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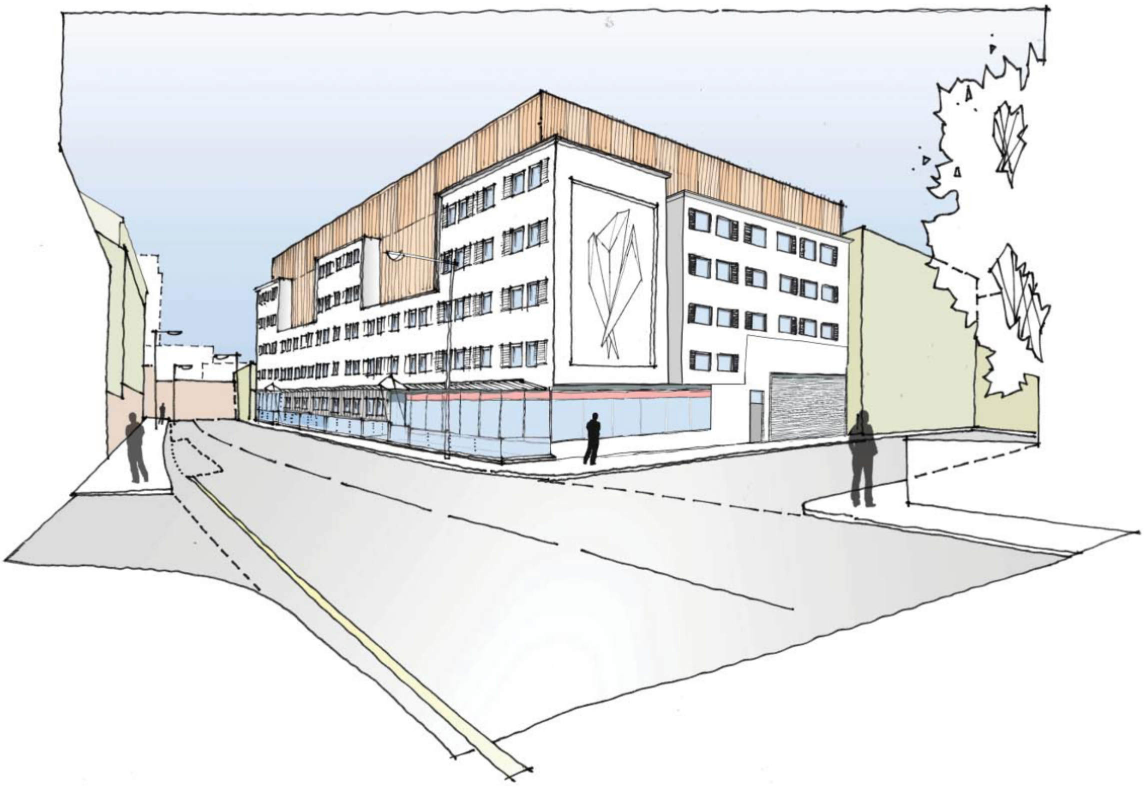

Sustainable Drainage Systems (SuDS) Strategy

Prepared For:

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01	For Comment	Vlad Myrsikov		25.05.16

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Table of Contents

Executive Summary

To comply with NPFF and London Plan, Sustainable Drainage Systems must be introduced within the development, runoff rate must be controlled to Greenfield rate or to 50% of developed (Brownfield) rate.

The existing site is a combination of impermeable car park and a building with normal roofs. The proposed site is a multi-story development with multi-level basement. The basement slab for new building will span entire site footprint.

The report looked in detail at all potential SuDS component listed in technical and non-technical recommendations, and determined that there are only 2 suitable SUDS options that can be used for the development: Green roofs and Attenuation storage systems (tanks, blue-roof). Rainwater harvesting was deemed as potentially viable, however the practicalities can only be reviewed during detailed design stage.

*The report proposes that the following SUDS components - **Green Roofs** and **Attenuation Storage** are to be implemented as part of the development works.*

The report looked at the existing pre-development Brownfield discharge rate from site and determined this to be 78.6 l/s. Greenfield rate was determined to be 5.0l/s as this is the minimum recommended rate to minimise blockages to flow control structures.

The review of discharge volumes pre- and post- development was undertaken. As the site cannot have any infiltration systems a reduction in volume is difficult to achieve. Introduction of Green roofs help to reduce the volumes, however change from car park to roof results in slight increase in volume in the immediate term.

It was shown impractical to install “long-term” storage to restrict site discharge rate to Greenfield rate or to provision for future Climate Change. The tank would be below basement level and would require pumping.

Given the size of the attenuation storage, the extensive basements, and practicalities of connecting to Thames Water sewer is was determined that achieving Greenfield rate may provide difficult and impractical.

*The report proposes that the site discharge rate is **restricted to 39.3l/s** discharge rate, which is equivalent to 50% reduction from existing discharge rate.*

1 Introduction

1.1 Project description

The existing site is 0.245 ha in size, comprises a warehouse and car park, and is fully impermeable.

The proposed development comprises the new construction of student accommodation over several floors, warehouse spaced, some commercial spaces and over 3 floors of basements. The unique feature of this development is that above ground floor the building will be built using shipping containers.

The development proposals will incorporate extensive green roofs, that will provide aesthetic and biodiversity benefits and help with reducing storm water runoff and therefore will provide betterment relative to existing conditions.

The development will require discharge of surface water in line with the requirements of the local planning authority and statutory undertakers. Discharge of foul water is outside the scope of this report. Where possible existing connections and drainage will be utilised to reduce works within the highway and the development of building drainage should be co-ordinated with the external drainage.

This report describes overall drainage strategy for the site including potential SUDS considered and attenuation requirements.

1.2 Planning and Technical Considerations for SUDS

NPFF requires that SuDS measures are implemented to manage surface water runoff within new developments. The following are the key criteria and guidance given by PPS25, London Plan and Camden Council.

- PPS 25: both the rates and volumes of run-off from new developments should be 'no greater than the rates prior to the proposed development, unless specific off-site arrangements are made which result in the same net effect'.
- London Plan Polocy 5.13: A Development should utilise sustainable urban drainage systems (SUDS) unless there are practical reasons for not doing so, and should aim to achieve greenfield run-off rates and ensure that surface water run-off is managed as close to its source as possible.
- Camden Planning Guidance 3: The Council will expect developments to achieve a Greenfield surface water run-off rate once SUDS have been installed. As a minimum, surface water run-off rates should be reduced by 50% across the development.
- Camden general guidance on Surface Water management: We will be requiring major developments to achieve greenfield run-off rates and where reasonably practicable to constrain run-off volumes to greenfield run-off volumes for the one in 100 year six-hour event.

The Non-Statutory Technical Standards for Sustainable Drainage Systems set out general recommendations for control of development runoff, including the requirement to ensure that runoff from the site is not increased by development, and the requirement to manage surface water runoff for events up to the 1 in 100 year storm (including an additional allowance for the projected impacts of climate change).

PPS advises that climate change allowances should be determined with reference to the guidance provided in the EA document 'Flood Risk Assessments: Climate Change Allowances' (February 2016). It is however unclear if this increase is applicable in Camden, thus only +30% additional climate change allowance has been incorporated to future proof the attenuation system.

EA Technical report W5-074/A/TR/1 "Preliminary rainfall runoff management for developments" states that it "is technically extremely difficult to achieve" reduction in volume and thus only run-off rate reduction is required as the key criteria for sites. Infiltration can help reduce run-off volume, whenever practical to implement on developed sites.

2 SUDS Principles

The most appropriate means of surface water control and discharge has been determined based on the hierarchy as set out in the London Plan (January 2015).

Methods for controlling storm water:

- Storing Water for later use
- Infiltration techniques, such as porous surfaces in non-clay areas;
- Attenuate rainwater in ponds or open water features for gradual release;
- Attenuate rainwater by storing in tanks or sealed water features for gradual release;

Methods for discharging storm water:

- Discharge rainwater direct to a watercourse;
- Discharge rainwater to a surface water sewer/drain;
- Discharge rainwater to the combined sewer.

2.1 Methods for controlling storm water

Storing Water for later use

Rainwater harvesting is the most common method of storing water for later use. Other options include storing water in ponds for irrigation.

Rainwater harvesting is the collection of rainwater run-off for use. Run-off can be collected from roofs and other impermeable area, stored, treated (where required) and used as a supply for water for domestic, commercial, industrial and/or institutional properties.

Such systems are not intended to control peak run-off rate during critical events, and are mainly useful during medium and small events to capture run-off and thus reduce the over volume entering the drainage system during these smaller events.

Infiltration techniques

The key principle of infiltration is to allow water to infiltrate into the ground instead of being piped. There are many different types of drainage components can be used to facilitate infiltration. These include soakaways, infiltration trenches, filter strips (with infiltration), infiltration blankets and infiltration basins. Bio-retention and permeable paving systems can also be designed to infiltrate into the ground.

Infiltration can contribute to reducing runoff rates and volumes while supporting base flow and groundwater recharge.

The four key criteria has to be satisfied before infiltration can be considered:

- Ground must be suitable for infiltration (i.e. sandy gravelly soils).
- Groundwater must be a minimum 1m below surface for permeable pavements, swales, ponds etc, or at least 1m below invert level of any soakaways.
- Ground must be not contaminated or it must be proved that infiltration will not activate pollution in the soil.
- Soakaways cannot be placed closer than 5m to a building (Building Regulations Part H).

Attenuate rainwater in ponds or open water features for gradual release

The most commonly known features are detention basins, ponds and wetlands. Others can include specifically designed paved areas that can hold and store water temporarily on the surface for gradual release. All of the features are used to control peak run-off rate, while open ponds or detention basins can reduce volume of run-off through evaporation or infiltration (see above).

Detention basins are landscaped depressions that are normally dry except during and immediately following storm events. Ponds and wetlands are features with a permanent pool of water that provide both attenuation and water treatment. Attenuation is provided above the permanent pool of water.

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

The most common method of controlling runoff on developed sites is through storage in attenuation tanks. Another common method that falls into this group are green roofs and podiums.

The purpose of both systems is to collect the water and slowly release it into the drainage network. The attenuation systems, such as geo-cellular tanks below ground, above ground tanks, blue roofs, provide no volume reduction benefit and provide only minimal treatment benefit. Green roofs, when properly designed attenuate storm water for gradual release, allow for evaporation of first 5mm of rainfall, provide water treatment and improve biodiversity and community benefits.

2.2 Methods for discharging storm water

Methods for discharging storm water are entirely site dependant, and are driven by practicalities rather than specific legislation or environmental requirements.

Discharge rainwater direct to a watercourse

Discharge to watercourse is preferred as this reduces the need to provide drainage network, allows recharge to rivers and groundwater, and reduced sewer flooding. Discharge to the river would need to be at greenfield rates and ideally without increasing the volume of runoff. Contamination from roads and car parks must be carefully considered and provided to ensure that only clean runoff enters the river system.

Discharge rainwater to a surface water sewer/drain

British Standards require that storm water must be connected to storm water sewer whenever such sewer is present. The sewers must be kept separate on-site. Storm sewers are present in newer developments built in the late last century, and the key purpose is to minimise the storm surcharge to foul treatment stations and reduce water treatment overall, focusing on surface water specific contaminants such as litter, oils/grease and sediment.

Discharge rainwater to the combined sewer.

Older parts of the country, especially London, do not have separate system, and in such instances the only viable option is to connect to combined water sewer.

3 Proposed SUDS Strategy

3.1 Proposed SUDS

CIRIA The SuDS Manual C753 provide a good guide on all possible SuDS systems, their use and constrains. The below table summarises all available SuDs options listed in C753 and checks their suitability to the development site.

Key Benefit Codes are in accordance to C753 listed as "likely valuable contribution to delivering design criteria": P – Peak runoff reduction, V – Volume reduction, Q –Water quality improvement, A – amenity, B - Biodiversity

Component Type	Key Benefit	Development site	
		Viable	Proposed
Rainwater Harvesting	V, A	Maybe	No. Limited space to introduce the tanks in development.
Green roofs	V, Q, A, B	Yes	Yes. Extensive. In line with Camden Planning Guidance
Infiltration Systems	P, V, Q, A, B	No	The site is completely covered by the building footprint.
Proprietary treatment systems	Q	Yes	Silt Traps to control water quality, as the site only consists of roofs and gardens, requiring minimal treatment.
Filter Strips	V, Q	No	The site is completely covered by the building footprint.
Filter Drains	P, Q	No	The site is completely covered by the building footprint.
Swales	P, V, Q, A, B	No	The site is completely covered by the building footprint.
Bioretention systems	P, V, Q, A, B	No	The site is completely covered by the building footprint.
Pervious Pavements	P, V, Q,	No	The site is completely covered by the building footprint.
Attenuation storage tanks	P	Yes	Yes. To control storm water runoff.
Detention basins	P, V, Q, A, B	No	The site is completely covered by the building footprint.
Ponds and wetlands	P, Q, A, B	No	The site is completely covered by the building footprint.

Table 1 - SUDS options, CIRIA SuDS Manual C753

3.2 Proposed discharge method

The site is located in a fully developed area and is 850m from nearest open watercourse, which is Regents Canal. There are no storm water sewers in the area.

A culverted watercourse that once was River Fleet passes in direct proximity to the site, and the combined sewer in Holmes Road discharges directly into the River Fleet sewer. See Appendix A for sewer asset map.

The proposed method of discharge is to Thames Water Combined Sewer in Holmes Road for the development site, unless storm water connection to culverted watercourse is considered viable. Foul Water will connect to existing combined sewer in Holmes Road.

4 Proposed Runoff Rates

4.1 Background

The PPS and London Plan require that the development discharge rate should be limited to the equivalent greenfield runoff rates, or if not achievable, a minimum reduction of 50% should be applied to the existing runoff rates for brownfield sites. Before a specific rate is adopted, the implication on storage volumes and practicalities of installing larger tanks within the development must be understood.

4.1.1 Choice of Methodologies

CIRIA The SuDS Manual C753 provide an overview of all currently available method of runoff rate and volume calculation and provide recommended methodology. The table low is taken from the C753 report, Table 24.1, page 509

Runoff estimation method	Reference	Greenfield site		Developed site	
		Peak runoff rate	Runoff volume	Peak runoff rate	Runoff volume
FEH ReFH2	Kjeldsen (2007)	✓	✓	✓	✓
FEH Statistical Method	Kjeldsen et al (2009)	✓			
IH124	Marshall and Bayliss (1994)	✓			
FSSR16	NERC (1985)		✓		
Modified Rational Method	HR Wallingford (1981)			✓	
Wallingford – Fixed	HR Wallingford (1981)			(see note)	(see note)
Wallingford – Variable	Packman (1990), Osborne (2009)			✓	✓
UKWIR	UKWIR (2014)			✓	✓

(note) – No Longer recommended, but still used in software packages.
Table 2 - Calculations Methods, CIRIA The SuDS Manual, C753

The two methods for estimating existing peak runoff rates for the current site, based on preferences set out in CIRIA C753 report are:

- Greenfield rate – IH124
- Developed site – Modified Rational Method

CIRIA C753 report states that Modified Rational Method is relevant for initial design estimates and very simple sites.

UK has two principle data sets of rainfall date to be used for calculation of pear runoff and volumes.
- The Flood Studies Report (FSR) was published in the mid-1970s and used rainfall from 1941 - 1970.
- The Flood Estimation Handbook (FEH) was published in 1999 and used rainfall from a dataset between 1961 - 1990.

FEH has a more recent dataset and used a larger rainfall record for generating the methodology. FEH concentrated on rainfall event durations of one hour and above and returns 1-in-2 year and above. Although it could be relied on for durations as short as 30 minutes it is currently not recommended to be used for intensities below 30minutes.

The FSR report analysed sub-hourly rainfall and therefore is more appropriate for shorter storm durations such as required for modelling below ground drainage systems, where short duration storms are critical. This intensity will be appropriate for peak rainfall runoff modelling, which is generally 5-15 minutes.

4.1.2 Runoff Rates

For Greenfield runoff rate FEH data will be used as the time of concentration is usually larger than 30minutes for Greenfield sites. For existing Brownfield site, FSR data will be used as it is not recommended to use FEH data below 30minute duration, whereas critical storm event for drainage, especially for smaller catchments, is typically between 5 and 15 minutes.

Existing Runoff Rates
The site currently is 100% impermeable and consists of only hard paving and roofs. For such a site, the time of concentration for calculating peak existing discharge rate will be low, and peak discharge to sewer could be reached at as low as 5-10 minutes. However a more conservative figure of 15minutes was used and using Wallingford Modified Rational Method with FSR rainfall used to calculate peak existing run-off rate.

- Q_{ex} (1 year) = 24.71 l/s
- Q_{ex} (30 year) = 61.70 l/s
- Q_{ex} (100 year) = 78.65 l/s

50% Brownfield Runoff rate, in Lone with PPS and London Plan for the new development would be 39.3 l/s

Greenfield Runoff Rates
The equivalent Greenfield runoff rates for the existing site were calculated using IH124, the method set out in the Institute of Hydrology Report 124 (IH 124). Rainfall and catchment descriptors have been determined using the Flood Estimation Handbook (FEH) data for the area. The calculated Greenfield runoff rates are as follows, a copy of the Greenfield runoff calculations are included in Appendix B:

- Q_{bar} = 1.09 l/s
- Q (2 year) = 5.0l/s (calculated rate – 0.96 l/s)
- Q (30 year) = 5.0 l/s (calculated rate - 2.61 l/s)
- Q (100 year) = 5.0 l/s (calculated rate - 3.47 l/s)

EA Technical Report W5-074/A/TR/1 “Preliminary rainfall runoff management for developments – Revision E” (2012) recommends minimum run-off rate from any development to be 5.0 l/s to minimise the risk of blockages of flow-control structures. Therefore a figure of 5.0 l/s is adopted whenever the Greenfield rate is below this figure.

Climate Change Allowance
PPG advises that climate change allowances should be determined with reference to the guidance provided in the EA document ‘Flood Risk Assessments: Climate Change Allowances’ (February 2016). As it’s unclear if the revised climate change is applicable to Camden, only +30% additional climate change allowance has been incorporated to future proof the attenuation system.

4.1.3 Runoff Volumes

CIRIA The SuDS Manual C753 described preferred method for calculating run-off volumes from the developments and is shown in Table 2 above. The volumetric criteria pre- and post- development is compared at the 6-hour mark for 1-in-100 year storm.

FEH rainfall data is used for calculation of pre- and post- development volumes and Greenfield volumes. For comparison with Greenfield discharge rates, only the minimum permitted rate (5.0l/s rates) is shown as the site cannot physically restrict runoff to below 5.0l/s without increasing risk of blockages and thus localised flooding.

Impact of green roofs on runoff

Green Roofs cannot be considered a permeable soil and instead must be understood in the context of a complex system principally designed for biodiversity and amenity benefits, while providing only some benefits in reducing run-off rate and volume. Green Roofs provide most drainage benefit during low intensity storms, and can capture water equivalent to 5% or 5mm for 100mm thick roof.

The peak run-off benefit of green roofs is limited for high intensity storms. Microdrainage shows that green roofs would shed around 80% of all the water falling on it during the first 25-30 minutes. Considering that for small catchments where peak attenuations storage occurs around 15-30 minute mark, Green Roofs would provide limited benefits peak run-off attenuation benefit.

The volume reduction benefit of green roof is clear. After 120minutes of rainfall green roofs become fully saturated and will hold this water until rain stops.

Meeting the run-off criteria

To meet peak run-off discharge rate, an attenuation system has been proposed. The SuDS Manual advises that simulation modelling is required for sizing of different components, owing to the need to determine multiple critical durations for individual points in the drainage system.

Peak Run-off Rate

Micro-drainage Quick Storage estimate was used to determine potential attenuation tank size, using the following variables:

- Cv = 0.9 (the site is roof area)
- Total impermeable area = 0.219
    - Total site area = 0.245
    - Impermeable roof/podium = 0.1160
    - Impermeable “green roof” contribution = 0.103 (i.e. 0.1290 x 80%)

Table 3 below shows the attenuation requirements for the site. The attenuation tanks have been futureproofed by including future +30% climate change allowance. Refer Appendix C for Micro-drainage printout.

Run-off Rate attenuation storage	**Discharge rate**	**Attenuation Tank size (m3)**
Existing Site	78.4 l/s	-
“Proposed + CC” vs “Greenfield”	5.0 l/s	92 to 126
“50% Existing + CC” vs “Existing”	39.3 l/s	31 to 66

Table 3 - Peak runoff rate comparison

Peak Volume

To meet volumetric criteria, the difference between flow-rates for 6-hour events is used. Because infiltration is not a suitable option for this development, the overall volume increase would be required to be stored as "long-term" storage and discharged slowly over 24-hour period. Long Term Storage is separate from Attenuation Storage and is specifically intended to control the volumetric criteria.

Green roofs reduce volume of runoff. After 120minutes of rainfall green roofs become fully saturated and will hold 5% (or 5mm) of water until rain stops. For calculations, the volume volume held by Green Roofs (6.5 cub.m. = 1,290sq.m x 0.005m) has been deducted from total volume of Long Term Storage.

Because climate change is not projected to occur quickly, the table compares pre- and post- development conditions that will occur immediately following completion of the project and the long term impact of climate change.

Refer to Appendix B for runoff rate calculations:

Target	**Target Volume (m3)**	**Volume generated**	**"Long time storage" (m3)**
Existing Site	184.8	-	-
"Proposed" vs "Greenfield"	108	189.1	118.8
"Proposed + CC" vs "Greenfield"		233.7	125.7
"50% Existing" vs "Existing"	184.8	189.7	4.9
"50% Existing + CC" vs "Existing"		233.7	48.9

Table 4 - Peak runoff Volume comparison

5 Proposed discharge rate and volume for development

5.1 Peak runoff rate criteria

The site is fully impermeable and discharges un-attenuated into the public combined sewer system. Public sewers in direct proximity of the site are shallow. The sewer in Holmes road has an invert level of IL30.55, while the underside of the basement slab is around 32.50.

River Fleet sewer is lower (IL26.21) however given the age of the sewer it is currently considered unviable to connect to this sewer due to technical difficulties and costs.

The extensive basements and the use of warehouse space, make the use of below ground attenuation impractical. Installing the attenuation tank below basement levels would require pumping, which is not sustainable, increases basement flood risk significantly and increases maintenance and operating costs.

The practical option at this stage is to consider blue-roof and above ground storage systems are the primary storm water attenuation storage systems:

- Above ground storage, although viable, results in loss of space and is an expensive solution to implement
- Blue-roofs are potentially viable, however only limited volume of water stored on the roofs/podium due to height limitation.

The proposed development has a total height of 0.43m between top of parapet and top of eyelet. This space needs to facilitate thermal insulation, greenroof and a gap between top of parapet and top of greenroof to avoid rainwater overflowing the façade. Introducing blue-roof would be directly offset the greenroof depth and reduce water holding ability of the system.

Considering a practical 100mm thick geo-cellular blueroof system, only 80% will be used as holding volume (with 20% allowance for exceedance). The total space required to meet greenfield run-off rate would be between 1,150sq.m and 1,575sq.m which exceeds the total green roof area of 1,290sq.m. It should be noted that not entire green roof can be used for blue-roof drainage and restriction such as plant and services, reduce this space further.

Meeting 50% Brownfield rate would result in approximately 388sq.m. to 825sq.m. of storage space.

Meeting greenfield run-off criteria without pumping is impractical and risks constraining the development. Thus is proposed that:

- Peak Runoff Criteria: **It is proposed that the site is restricted to 39.3 l/s (50% Existing)**

5.2 Volume of runoff criteria

In the immediate term, the introduction of the Green Roofs would help reduce the overall volume of discharge from the site, however the change of site from car-park plus warehouse to roofs, increase the impermeability factor, and thus drives increase in overall volume of discharge.

Providing dedicated long-term storage to meet Greenfield rate or providing storage to meet future climate change is impractical as the storage would not be used for a considerable length of time. Furthermore, any such storage would been to be placed below the basement level and be pumped back up to discharge level at low rate.

As pumping would increase the risk of flooding to the building, and is unsustainable, it is proposed that

- Volumetric Criteria: **not met as it's not reasonably practical to do so**.

Appendix D shows the proposed development with a possible location of blue roofs tank. It should be noted that blue-roofs are only concept measure. The final attenuation system design will be completed at later stages.

5.3 Other considerations

5.3.1 Pollution Control

Appropriate pollution control measures will be included in the surface water drainage system to minimise the risk of contamination entering the receiving watercourse from surface water runoff from the development.

The final strategy for pollution control will be confirmed as part of the detailed design.

5.3.2 Adoption and Management

Due to the small nature of the site, it is unlikely that any SuDS features would be adopted by the LLFA or Highways Authority. The ongoing management and maintenance of the proposed surface water management systems will be expected to fall under the responsibility of the relevant site management company.

The long term management of surface water drainage assets, including any SuDS components, is essential to ensure they continue to function to their design standard. As such, a management and maintenance plan will need to be developed in order to ensure the systems continue to work effectively.

The final strategy for the adoption of SuDS and the SuDS maintenance plan, including a maintenance schedule and details of outfalls for the drainage system, will be produced at the detailed design phase, once details of any SuDS features to be incorporated into the site have been finalised.

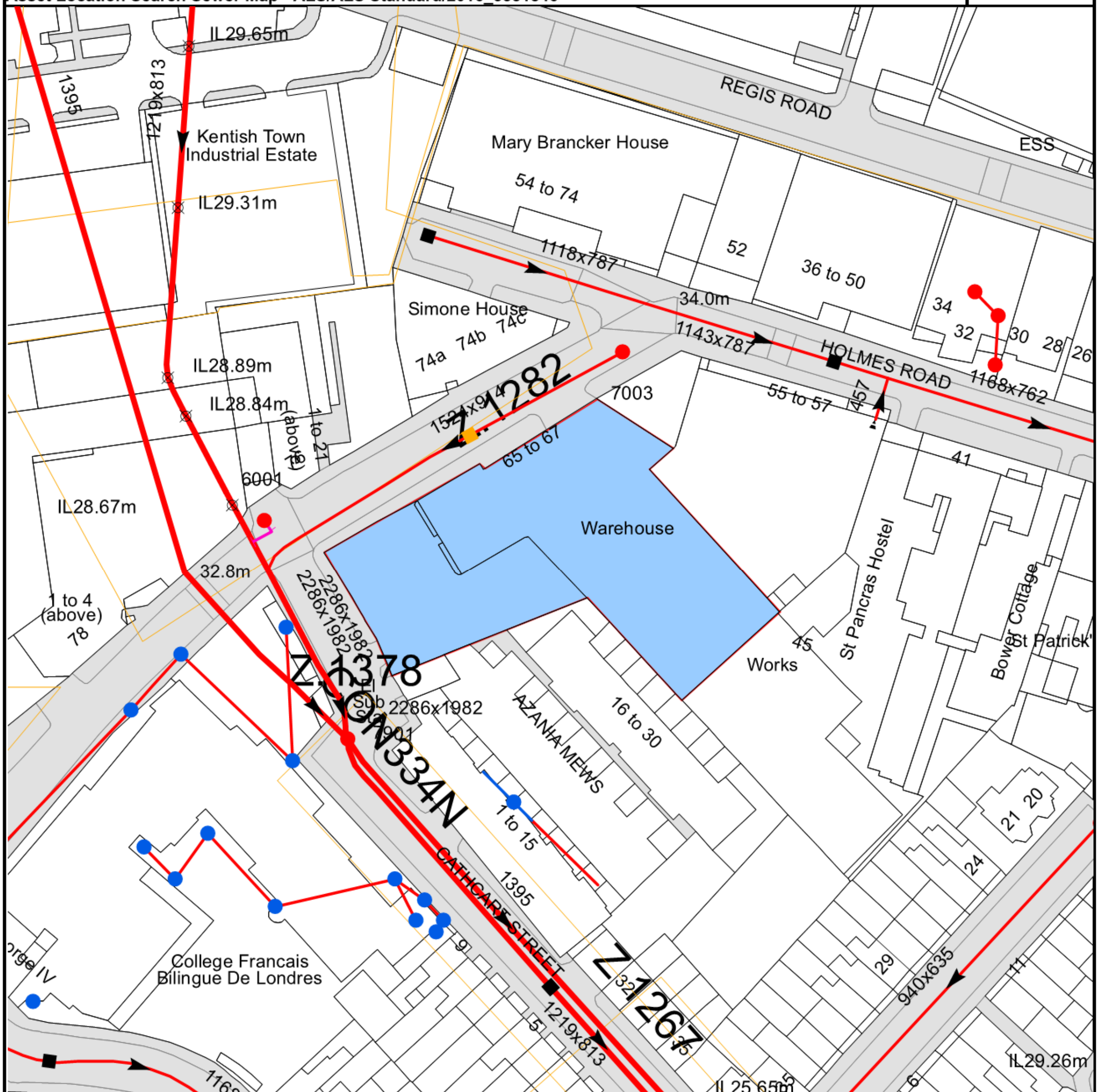
5.3.3 Public Sewers

Any works over, or within three metres of a TWUL public sewers will require prior agreement from TWUL Consideration should also be given to the proposed on-site sewer system and whether access requirements can be adequately maintained.
A maintenance schedule will be required for any SuDS schemes which are to be implemented at the site.

Appendix A – Thames Water Asset Map

Sewer Asset Map showing extents of proposed development

Asset Location Search Sewer Map - ALS/ALS Standard/2016_3331846



The width of the displayed area is 200 m and the centre of the map is located at OS coordinates 528752,185025

Appendix B – Greenfield Calculations

Equations

GREENFIELD AREAS

IH124: Catchment descriptor equation

Peak Run-off

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

$Q_{BAR\ (rural)}$	=	mean annual flood (a return preiod in the region of 2.3 years)
AREA	=	area of catchment in km^2
SAAR	=	Standard Average Annual Rainfall for the period 1941-1970 in mm
SOIL	=	soil index, taken from FST soil maps or the WRAP map of the Wellington procedure

Calculation is completed for 50ha and linearly interpolated for required site area

DEVELOPED AREAS

Calculated using Modified Rational Method and FEH data

Peak Run-off Rate

$$Q_o = 2.78\ C_v\ C_r\ i\ A$$

C_v	=	Volumetric Runoff coefficient
C_r	=	1.3 (routing Coefficient)
i	=	Rainfall Intensity
A	=	Area
2.78	=	Coefficient which accounts for the differences in units used for the inputs and the outputs of the equation

$$V = PR / 100\ \ I\ \ A$$

V	=	Volume of runoff
PR	=	Percentage of Run-off
I	=	rainfall depth (mm)
A	=	Area

Rainfall data:

FEH and FSR

Growth Factors for FSR rainfall and FEH rainfall are calculated using standard methodology and thus are not included here.

Rainfall Data							
Location		528740	185033				
FEH data							
Return Period		2	10	30	100	100+CC (+30%)	
Duration (mins)	Duration (hrs)	Rainfall depths (mm)					
60	1	11.89	27.2	37.82	50.76	65.988	
120	2	17.72	35.57	48.21	65.03	84.539	
240	4	23.56	43.68	58.47	80.38	104.494	
360	6	26.75	47.94	63.85	88.72	115.336	
480	8	28.81	50.67	67.29	94.07	122.291	
600	10	30.35	52.67	69.78	97.82	127.166	
840	14	32.6	55.57	73.26	102.77	133.601	
1440	24	36.29	60.27	78.54	109.47	142.311	
2880	48	42.38	67.88	86.57	117.27	152.451	

FSR data						
M5-60	**20.6**					
Ratior "r"	**0.438**					
Return Period		1	10	30	100	100+CC (+30%)
Duration (mins)	Duration (hrs)	Rainfall depths (mm)				
5	0.08	4.88	9.60	11.86	14.80	19.24
10	0.167	6.76	13.52	16.85	21.27	27.66
15	0.25	8.21	16.41	20.49	26.12	33.96
30	0.5	10.54	20.84	26.24	33.69	43.80
60	1	13.23	25.54	32.52	41.77	54.30

Calculation of Greenfield Run-off Rates - Institute of Hydrology Report 124 FSR 3-parameter equation						
Site name		**AREA (km^2)**	**SPRHOST (%)**	**SAAR (mm)**	**SOIL (SPR)**	**QBAR (m^3/s)**
65-65 Holmes Road		0.5		651	0.47	**0.22**
Growth Factors						
Greenfield runoff in m^3/s for 50ha Area	Return Period Q_{BAR}	2	10	30	100	100+CC
Region	0.22	0.20	0.36	0.53	0.71	
6		0.88	1.62	2.4	3.19	
Greenfield runoff in l/s for 50ha Area	Return Period Q_{BAR}	2	10	30	100	100+CC
	221.74	195.13	359.22	532.18	707.36	990.30
Greenfield runoff in l/s/ha	Return Period Q_{BAR}	2	10	30	100	100+CC
	4.43	3.90	7.18	10.64	14.15	19.81
Actual Site Area (existing)	0.245	ha				
	Return Period Q_{BAR}	2	10	30	100	100+CC
Existing Flood Discharge from site	1.09	0.96	1.76	2.61	3.47	4.85

Peak runoff rate calculations

IMPERMEABLE AREAS (Pre-development)			
Roofs	=	0.9	normal roofs
Pavements	=	0.75	hard standing

Surface	**Area (ha)**	**Cv**	**Weighted Cv**
Roofs	0.1636	0.9	0.14724
Pavement	0.0814	0.75	0.06105
TOTAL	0.245	0	0.85

Return Period	1 in 1

Duration (mins)	FEH rainfall Depth (mm)	Intensity (mm/hr)	Peak Flow Rate (l/s)
5	4.88	58.60	44.11
10	6.76	40.55	30.52
15	**8.21**	**32.82**	**24.71**
30	10.54	21.09	15.87

Return Period	1 in 30

Duration (mins)	Rainfall Depth (mm)	Intensity (mm/hr)	Peak Flow Rate (l/s)
5	11.86	142.30	107.12
10	16.85	101.11	76.11
15	**20.49**	**81.97**	**61.70**
30	26.24	52.47	39.50

Return Period	1 in 100

Duration (mins)	FEH rainfall Depth (mm)	Intensity (mm/hr)	Peak Flow Rate (l/s)
5	14.80	177.56	133.66
10	21.27	127.64	96.08
15	26.12	104.49	78.65
30	33.69	67.39	50.73

Volume of Runoff

IMPERMEABLE AREAS – Pre-development			
Surface	Area (ha)	Cv	Weighted Cv
Roof	0.1636	0.9	0.14724
Pavements	0.0814	0.75	0.06105
TOTAL	0.245	0	0.85

IMPERMEABLE AREAS – Post-development			
Surface	Area (ha)	Cv	Weighted Cv
Roof	0.245	0.9	0.245
Pavements	0	0.75	0
TOTAL	0.245	0	0.9

Greenfield Rates:

Storm Duration (minutes)	Greenfield discharge rate l/s	Greenfield volume, m3
360	5.00	108.0

Pre-development Rate:

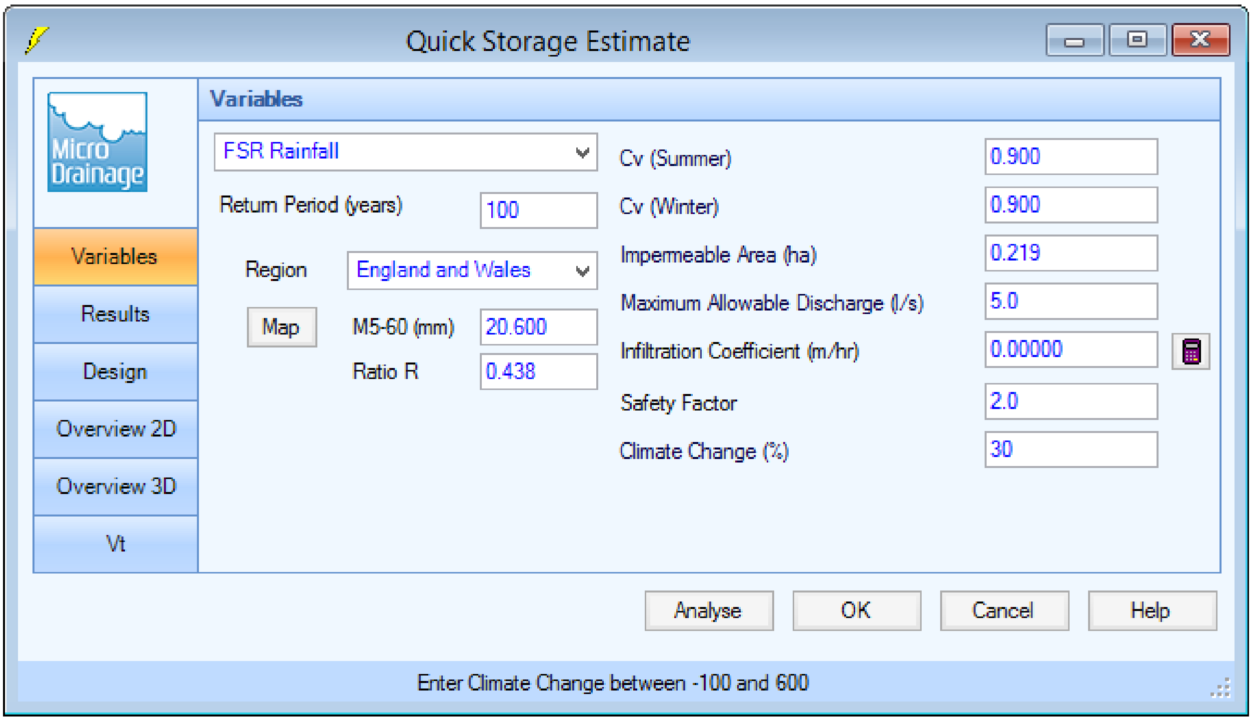
Storm Duration (minutes)	Pre-development discharge rate l/s	Pre-development volume, m3
360	11.131	184.8

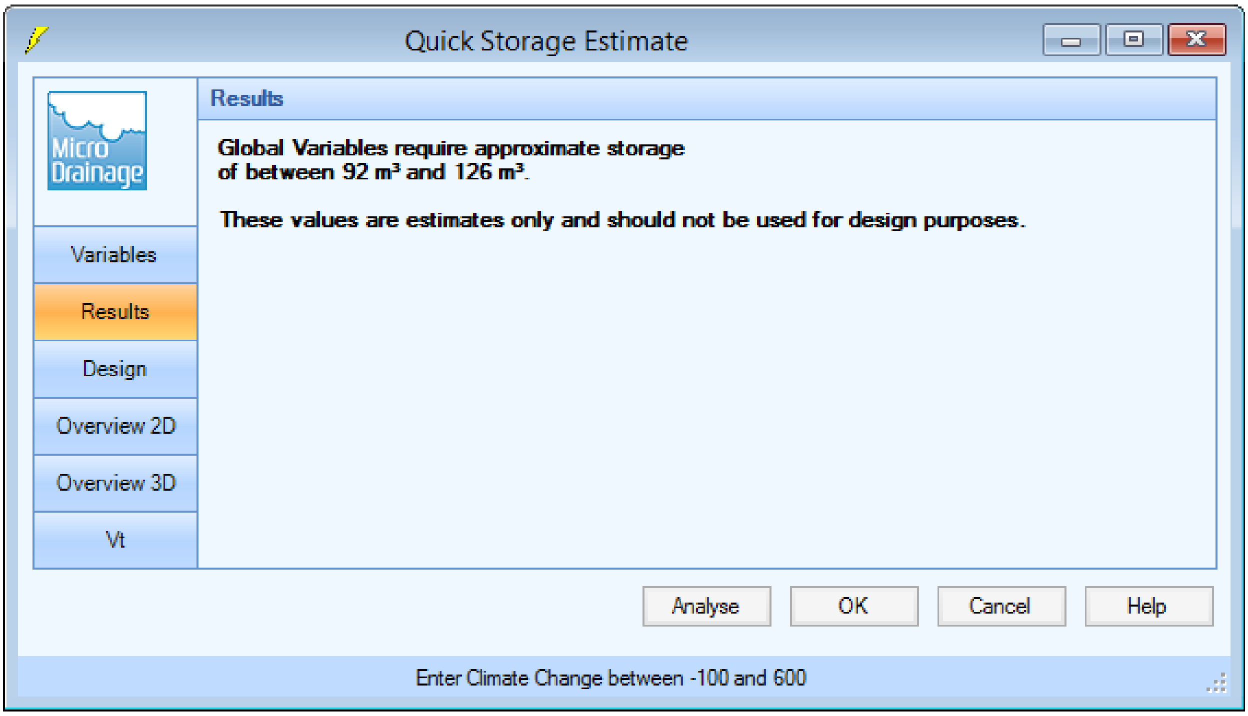
Storm Duration (minutes)	Post Development run-off, l/s	Post development run-off volume, m3	Green Roof holding volume, m3	Total Post Development volume, m3
360	11.783	195.6	6.5	189.1

Storm Duration (minutes)	Post Development run-off + 30% Climate Change, l/s	Post development run-off volume, m3	Green Roof holding volume, m3	Total Post Development volume, m3
360	14.470	240.2	6.5	233.7

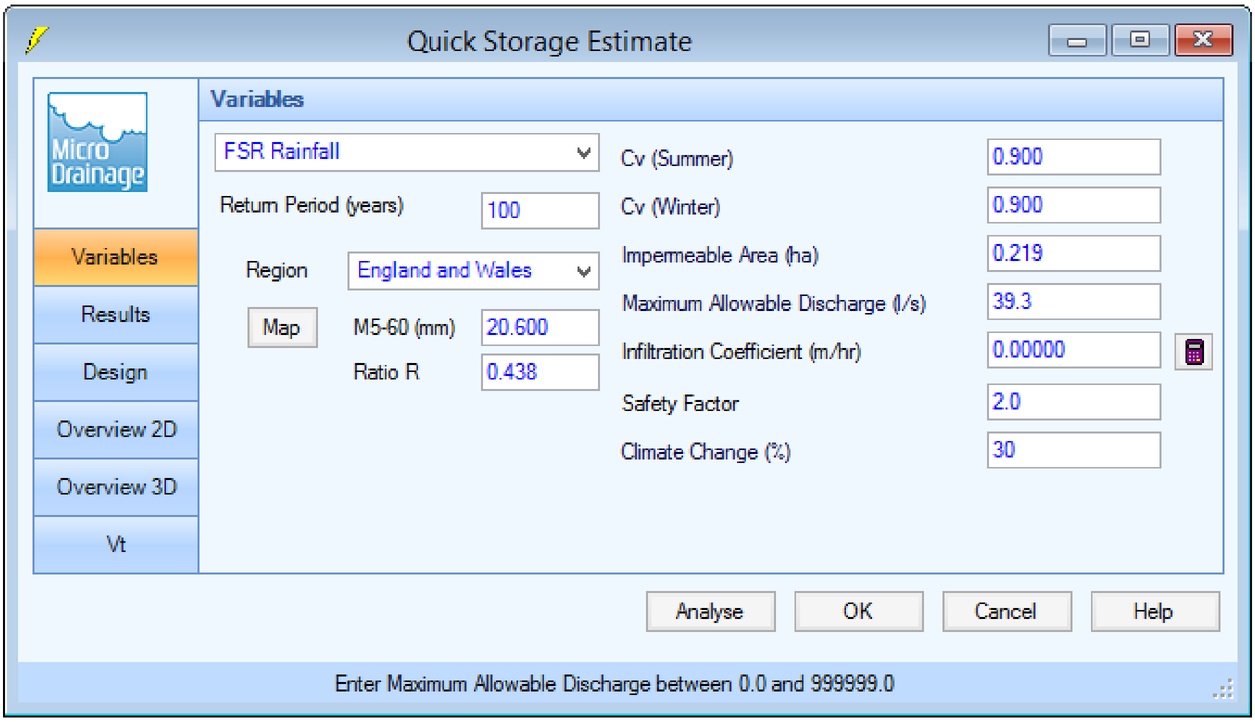
Appendix C – Quick Storage Estimate Calculations

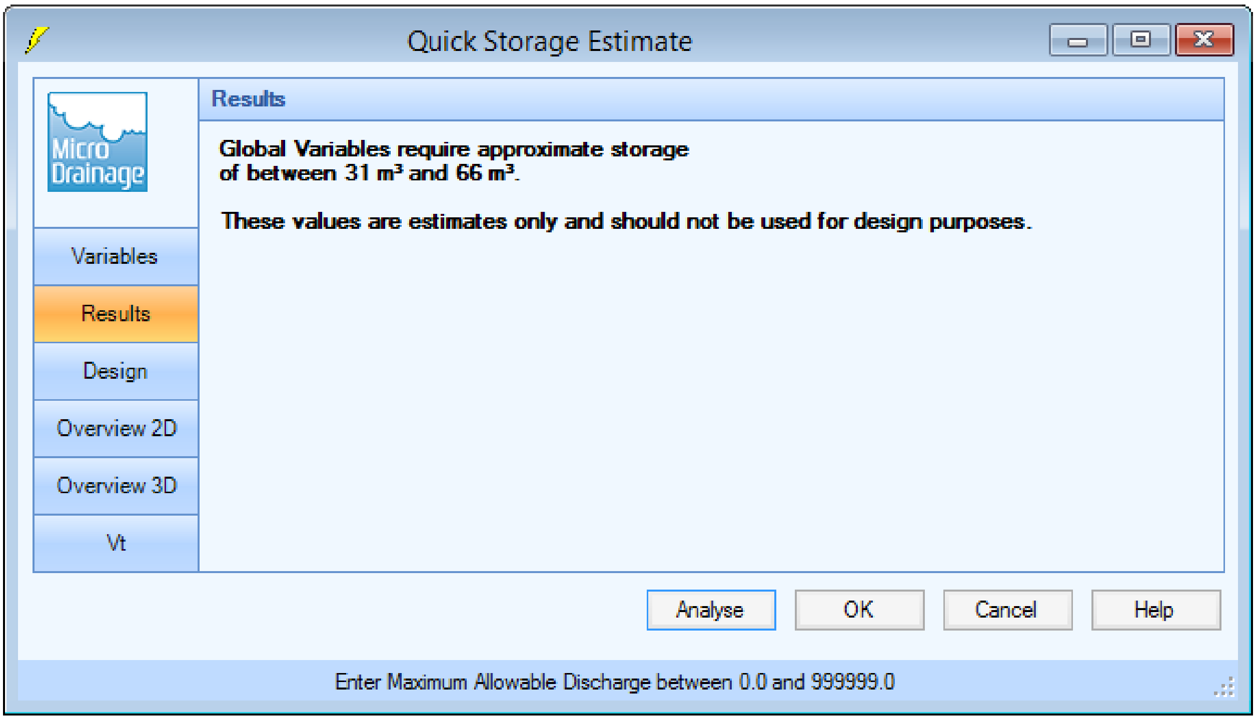
Proposed Site + 30% Climate Change Vs Greenfield Rate





Proposed Site (50% of existing run-off rate) + Climate Change Allowance Vs Existing Site





APPENDIX D

Site plan sketches and proposed system

L1405-SK-C-01 – Green Roofs
L1405-SK-C-02 – Existing Areas Split
L1405-SK-C-03 – Proposed Attenuation System
L1405-SK-C-04 – River Fleet Sewer
L1405-SK-C-05 – Ground Floor Plan
L1405-SK-C-06 – Upper Basement Plan
L1405-SK-C-07 – Lower Basement Plan

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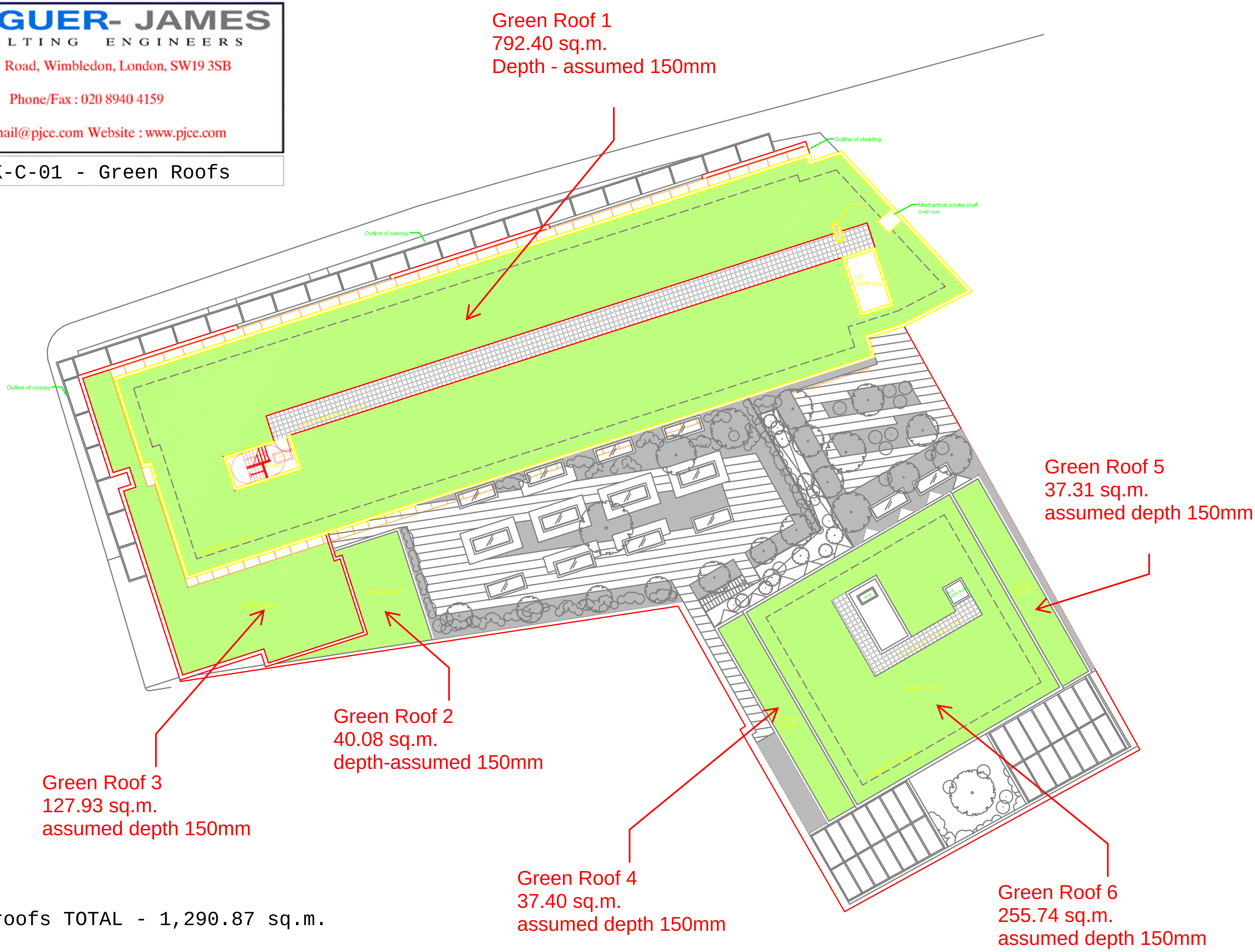
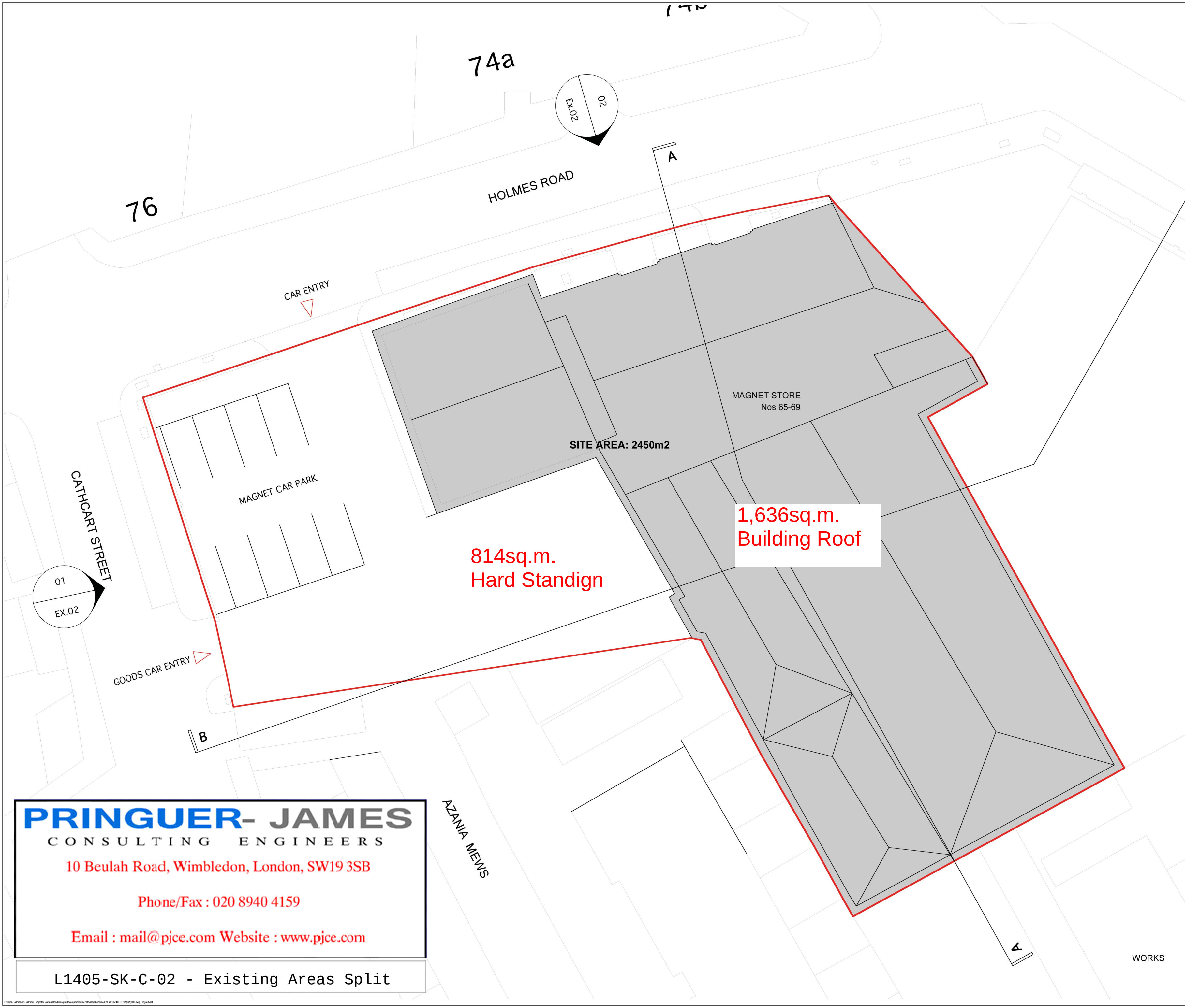
L1405-SK-C-01 - Green Roofs



Greenroofs TOTAL - 1,290.87 sq.m.



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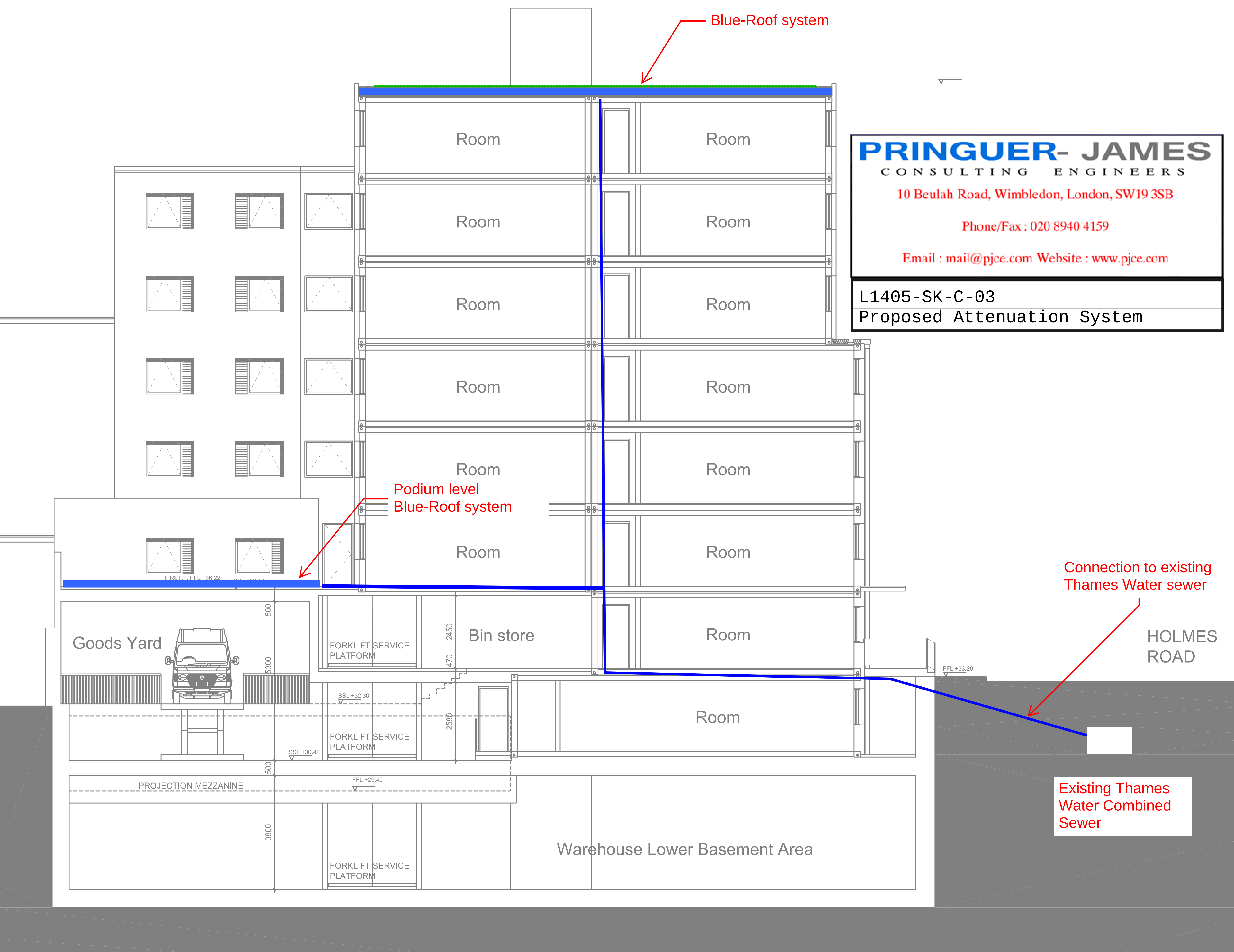
L1405-SK-C-02 - Existing Areas Split



Blue-Roof system
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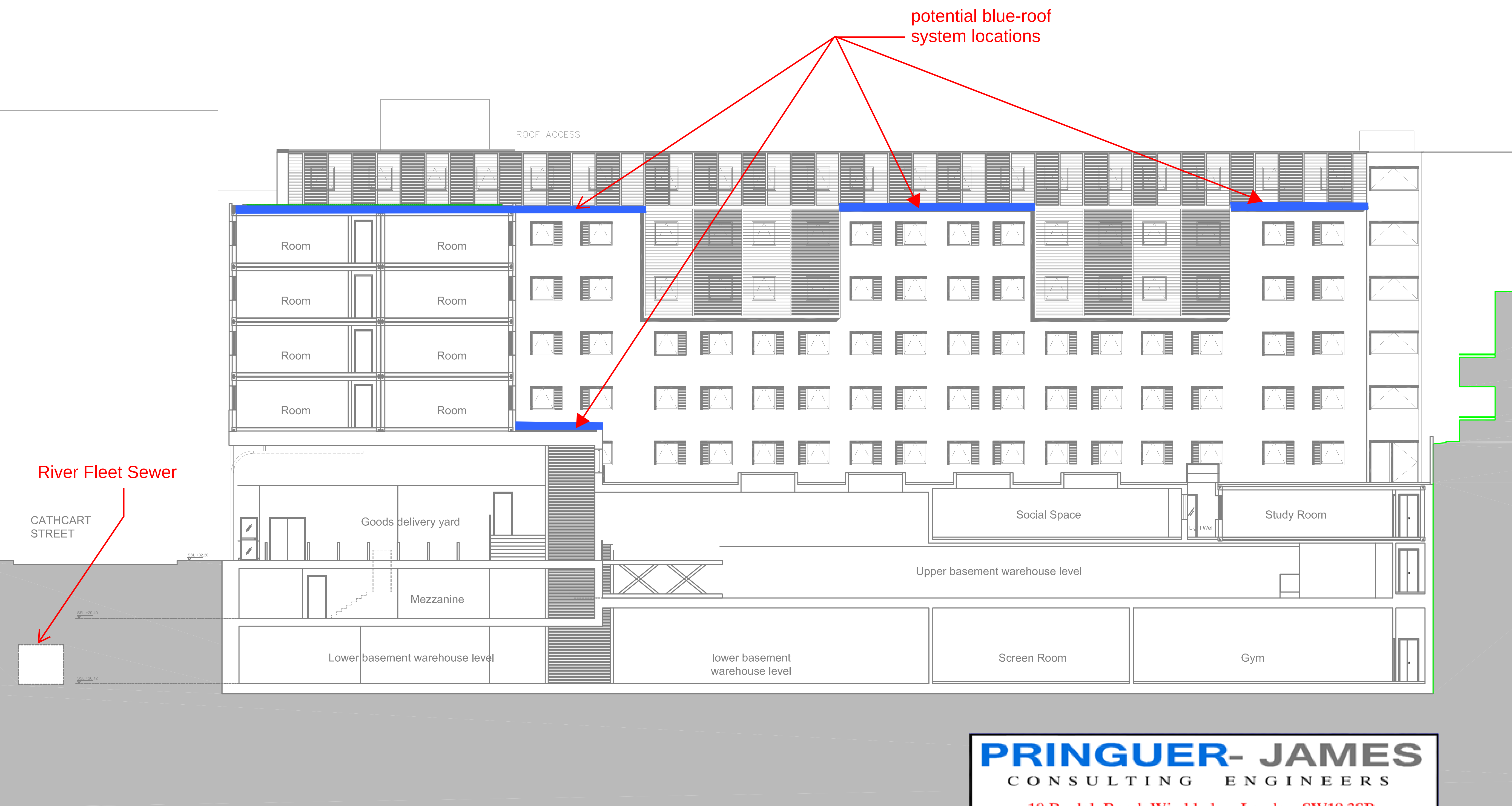
L1405-SK-C-03
Proposed Attenuation System
Room
Podium level
Blue-Roof system
Connection to existing
Thames Water sewer
HOLMES
ROAD
Goods Yard
FORKLIFT SERVICE
PLATFORM
Bin store
FFL +33.20
SSL +32.30
SSL +30.42
FFL +29.40
PROJECTION MEZZANINE
Existing Thames
Water Combined
Sewer
Warehouse Lower Basement Area
500
5300
2450
470
2580
3800



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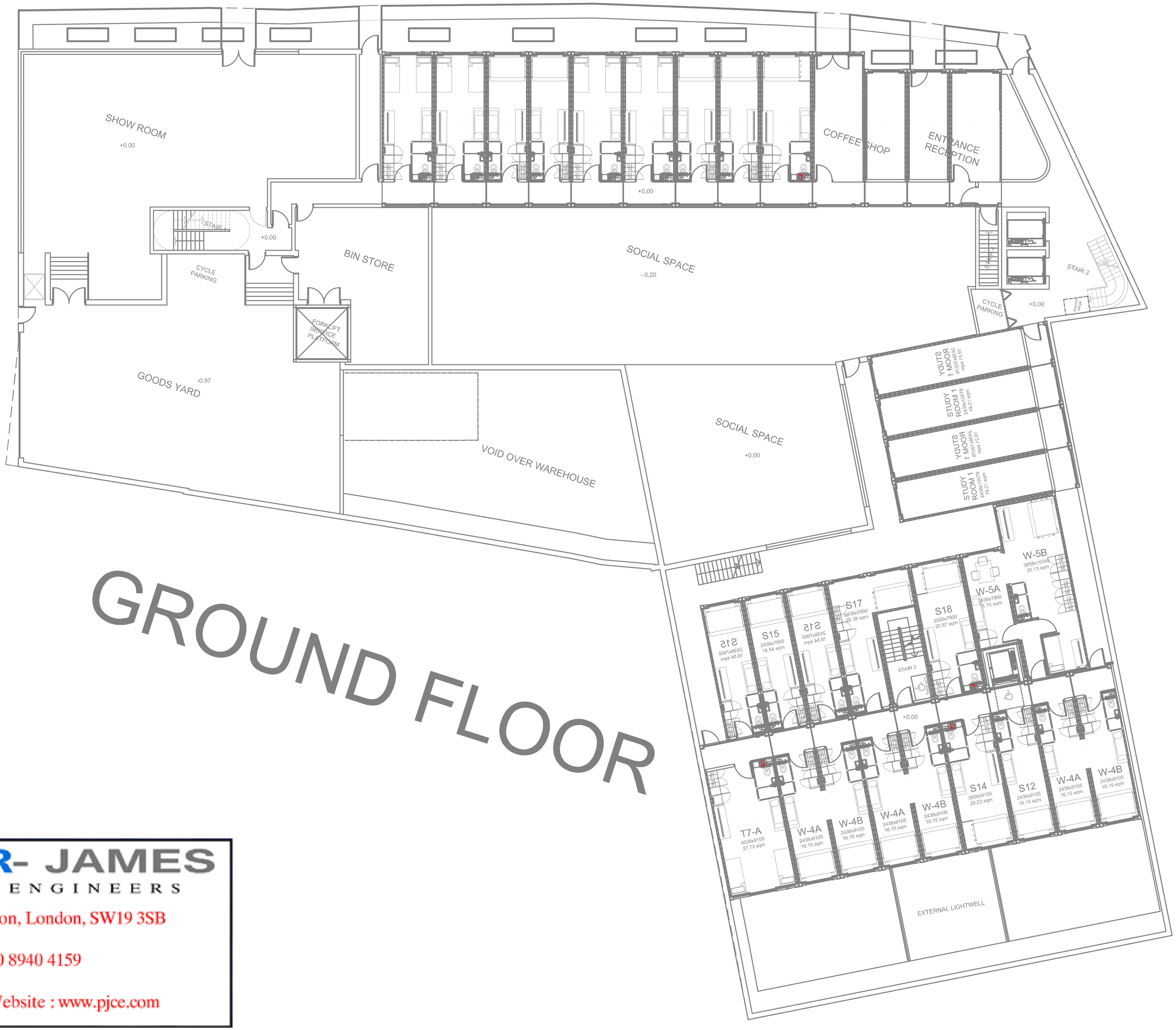
L1405-SK-C-04 - River Fleet Sewer



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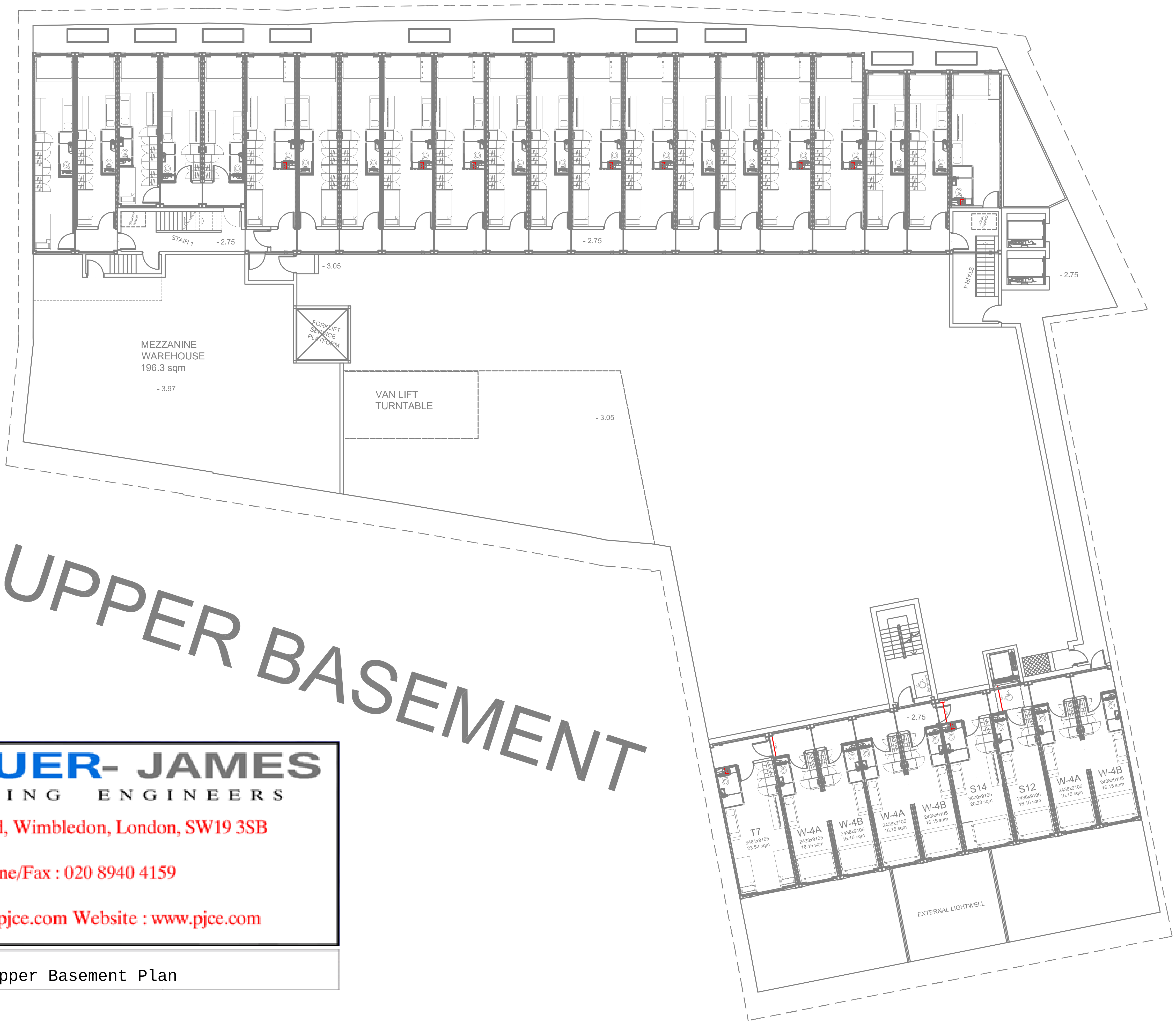
L1405-SK-C-05 - Ground Floor Plan



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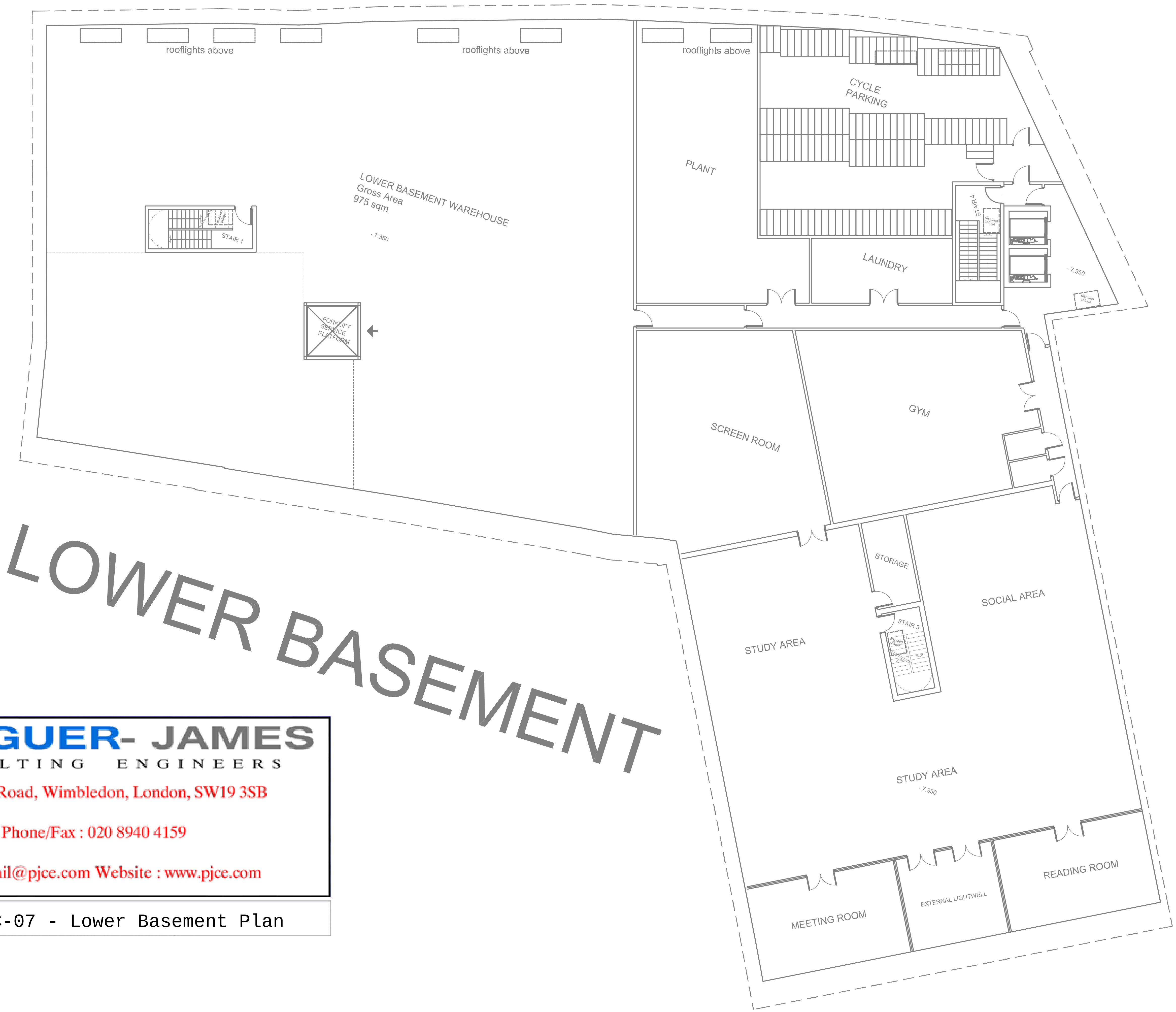
L1405-SK-C-06 - Upper Basement Plan



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L1405-SK-C-07 - Lower Basement Plan