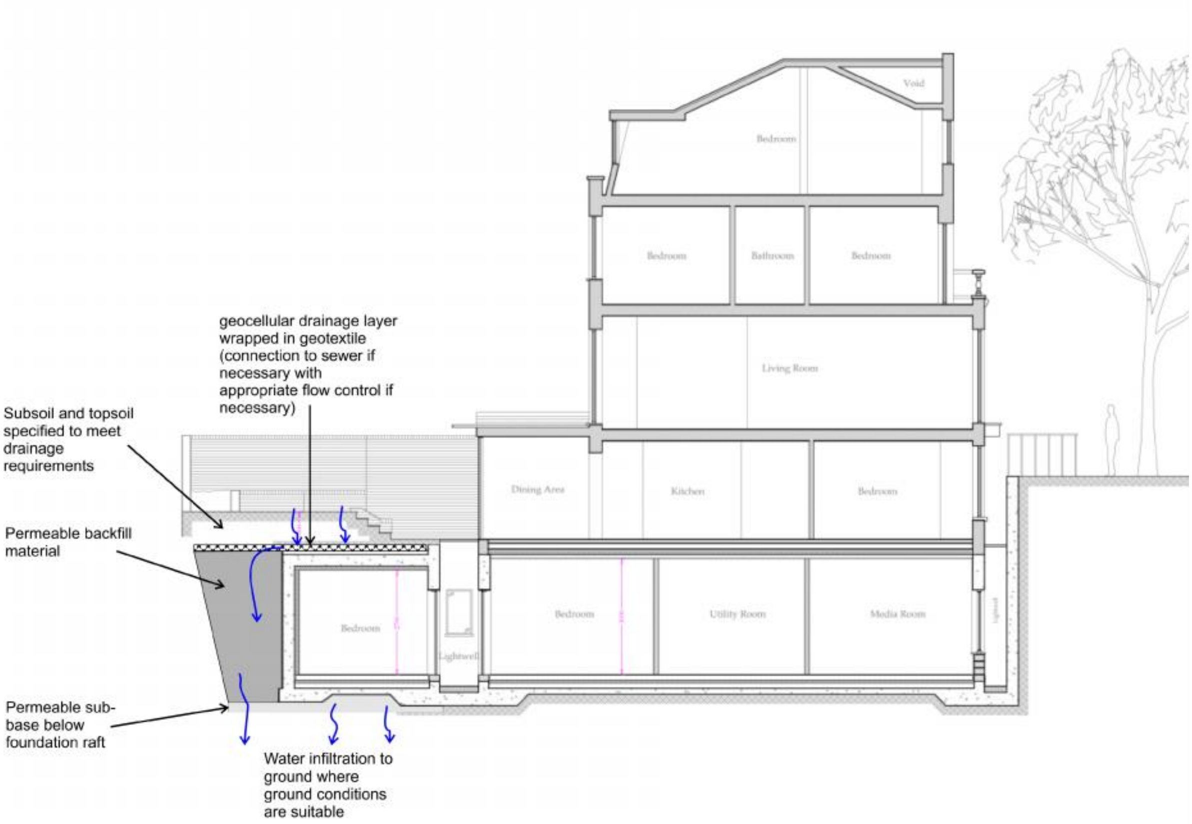


Figure 5 Example layout of an infiltration blanket for basement roof runoff

These calculations show that the requirement suggested in the Alan Baxter report (clause 9.8.3) for basements to not occupy more than 75% of the garden area is not justified. The design requirements stated by Alan Baxter can be achieved in most cases by site specific design of the drainage system which could include attenuation storage on the roof of the basement.

The volume of water that is introduced into the ground by these methods is no greater than that which was originally falling on the garden (providing drainage from the existing roof is not connected into the basement roof drainage). Therefore there should be minimal effect on neighbouring properties in the majority of cases, although this should be assessed on a site specific basis.

5.2 Building Regulations

There is often a concern that water soaking into the ground will cause movement of foundations and that the Building Regulations do not allow infiltration within 5m of buildings. As has been shown above the volume of water infiltrating the ground from the roof will be minimal and no different in reality to water soaking into a gravel driveway or similar. The volumes of water are small the water will soak into the ground over a wide area (compared to traditional soakaways) and the head of water will be small. Providing there are no unusual features such as poorly compacted fill, solution features or desiccated clay then the amount of water being allowed to soak into the ground via the 1m of soil on the basement roofs will not cause adverse movements of foundations. The 5m rule in the Building Regulations is provided as guidance. It was also intended for conventional soakaways that take runoff from relatively large areas and concentrate it into a small area. The requirement can be over ruled based on expert advice.

This is again a site specific issue and the foundation design should take account of the presence of any water in the ground. The requirements should be confirmed by a Registered Ground Engineering Advisor. Further information on allowing water to soak into the ground within 5m of a building is available at www.susdrain.org.uk[14]

[14] Susdrain. *Using SuDS close to buildings*. Fact Sheet, September 2012. www.susdrain.org.uk/files/resources/fact_sheets/1209_fact_sheet_using_suds_close-to-buildings.pdf

6. CONCLUSIONS

The RBKC policy indicates that there are concerns that basement development of greater than 50% of the garden area may lead to reduced surface water infiltration, increased surface water run-off and hence increased flooding risk.

This assessment has demonstrated that:

1. Runoff from the roof of a basement with 1m of soil is not likely to occur for most frequent rainfall events. This meets one of the requirements of the SuDS Manual.

2. It is easy to provide the roof with a sustainable drainage system that can manage more extreme events in accordance with SuDS Manual and the current draft version of the National Standards for Sustainable Drainage Systems[15].

3. Provision of a pumped outfall from the basement will provide adequate mitigation against flooding from sewers into basements.

4. Protection of basements from other flooding such as due to breaching of river walls can be achieved by providing the threshold to the basement at a suitable level to minimize the risk.

Therefore the proposed RBKC policy is far too generic in relation to flood risk and drainage. It does not take into consideration the particulars of the specific development such as existing groundwater levels, the permeability of the ground, SuDS measures incorporated into the design, etc. There is no valid reason why basement construction should be limited to a blanket 50% of a garden area on the basis of drainage or flood risk. Any assessment should be on a site specific basis and include consideration of the proposed SuDS. The existing requirement to limit basements to 85% of the garden area is more than sufficient to allow reasonable SuDS provision and aquifer recharge on most sites.

[15] DEFRA, National Standards for sustainable drainage systems. Designing, constructing, operating and maintaining drainage for surface runoff. December 2011.

Appendix A

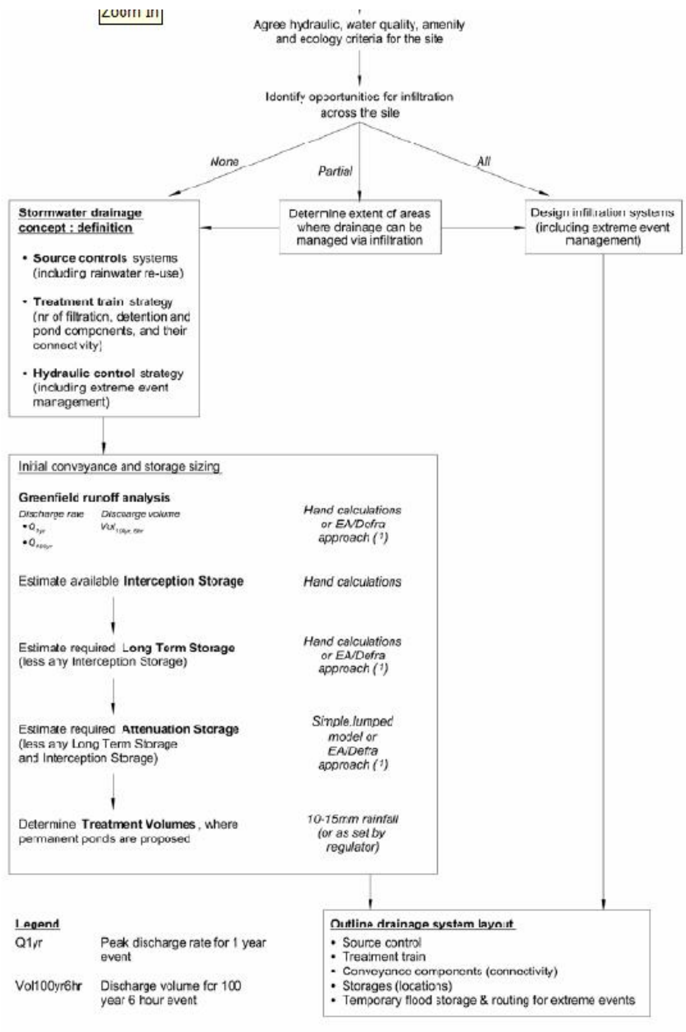
Storage and interception capacity of soil construction above a green roof

Contribution of green roof on a basement extension to SUDS storage

Example calculations

The requirements for estimating the capacity of a sustainable drainage system are described in *The SUDS Manual* (Environment Agency R&D report SCO20114/2)

The requirements are summarised below (Figure 4.1 from *The SUDS Manual*):



(1) Kellagher, 2004 (Preliminary rainfall runoff management for developments)

Figure 4.1 Initial stormwater drainage design assessment

This indicates that interception storage can be subtracted from the required attenuation storage.

Definitions

Attenuation storage – Storage that reduces the peak runoff rate from a site during extreme events. The runoff rate is usually restricted to greenfield values and storage provided to temporarily hold water as it flows away at the restricted rate.

Interception storage – storage that essentially prevents runoff from a site for rainfall events up to a given rainfall depth (usually 5mm to 10mm).

Green roofs contribute to interception storage as they can prevent runoff from the roof for frequent small rainfall events.

Example
Green roof over a basement with a 1000mm thick substrate and topsoil that complies with the German FLL specification. In this case the design will specify a requirement for 30% maximum water capacity. Note this is the volumetric water content. The relationship between gravimetric and volumetric water content given by:

Gravimetric moisture content = volumetric content/bulk specific gravity of substrate

The bulk specific gravity of a typical substrate is assumed to be 1.2

Gravimetric moisture content = 25%

Dry weight of substrate = 980kg/m^3

25% of dry weight = 245kg/m^3 – this is the amount of water the substrate can retain

For a 1000mm thick substrate the water retention capacity

= 245 x 1000/1000 = 245kg/m^2 of roof

Density of water = 1000kg/m^3

So volume of water = 245/1000 = 0.245m^3/m^2 (or m of rainfall)

= 250mm interception storage capacity.

This ignores any storage in the vegetation layer.

The storage for the whole roof is 250mm x area of roof.

Alternatively consider a well drained loam and topsoil over the roof.
Loam air filled porosity is 0.25 (from Environment Agency R&D Publication CLR 10, Contaminated Land Exposure (CLEA) Model: Technical Basis and Algorithms. March 2002.)

Volume of water that can be stored in air pores in a $1m^2$ area of soil to 1m depth = 0.25 x 1m x 1m = $0.25m^3/m^2$

ie 250mm as above.

In practical terms much of the 250mm would flow into the underlying ground or drainage layer and a maximum of about 40mm is likely to be removed by evaporation and provide true interception.

An alternative design method is to calculate the attenuation storage using reduced runoff coefficients for the green roof (values are provided in the FLL guidelines). These coefficients are based on a rainfall event of 108mm/h intensity (27mm depth over 15minutes) are based on the performance of the roof when it has been saturated and allowed to drain down for 24 hours (this is a reasonably (but not over) cautious approach).