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Project: Surface Water Drainage Strategy (SWDS)

Prepared for: Ms Helena Griffiths

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Site Location: Jeffrey's Farm, Horsted Keynes, Haywards Heath, West Sussex, RH17 7DY

Proposed Development: It is understood that the development is for the construction of 40 residential units.

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1. Summary

SITE DETAILS			
Site Name	Jeffrey's Farm, Horsted Keynes, Haywards Heath, West Sussex, RH17 7DY		
Total Site Area	5.24 ha		
Developed Area	2.61 ha		
Predevelopment Use	Partly Jeffrey's Farm and partly Greenfield Site		
Site Constraints	Jeffrey's Farm		
	Groundwater Source Protection Zone: YES. (Outer zone, Zone 3)		
	Groundwater Vulnerability Zone: Minor Aquifer Intermediate		
	- Poor Infiltration Soils		
	- Unknown Groundwater Table		
IMPERMEABLE AREAS			
	Existing	Proposed	Difference (Proposed - Existing)
Impermeable Area (Ha)	0.42 ha	0.89 ha	0.47 ha
Drainage Method (Infiltration/Sewer/Watercourse)		Infiltration	N/A
PROPOSED TO DISCHARGE SURFACE WATER VIA			
	YES	NO	Evidence
Infiltration	X		Soils with Good Infiltration Media.
To Watercourse		X	Distance to discharge to a watercourse is not viable.
To Surface water sewer		X	Following hierarchy line, this option is dismissed.
Combination of above		X	N/A

PEAK DISCHARGE RATES		
	Greenfield Rates (l/s)	Proposed Rates (l/s)
Greenfield Q_{BAR} (Mean Flow Rate)	9.46	9.46
1 in 1	8.04	8.04
1 in 30	23.28	23.28
1 in 100	30.18	30.18
1 in 100 plus climate change	N/A	N/A

FLOW CONTROL		
Flow Control Type	Variable	
Greenfield Flow 1 in 1 (Daily storm event)	3.62 l/s*ha	**9.46 l/s**
Greenfield Flow 1 in 100 (Extreme event)	3.62 l/s*ha	**30.18 l/s**

SITE STORAGE VOLUME	
Source Control Provided	Yes
Interception Volume Storage (Daily Storms)	39.48 m^3

Attenuation Volume Storage (1 in 100 yr + CC storm)	979.43 m^3	
Approach used for Long Term storage (Either *Use Long Term Storage* or *Discharge rate at 2 l/s/ha*)	*Use Long Term Storage*	
LTS (1 in 100 years, 6 hours event)	55.12 m^3	
Total Site Storage	1074.05 m^3	

INFILTRATION FEASIBILITY ANALYSIS		
Geology	Ashdown Formation – Sandstone and Siltstone	
Infiltration Rates	Less than $1x10^{-7}$ m/s	This value must be confirmed through trial pit infiltration tests on site prior to the final detailed drainage design stage being carried out.
Infiltration Rates Suitability	Suitable	
Groundwater Level	Groundwater level is unknown	
Is the site within a known Source Protection Zones (SPZ)?	Yes	Outer zone (Zone 3)
Site's Contamination	Greenfield Site, thus it is considered uncontaminated	
Infiltration Feasibility	Yes	

PROPOSED DRAINAGE COMPONENTS	
Permeable Pavement	Pervious surfaces provide a surface suitable for pedestrian and/or vehicular traffic, while allowing rainwater to infiltrate through the surface and into underlying layers.
Soakaways	Soakaways are square or circular excavations either filled with rubble or lined with brickwork, pre-cast concrete or polyethylene rings/perforated storage structures surrounded by granular backfill. The supporting structure and backfill can be substituted by modular or geocellular units.
Bioretention Systems	Bioretention areas are shallow landscaped depressions which are typically under drained and rely on engineered soils, enhanced vegetation and filtration to remove pollution and reduce runoff downstream. They are aimed at managing and treating runoff from day-to-day rainfall events.
DESIGN CHECKS	
All SuDS storage located outside Q_{100} floodplain	Yes
Provision for blockage / Design Exceedance	Yes

Proposed Strategy Layout

2. Introduction

2.1 This Surface Water Drainage Strategy has been prepared by Ambiental Technical Solutions, in respect of a planning application for the development at Jeffreys Farm, Horsted Keynes, Haywards Heath, West Sussex, RH17 7DY. See *Appendix 1, Plan 1 – Site Location* and *Figure 1* below.

Figure 1 – Site Location (Source: OS-StreetView)

Development Proposal

2.2 It is understood that the development is for the construction of 40 new residential units on land associated with Jeffrey's Farm.

2.3 This study is based on the plans provided by the client in *Appendix 1* (please see *Plans 1* and 2).

Need for Study

2.4 The purpose of this assessment is to demonstrate that the development proposal outlined above can be satisfactorily accommodated without worsening flood risk for the area and without placing the development itself at risk of flooding, as per National guidance provided within the National Planning Policy Framework (NPPF).

3. Development Description and Site Area

3.1 The site is located at Jeffreys Farm, Horsted Keynes, Haywards Heath, West Sussex, RH17 7DY. *See Appendix 1, Plan 1 – Site Location, Plan 2 – Existing Site Location Plan and Figure 2 below*. Specifically the site is bounded by existing residential properties to the south east, east and north while it is bounded by existing vacant fields to the west. An area in the centre of the site, associated with the existing Jeffrey's Farm, has been excluded in the red line application boundary.

Figure 2 – Aerial View of Development Site (Source: Google Earth)

3.2 It is understood that the development is for the construction of 40 new residential dwellings and associated hard standing on land associated with Jeffrey's Farm.

3.3 The total area of the site is approximately 52416 m^2 (approximately 5.24 Ha), based on plans provided by the client.

3.4 The existing site is considered 92% pervious due to the existing green areas, 48169 m^2, (approximately 4.8 Ha). Following development, the pervious areas on site will be reduced to 41516 m^2 4.1 Ha), while the impervious areas will be increased to 10899 m^2 (1.09 Ha).

3.5 According to topographical data (Source: LiDAR), the topography of the site ranges from approximately 87.19mAOD at the eastern side of the site to 77.120mAOD at the topographic high point on the north western side. The site is relatively flat in the south eastern and central areas, before sloping down in a north westerly direction towards Keysford Lane.

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Existing Drainage Infrastructure

3.6 The existing site is largely undeveloped, and has been calculated to be approximately 92% pervious.

3.7 Information regarding the existing drainage infrastructure on site has not been provided by the client. Given that the site is primarily undeveloped land it is unlikely that drainage infrastructure is present in these areas.

Existing Ground Conditions

3.8 The British Geological Survey (BGS) Map indicates that the bedrock geology underlying the site is the *Ashdown Formation – Sandstone and Siltstone*. Sedimentary Bedrock formed approximately 134 to 146 million years ago in the Cretaceous Period. The local environment of the origin of these rocks was previously dominated by swamps, estuaries and deltas, hence these rocks were formed in marginal coastal plains with lakes and swamps periodically inundated by the sea (*See an extract from the BGS Geology map in Appendix 2, Figure 1*).

3.9 There is no records of Superficial Deposits on the site in the BGS database. See the extract from BGS Geology map in *Appendix 2, Figure 2 – Superficial Deposits*.

3.10 The Soil Parental Material across the site taken from the UK Soil Observatory (UKSO) website is classified as *Sandstone and Mudstone* while the Soil Texture is defined as Silty *Loam to Sandy Loam See Appendix 2, Figure 3 – Soil Parental Material and Figure 4 – Soil Texture*. Standard values from the specialized literature CIRIA 753 'The SUDS Manual' suggest the infiltration coefficient of these types of soils is between $1x10^{-7}$ m/s (0.18 m/h) and $1x10^{-5}$ m/s (0.018 m/h) for Sandy Loam, while the range for Silty Loam is between $1x10^{-7}$ m/s (0.0036 m/h) and $1x10^{-6}$ m/s (0.036 m/h). *See Table 1 – Typical Infiltration Coefficients based on Soil Texture* below. It is recommended that these values are checked through trial pit infiltration tests on site prior to the final detailed drainage design being carried out.

SOIL TYPE	Typical infiltration Coefficients (m/h)
Good infiltration Media	
Sandy Loam	0.00036 - 0.036
Poor infiltration Media	
Silty Loam	0.00036 - 0.036

Table 1 – Typical Infiltration Coefficients based on Soil Texture

3.11 The rocks underlying the site lies in an aquifer with significant intergranular flow and considered as a moderately productive aquifer according to the BGS hydrogeological database. It is recommended that a groundwater level check be undertaken at the later detailed design stage in order to accurately identify the depth of the water table at the site (*see Appendix 2, Figure 5 – Hydrogeology*).

3.12 The *Environmental Agency's Groundwater Source Protection Zone Map* confirms that the site is within a Source Protection Zone classified as Total Catchment (Zone 3). The site also lies within a Groundwater Vulnerability Zone classified as a 'Minor Aquifer' with 'Intermediate' vulnerability. *See Appendix 2, Figure 6 – Groundwater Source Protection Zones* and *Figure 7 – Groundwater Vulnerability Zones.*

Nearby Watercourses and Drainage

3.13 An ordinary watercourse is located 170m south of the site. The closest named watercourse is the Cockhaise Brook located approximately 800m west of the site, the Cockhaise Brook is defined as an EA main river.

3.14 Existing flow pathway analysis was undertaken at the site using topographic LiDAR data (Figure 3). The analysis shows that flow on the northern half of the site flows in a north western direction and exits the site on the north western boundary towards Keysford Lane. Flow direction on the southern side of the site is predominantly in a western direction, before flowing south west and exiting the site on the south western boundary.

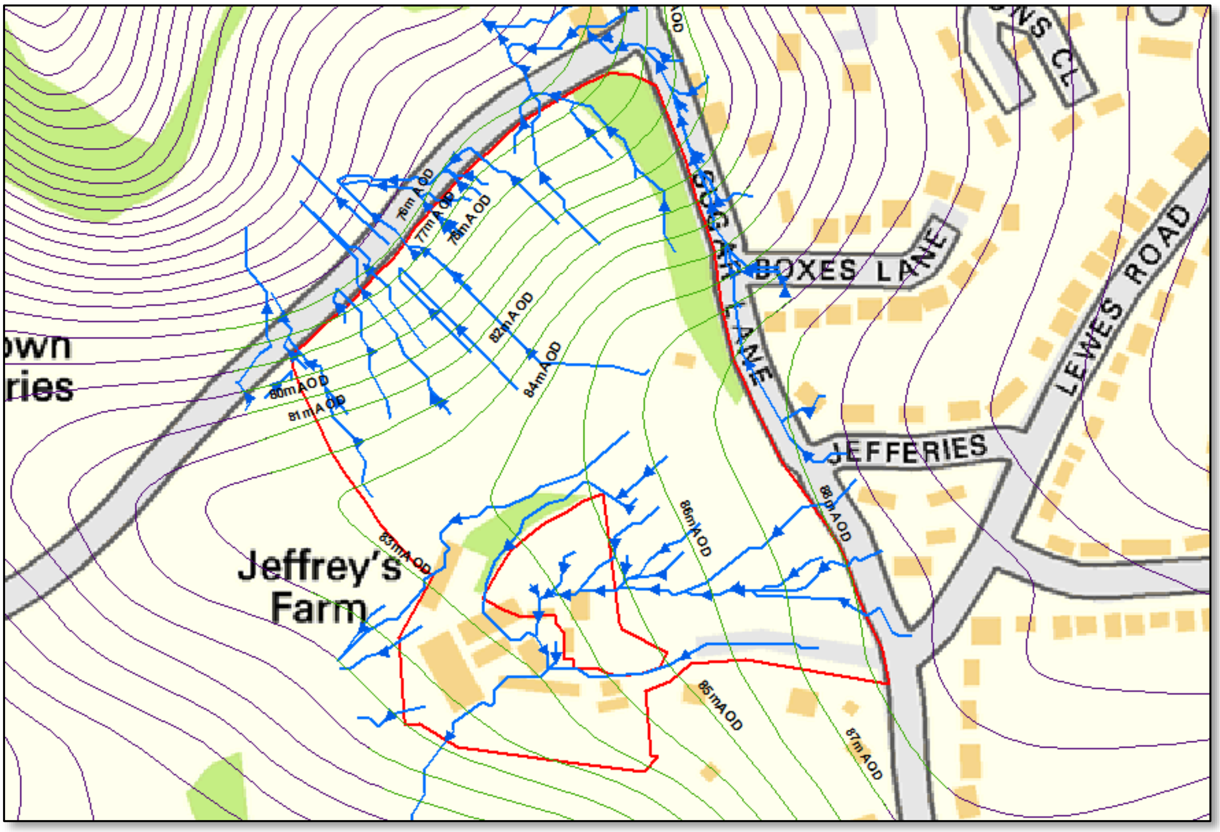


Figure 3: Existing Flow Direction (Source: OS, LiDAR)

4. Surface Water Drainage

4.1 In order to mitigate flood risk posed by the proposed development adequate control measures are required to be considered. This will ensure that surface water runoff is dealt with at source and the flood risk off site is not increased.

4.2 In accordance with the provided plans for the proposed development, the proposed development will increase the impermeable surface cover to the site by approximately 10899m², based on plans provided. The runoff arising from the development will need to be managed in accordance with National Planning Policy Framework (NPPF) policy which requires SuDS to be considered where appropriate for major developments.

Infiltration Potential

4.3 *UK Soil Observatory* records indicate the site is underlain by *Sandstone and Mudstone* with a texture ranged from Silty *Loam* to Sandy *Loam*. According to specialised literature, the *CIRIA 753 – 'The SuDS Manual'*, although the Infiltration Media for the Silty L*oam* and *Sandy Loam* soil is considered 'Poor' and 'Good', respectively, thus the soils underlain the site are likely to be suitable for infiltration SuDS. **Therefore, it is proposed that surface water will be discharged post development via infiltration SuDS.** Nevertheless, it is advised that this should be confirmed through trial pit infiltration tests on site prior to the final detailed drainage design stage being carried out.

4.4 Notwithstanding, there are constraints to deal with in order to consider the viability of any infiltration device. Based on *The Building Regulations 2000, Section 3.25*:

> "*Infiltration drainage is not always possible. Infiltration devices should not be built:*
>
> *a. Within 5m of a building or road or in areas of unstable land (see Planning Policy Guidance Note 14 Annex 1);*
>
> *b. In ground where the water table reaches the bottom of the device at any time of the year (…)".*

4.5 Furthermore, in compliance with the CIRIA 753 – 'The SuDS Manual', the groundwater table must be always, at least, 1 m below of the bottom of the device.

4.6 Thus, it will be taken into account a 5 metres distance of any building or road for the location of the soakaways as well as the restriction of 1 metre depth between the bottom of them and the groundwater table.

Runoff rates

4.7 Greenfield runoff rates have been calculated using the *Institute of Hydrology Report 124 (*Marshall and Bayliss, 1994*)*, as recommended in the *CIRIA 753 'The SUDS Manual'* (See calculations in *Appendix 3, Table 1 – Greenfield Runoff Rates Calculation Summary*).

4.8 The Greenfield runoff rates for the several storm duration for various return periods have been calculated based on the following equation:

$$QBAR_{rural} = 0.00108 * AREA^{0.89} * SAAR^{1.179} * SOIL^{2.17}$$

Where,

$Q_{BAR,rural}$: Mean Annual Flood (m^3/s).

AREA: Catchment Area (km^2).

SAAR: Standard Average Annual Rainfall for the 1941 to 1970 (mm).

SOIL: Soil Index of the catchment from Wallingford Procedure Volume 3.

Equation 1 – IH 124 Mean Annual flood flow Rate Equation.

4.9 Preliminary calculations based on Equation 1 show that the *Greenfield Runoff Rate* ($Q_{BAR,rural}$) from the site is 181.02 l/s. In keeping with the standard practice this is the value for 50 hectares, therefore the rate per hectare is 3.62 l/s/ha. **According to the size area (5.24 ha), the *Greenfield Runoff Rate* from the area of the site is 9.46 l/s.** Other results properly factored for each return period and area of the site are shown in *Appendix 3, Table 1 – Greenfield Runoff Rates Calculation Summary*.

SURFACE WATER DISCHARGE RATES SUMMARY					
Impermeable Area (m^2)		Discharge Rates (l/s)			
		1:1 year	Q_{BAR}	1:30 years	1:100 years
Existing Site	23849.95	8.04 l/s	9.46 l/s	23.28 l/s	30.18 l/s
Proposed Site	24568.98	8.04 l/s	9.46 l/s	23.28 l/s	30.18 l/s

Table 2 – Surface Water Discharge Rates Summary

4.10 Other results properly factored for each return period and areas of the site are shown in *Appendix 3, Table 1 – Greenfield Runoff Rates Calculation Summary* and *Table 3 – Flow and Volume Information Summary*.

Interception Storage

4.11 Preliminary calculations have been carried out for a typical rainfall depth of 5 mm/m^2 to store the volume owing to these very frequent storms.

4.12 Urban Creep Factor (UCF) is defined as any increase in the impervious area that is drained to an existing drainage system without planning permission being required, such as the construction of patios, conservatories, small extensions, etc. Hence, an increase in paved surface area of 10% is often suggested by the *CIRIA 753 'The SUDS Manual'*. Also, a usual *Runoff Percentage* of 80% have been taken into account.

4.13 **Based on the size of the increase in impervious area of the site, the UCF and the Runoff Percentage, the Interception Storage is 39.48 m^3.**

Long Term Storage

4.14 Long-term storage is required to address the additional runoff caused by the development compared to the volume that would be contributed from the site in its Greenfield state. It is based on a 100 year, 6 hours storm event plus climate change (30%). Preliminary calculations show that this volume is **0.00 m^3**, which must be prevented from leaving the site (via rainwater harvesting and/or infiltration) or, where this is not possible, controlled so that it discharges at very low rates that would have negligible impact on downstream flood risk.

4.15 As recommended in the *CIRIA 753 'The SUDS Manual'*, Long-term Storage Volume has been calculated according to the following formula:

$$Vol_{XS} = 10 \cdot RD \cdot A \left[\frac{PIMP}{100} (\alpha \cdot 0.8) + \left(1 - \frac{PIMP}{100}\right) (\beta \cdot SOIL) - SOIL \right]$$

Where,

Vol_{xs}: Extra runoff volume (m^3) of development runoff over Greenfield runoff.

RD: Rainfall Depth for the 100 year, 6 hour event (mm).

PIMP: Impermeable Area as a percentage of the Total Area.

A: Area of the site (ha). (Area Positively Drained).

SPR: "SPR" Index for the FSR SOIL type.

α: Proportion of paved area draining to the network or directly to the river (values from 0 to 1) with 80 per cent runoff.

β: Proportion of Pervious Area draining to the network or directly to the river (values from 0 to 1).

Equation 2 - Long-Term Volume Storage Equation.

4.16 As Interception Storage is provided, *RD* is reduced 5 mm. See values for each variable in the table 3 below:

LONG-TERM STORAGE VOLUME SUMMARY	
RAINFALL DEPTH (mm)	70.30
AREA (ha)	2.61
PIMP	17.12%
SOIL TYPE	3
SPR	0.37
α	1
β	0
Long-Term Storage Volume (m^3)	**0.00 m^3**

Table 3 - Values for Long-Term Storage Volume Equation

4.17 **Therefore, the Long-Term Storage Volume is 0.00 m^3.**

Attenuation Storage

4.18 Attenuation storage is needed to temporarily store water during periods when the runoff rates from the development site exceed the allowable discharge rates from the site.

4.19 Rainfall depths for the 1 in 100 years Return Period plus 30% of climate change were produced using the FEH CD-ROM DDF (Depth-Duration-Frequency) modelling function. These have been used as Inflows. Long-Term Storage Volume and Interception Volume were subtracted from the Inflows.

4.20 Outflow values have been calculated for several durations based on the Discharge Rate obtained as an average of the Greenfield Runoff Rates of the site for the 100 years and 1 year Return Periods.

4.21 Preliminary calculations have been undertaken in compliance with the objective of obtaining the largest volume for typical storm durations up to and including 4 days for a 100 year Return Period Event with an allowance for climate change (30%) for the proposed site, *Critical Storm*, subtracting the Outflow values from Inflow values for each duration. In addition to this, the Urban Creep Factor, 10%, is applied for the impervious surface.

4.22 Thus, it meets with the minimum standards required by the *DEFRA - Non-statutory technical standards for sustainable drainage systems (March 2015)* to avoid the flood risk within the development in a 1 in 100 year rainfall event. Values are increased by 25% to provide a conservative, risk adverse approach. See summary calculations in *Appendix 3, Table 2 – Summary of Attenuation Storage Estimation – 1 in 100 years + cc*.

4.23 In terms of storage, for a 100 years storm event with an allowance for climate change, the **Critical Durations is 10 hours**, the largest volume per square metre being **0.1069 m^3/m^2**. Therefore the Attenuation Storage Volume required for the whole site is **1055.23 m^3**. See *Appendix 3, Graph 1 - Attenuation Storage Volume required for site estimated for Critical Duration (m^3 per m^2)* and *Table 3 – Flow and Volume Information Summary*.

On Site Drainage and Storage Systems

4.24 **Preliminary calculations indicate that 1055.23 m^3 of storage will be required to attenuate runoff from the 1:100 year +30% climate change events and a 10% of Urban Creep Factor. 39.48 m^3 of storage is required for the day-to-day rainfall as Interception Volume and 0.00 m^3 storage required for the Long Term Storage Volume (6 hours, 100 year Return Period event).**

4.25 **A summary to identify these figures and other information regarding to the flow and volume for the following proposed SuDS scheme is showed in the *Appendix 3, Table 3 – Flow and Volume Information Summary*.**

4.26 As such all SuDS components have been designed to accommodate and dispose of runoff from storms up to and including the 1:100 year + 30% climate change event without flooding.

4.27 In accordance with the SuDS management train approach, the use of various SuDS measures to reduce and control surface water flows have been considered in details for the development.

4.28 Based on the hierarchy line provided by the specialized literature *CIRIA 753 'The SUDS Manual', Section 3.2.3*:

"The destination for surface water runoff that is not collected to be used must be prioritised in the following order:

1. *Infiltration*
2. *Discharge to surface waters*
3. *Discharge to a surface water sewer, highway drain or another drainage system*
4. *Discharge to a combined sewer*

Discharge to a foul sewer should not be considered as a possible option.

(…)".

4.29 Thus, at this stage the practicality and viability of certain SuDS options have been ruled out on the basis of ground conditions and constraints presented by the site layout:

4.30 *Infiltrating SuDS*

Infiltration components of SuDS, such as soakaways, are deemed appropriate due to the good conditions of the site soil for this purpose as long as a minimum distance of 5 metres between these SuDS techniques and a building/road are taken into account to comply with *Building Regulations, section 3.25* and there is a minimum distance of 1 metre between the bottom of the infiltration device and the groundwater table.

- *Soakaways.*

  This SuDS technique is considered **suitable** owing to the fact it could provide storm water attenuation and treatment, and also groundwater recharge.

- *Rain Gardens.*

  This SuDS technique is considered suitable as runoff water from roofs and pedestrian hardstanding surfaces can be intercepted or attenuated through this SuDS technique whereby the water is infiltrated or taken up by the plants. Besides this, other amenity benefits are included as space to relax and play, and ecological benefits such as reduction in water, air and noise pollution.

4.31 *Source Control Components*

- *Permeable Pavement*.
  Given the nature of the proposed development, including the provision of hardstanding areas to be used as public realm, access, etc. the use of permeable paving is deemed **appropriate**.

- *Green Roofs.*
  Options to attenuate at roof level have been looked into and are considered **suitable** based on the proposed development layout, providing reduction of the volume of runoff and attenuating peak flows. In addition, it includes visual benefit and ecological value.

However concerns have been raised about the effectiveness of green roofs once saturated.

- *Rainwater Harvesting*.
  Rainwater from roofs can be stored and used in and around properties. The collected water can be used potentially for a range of non-potable purposes. Rainwater systems may be able to provide potable water, but this is likely to require sophisticated and expensive water treatment systems and monitoring to ensure compliance with the Private Water Supplies Regulations 1991. Furthermore, demonstrating satisfactory attenuation through the provision of rainwater harvesting would be difficult due to the need to ensure storage availability during a storm event. Hence, this option is **dismissed**.

4.32 *Swales*

This type of SuDS technique is well considered to convey and treat water runoff. Nevertheless, there is insufficient space within the proposed layout to practicable offer these features as viable SuDS option, and as such they are deemed **unsuitable**.

4.33 *Rills and channels*

This SuDS technique is an excellent choice as part of the SuDS management train to convey the runoff water into further SuDS features due to its appealing visual features in urban landscapes, amenity value and effectiveness to treat pollution in water, acting as pre-treatment to remove silt. Therefore they are considered **suitable**.

4.34 *Bioretention Systems*

- *Rain Gardens.*
  Runoff water from hardstanding surfaces can be intercepted or attenuated through this SuDS technique whereby the water is infiltrated or taken up the plants. Besides this, other amenity benefits are included as space to relax and play and ecology benefits such as reduction in water, air and noise pollution. Therefore, lined Rain Gardens (in planters) are deemed an **appropriate** SuDS option.

4.35 *Retention and Detention Components*

- *Geocellular Systems*.
  This SuDS option can be tailored for any place owing to its modular nature to store and it is able to attenuate the water runoff, being used either as a soakaway or as a storage tank. Thus this SuDS technique is deemed to be **appropriate**.

- *Retention Ponds* and *Detention Basins*.
  They cannot be considered as a SuDS option for this site owing to the fact that they are appropriate to manage high volumes of surface water from bigger sites as a neighbourhood or even more. Given the scale of the development these are deemed **unsuitable**.

Consequently, several SuDS components are deemed appropriate. It is suggested to use a SuDS train formed by ***Soakaways***, ***Permeable Pavement*** and ***Bioretention Systems*.** Due to the good conditions of the soil for infiltration and following the hierarchy line stated in the section 3.32, it is suggested to set up Soakaways for each property at a distance of 5 metres from the building outline. While the arising runoff from the hardstanding areas will be conveyed through appropriate landscaping or Channels/Rills to the proposed Permeable Pavement located on the access roads on the site to be stored and drained into the sub-soil via the Permeable Pavement. See *Appendix 4, Figure 1 – Preliminary Drainage Strategy Layout.*

4.36 Preliminary calculations have been carried out based on the guidance of *CIRIA 753 – 'The SuDS Manual'* for infiltration systems sizing. Hence, several storm durations for the Return Periods 30 and 100 years plus an allowance of 30% as Climate Change (100+cc) have been populated in the following equation to obtain the maximum depth for an Infiltration:

$$h_{max} = a\left[e^{(-bD)} - 1\right]$$

$$a = \frac{A_b}{P} - i\frac{A_D}{Pq}$$

$$A_b = \frac{Pq}{nA_b}$$

Where

h_{max}: Maximum Depth of water in an Infiltration Device.

D: Duration of the rainfall (hours).

n: Porosity.

A_D: Area to be drained (m^2).

A_b: Area Base of the Infiltration Device (m^2).

P: Perimeter of the Base of the infiltration System (m).

i: Rainfall Intensity (m/h) for the Return Periods 30 and 100 +cc years.

q: Infiltration Coefficient Adjusted (m/h).

Equation 3 – Maximum Depth of water for Plane Infiltration Systems. (Source CIRIA 753 'The SuDS Manual').

4.37 The chosen filter material to fill the Infiltration Device was *Clean Stone*. The Effective Porosity, n_{eff}, of this material is 0.5.

4.38 In order to calculate the depth of the soakaways, the buildings were classified into 4 types based on approximations of their size area:

- Type A: 150 m^2
- Type B: 115 m^2

- Type C: 185 m^2
- Type D: 230 m^2
- Type E: 295 m^2

4.39 The Results are shown in Table 4 below.

SOAKAWAYS SUMMARY				
Building Type	Building Area (m^2)	Area Soakaway (m^2)	Depth (m)	Time for Half-Emptying
A	150	16	1.43	7.05 h
B	115	14	1.34	6.90 h
C	185	16	1.71	7.91 h
D	235	20	1.77	8.50 h
E	295	22	1.12	7.27 h

Table 4 – Soakaways Summary

4.40 Design of the *Soakaways* and best choice for the proposed development must be stated at the later detailed design by a specialist consultant on this matter and to be redesigned if it is required. Besides this, guidance about proper use and private maintenance must be provided.

4.41 The soakaway will deal with runoff from the proposed building roofs. The attenuation volume for these areas is approximately 350m^3. As such the remaining attenuation volume, and long term storage volume and interception volume (744m^3) will be managed by permeable paving and the Bioretention System.

4.42 The Permeable Paving will be Type A, and would be formed by 3 layers:

- Permeable Concrete blocks at the top.
- Laying Course Material.
- Sub-Base formed of a Geocellular System.

4.43 See Figure 4 below:

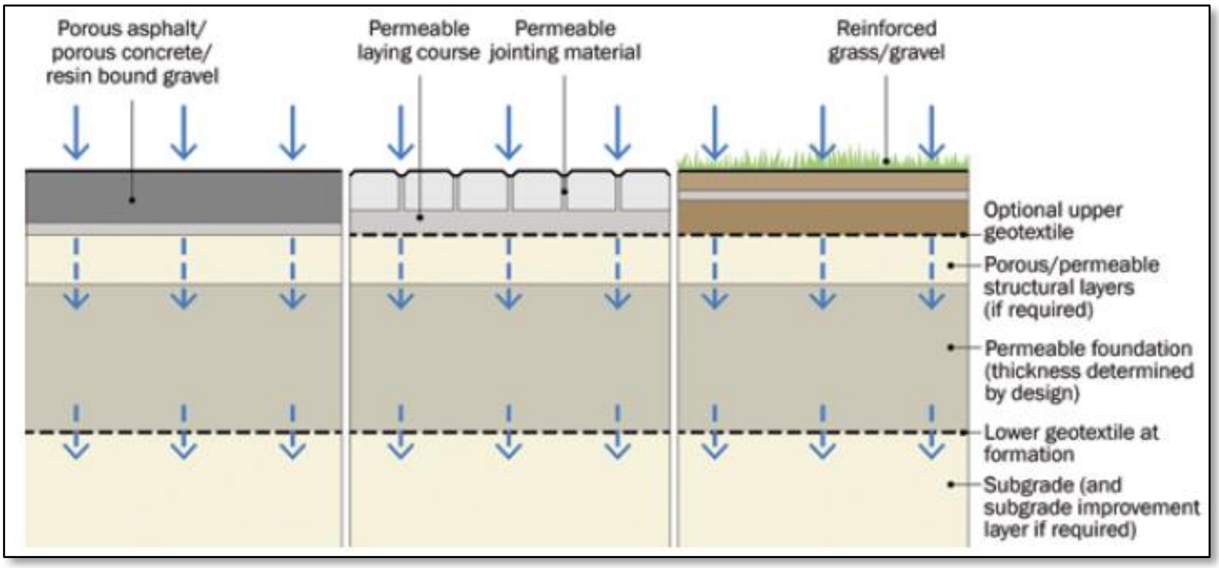


Figure 4 – Typical Section of a Permeable Pavement – Type A (Total Infiltration) (Source: SuDS CIRIA Manual

4.44 Following guidance of *CIRIA 753 – 'The SuDS Manual'* for plane infiltration systems sizing, preliminary calculations have been carried out for permeable pavement sizing. Hence, several storm durations for the Return Periods 30 and 100 years plus an allowance of 30% as Climate Change (100+cc) have been populated in the following equation to obtain the maximum depth for an Infiltration:

$$h_{max} = \frac{D}{n}(Ri - q)$$

Where

h_{max}: Maximum Depth of water in an Infiltration Device.

D: Duration of the rainfall (hours).

n: Porosity.

A_D: Area to be drained (m^2).

A_b: Area Base of the Infiltration Device (m^2).

R: Relation between A_D and A_b.

i: Rainfall Intensity (m/h) for the Return Periods 30 and 100 +cc years.

q: Infiltration Coefficient Adjusted (m/h).

Equation 4 – Maximum Depth of water for Plane Infiltration Systems. (Source CIRIA 753 'The SuDS Manual').

4.45 As aforementioned, the *Long-term storage* is required to address the additional runoff caused by the development compared to the volume that would be contributed from the site in its Greenfield state. It is based in a 100 year, 6 hours storm event plus climate change (30%). Preliminary calculations show that this volume is $0m^3$.

4.46 The capacity of the storage of the Permeable Paving must be sufficient to store the part of the Attenuation Volume. Preliminary calculations indicate that the $2309m^2$ of permeable paving, based on a sub-base of Geocellular Systems with a standard 360mm thickness would be enough to provide approximately 749m^3 of storage, enough to deal with the arising runoff from the hardstanding areas (4419m^2). The estimated remaining attenuation volume, long term storage volume and interception volume for the site is 744m^3. The Permeable Paving system will be able to deal with the remaining storage volume, the Bioretention system will also provide a small additional increase in on-site storage capacity. See *Appendix 4, Plan 1 – Preliminary Drainage Strategy Layout.*

4.47 To ensure that infiltration devices are not present within 5m of a building the permeable paving area to the south of the proposed road will be lined with runoff attenuated before being drained at a controlled rate to the permeable paving (Type A) to be infiltrated into the surrounding soil. Alternatively, this area of lined permeable paving could be replaced with standard black top surface, and runoff from these areas conveyed to the permeable paving via Channels/Rills or drains to be infiltrated into the surrounding sub soil. *See Appendix 4, Plan 1 – Preliminary Drainage Strategy Layout.*

4.48 The base area of the Permeable Pavement is approximately 2309m^2. This keeps the relation 2:1 with rest of the impervious surfaces areas (hardstanding surfaces) draining to the system, calculated to be 4419m^2. It is recommended to set up an outflow pipe connected to the existing drainage system should the drainage system reach capacity.

4.49 This has been confirmed to be sufficient for the loads of the site with maximum axle loads being 2000 kg due to the fact that the use of the road is light. See *Appendix 4, Figure 1 - Preliminary Drainage Strategy Layout*.

4.50 It is recommended to set up overflow pipes on the permeable paving system connected to the existing drainage infrastructure, to ensure that the permeable paving system does not exceed capacity.

4.51 The site has been shown to lie over vulnerable groundwater, as such runoff from driveways on the southern side of the road should be conveyed via appropriate landscaping or Channels/Rills to Bioretention systems to provide treatment before entering the permeable paving and being infiltrated into the surrounding soil. Runoff from driveways on the northern side should be conveyed to drains via Channels/Rills or appropriate landscaping to be treated via oil interceptors before entering the permeable paving system See *Appendix 4, Plan 1 – Preliminary Drainage Strategy Layout.*

4.52 This scheme is subject to the groundwater table depth, thus this layout could be modified and updated in the later detailed design stage. If Infiltrations techniques were not feasible it is suggested to collect, convey and discharge the arising water runoff to the drainage infrastructure associated with the existing farm at a controlled discharge rate.

4.53 Calculations and the design of the SuDS devices must be reviewed in the later detailed design stage and to be redesigned if required.

4.54 As such this SuDS management train has been designed to accommodate and dispose of runoff from storms up to and including the 1:100 year + 30% climate change event without flooding

Design Exceedance

4.55 In the event of drainage system failure under extreme rainfall events or blockage, flooding may occur within the site. In the event of the extension's drainage system failure, the runoff flow will be dictated by topography on site. This will not impact on the site or nearby dwellings. It is recommended that the ground floor of the proposed buildings are raised a minimum of 300mm above ground level to mitigate against any extreme surface water flows. See *Appendix 4, Plan 1 - Preliminary Drainage Strategy Layout*.

Water Quality

4.56 Adequate treatment must be delivered to the water runoff to remove pollutants through SuDS devices which are able to provide pollution mitigation. Pollution Hazards and the SuDS Mitigation have been indexed in the specialized literature *CIRIA 753 'The SUDS Manual'*. This is determined by the following restriction:

$$Total\ SuDS\ Mitigation\ Index\ \geq Pollution\ Hazard\ Index$$

4.57 The Pollution Hazard Indices are summarized in *Table 4 – Summary of Pollution Hazard Indices for different Land Use* overleaf:

POLLUTION HAZARD INDICES FOR DIFFERENT LAND USE CLASSIFICATIONS				
LAND USE	Pollution Hazard Level	Total suspended Solids (TSS)	Metals	Hydrocarbons
Roofs	Very Low	0.2	0.2	0.05
Individual property driveways, residential car parks, low traffic roads (eg cul de sacs, home zones and general access roads) and non-residential car parking with infrequent change (eg schools, offices) ie < 300 traffic movements/day	Low	0.5	0.4	0.4

Table 5 – Summary of Pollution Hazard Indices for different Land Use.

4.58 The Mitigation Indices of the proposed SuDS techniques are summarized in the *Table 5 - Indicative SuDS Mitigation Indices* below:

INDICATIVE SuDS MITIGATION INDICES FOR DISCHARGES TO GROUNDWATER			
SuDS Component	Total suspended Solids (TSS)	Metals	Hydrocarbons
Bioretention Systems	0.8	0.8	0.8
Permeable Pavement	0.7	0.6	0.7
Soakaway	0.4	0.4	0.4

Table 6 – Indicative SuDS Mitigation Indices

4.59 *Table 6 – Pollution Treatment* below, summarizes the water treatment for each zone:

POLLUTION HAZARD TREATMENT					
LAND USE	Treatment	Pollution Hazard Level	Total suspended Solids (TSS)	Metals	Hydrocarbons
Roofs	Soakaway	Very Low	0.2<0.4	0.2<0.4	0.05<0.4
Access Road / Car Park	Permeable Pavement	Very Low	0.5<0.7	0.4<0.6	0.4<0.7
	Bioretention Systems	Very Low	0.5<0.8	0.4<0.8	0.4<0.8
Pedestrian Accesses	Permeable Pavement	Very Low	0.5<0.7	0.4<0.6	0.4<0.7
	Bioretention Systems	Very Low	0.5<0.8	0.4<0.8	0.4<0.8

Table 7 – Pollution Treatment

4.60 Thus, the water treatment provided by this SuDS train is enough to remove the pollutants.

Adoption and Maintenance

4.61 All onsite SuDS and drainage systems will be privately maintained. A long term maintenance regime should be agreed with the site owners before adoption. In addition to a long term maintenance regime it is recommended that all drainage elements implemented on site should be inspected following the first rainfall event post construction and monthly for the first quarter following construction.

5. Conclusions

5.1 The existing site is considered developed, runoff from the proposed development is to be managed in accordance with the sustainable drainage principles.

5.2 Surface water will be managed as close to the source as possible, in line with the drainage hierarchy provided by the specialized literature *CIRIA 753 'The SUDS Manual', Section 3.2.3*:

"The destination for surface water runoff that is not collected to be used must be prioritised in the following order:

1. *Infiltration*
2. *Discharge to surface waters*
3. *Discharge to a surface water sewer, highway drain or another drainage system*
4. *Discharge to a combined sewer*

Discharge to a foul sewer should not be considered as a possible option.

(…)".

5.3 The proposed development will increase the impermeable surface cover on the site by 6653m^2. Due to the nature of the geology underlying the site and following the hierarchy line, it is proposed that runoff from the site is to be discharged via infiltration systems to the surrounding subsoil.

5.4 It is essential that an Infiltration Coefficient of the soil is checked through trial pit infiltration tests on-site prior to the final detailed drainage design being carried out. Besides this, it is advised that a groundwater level check be undertaken at the later detailed design stage.

5.5 This drainage strategy proposes the following SuDS devices to deal with the surface water runoff from the proposed impervious zones. It is proposed to use a SuDS train management composed by ***Bioretention Systems***, ***Permeable Paving***, *and* ***Soakaways***. It is proposed to use a ***Geocellular System*** as sub-base of the proposed *Permeable Pavement*. See *Appendix 4, Plan 1 - Preliminary Drainage Strategy Layout*.

5.6 The permeable pavement will be formed by these 3 layers:

- Permeable Concrete blocks at the top.
- Laying Course Material.
- Sub-Base: Geocellular System.

5.7 Water runoff from the access roads and hardstanding will be collected and conveyed to the sub-base of the *Permeable Pavement* to be stored and gradually infiltrated into the ground. It is recommended that an overflow pipe is connected to the existing drainage network to ensure the permeable paving system does not reach capacity. See *Appendix 4, Plan 1 – Preliminary Drainage Strategy Layout.*

5.8 The area of lined permeable paving could alternatively be replaced with standard black top impermeable surface, and runoff from these areas conveyed to the permeable paving via Channels/Rills or drains to be infiltrated into the surrounding sub soil.

5.9 These devices will be designed for a Critical Duration Storm, 100 year rainfall event plus 30% climate change allowance. Hence, they meet with the minimum standards required by the *DEFRA - Non-statutory technical standards for sustainable drainage systems (March 2015)* to avoid the flood risk within the development in a 1 in 100 year rainfall event.

5.10 As part of this surface water drainage strategy existing public sewers that may affect the site have not been considered. Nor has consultation been sort from the local water authorities with regards to the existing sewer system, nor has consultation been sort with regards to connection of site drainage to the existing sewer system. The developer should obtain this information and consent as part of a detailed site drainage design. Location of existing sewer lines across the site boundary should be obtained prior to any land cutting to inform any need for sewer protection on the site.

Design Exceedance

5.11 In the event of drainage system failure under extreme rainfall events or blockage, flooding may occur within the site. In the event of the extension's drainage system failure, the runoff flow will be dictated by topography on site. This will not impact on the site or nearby dwellings. It is recommended that the ground floor of the proposed buildings are raised a minimum of 300mm above floor level to mitigate against any extreme surface water flows.

Water Quality

5.12 Adequate treatment must be delivered to the water runoff to remove pollutants through SuDS devices which are able to provide pollution mitigation. Pollution Hazards and the SuDS Mitigation have been indexed in the specialized literature *CIRIA 753 'The SUDS Manual'*. This is determined by the following restriction:

$$Total\ SuDS\ Mitigation\ Index\ \geq Pollution\ Hazard\ Index$$

5.13 *The Table 6 – Pollution Treatment* overleaf, summarizes the water treatment for each zone:

POLLUTION HAZARD TREATMENT					
LAND USE	Treatment	Pollution Hazard Level	Total suspended Solids (TSS)	Metals	Hydrocarbons
Roofs	Soakaway	Very Low	0.2<0.4	0.2<0.4	0.05<0.4
Access Road / Car Park	Permeable Pavement	Very Low	0.5<0.7	0.4<0.6	0.4<0.7
	Bioretention Systems	Very Low	0.5<0.8	0.4<0.8	0.4<0.8
Pedestrian Accesses	Permeable Pavement	Very Low	0.5<0.7	0.4<0.6	0.4<0.7
	Bioretention Systems	Very Low	0.5<0.8	0.4<0.8	0.4<0.8

Table 6 – Pollution Treatment

Adoption and Maintenance

5.14 All onsite SuDS and drainage systems will be privately maintained. A long term maintenance regime should be agreed with the site owners before adoption. In addition to a long term maintenance regime it is recommended that all drainage elements implemented on site should be inspected following the first rainfall event post construction and monthly for the first quarter following construction.

5.15 This study has been undertaken in accordance with the principles set out in NPPF. We can conclude that providing the development adheres to the conditions advised in the conclusions of this report, the said development proposals can be accommodated without increasing flood risk within the locality in accordance with objectives set by Central Government and the EA.

The findings and recommendations of this report are for the use of the client who commissioned the assessment, and no responsibility or liability can be accepted for the use of the report or its findings by any other person or for any other purpose.

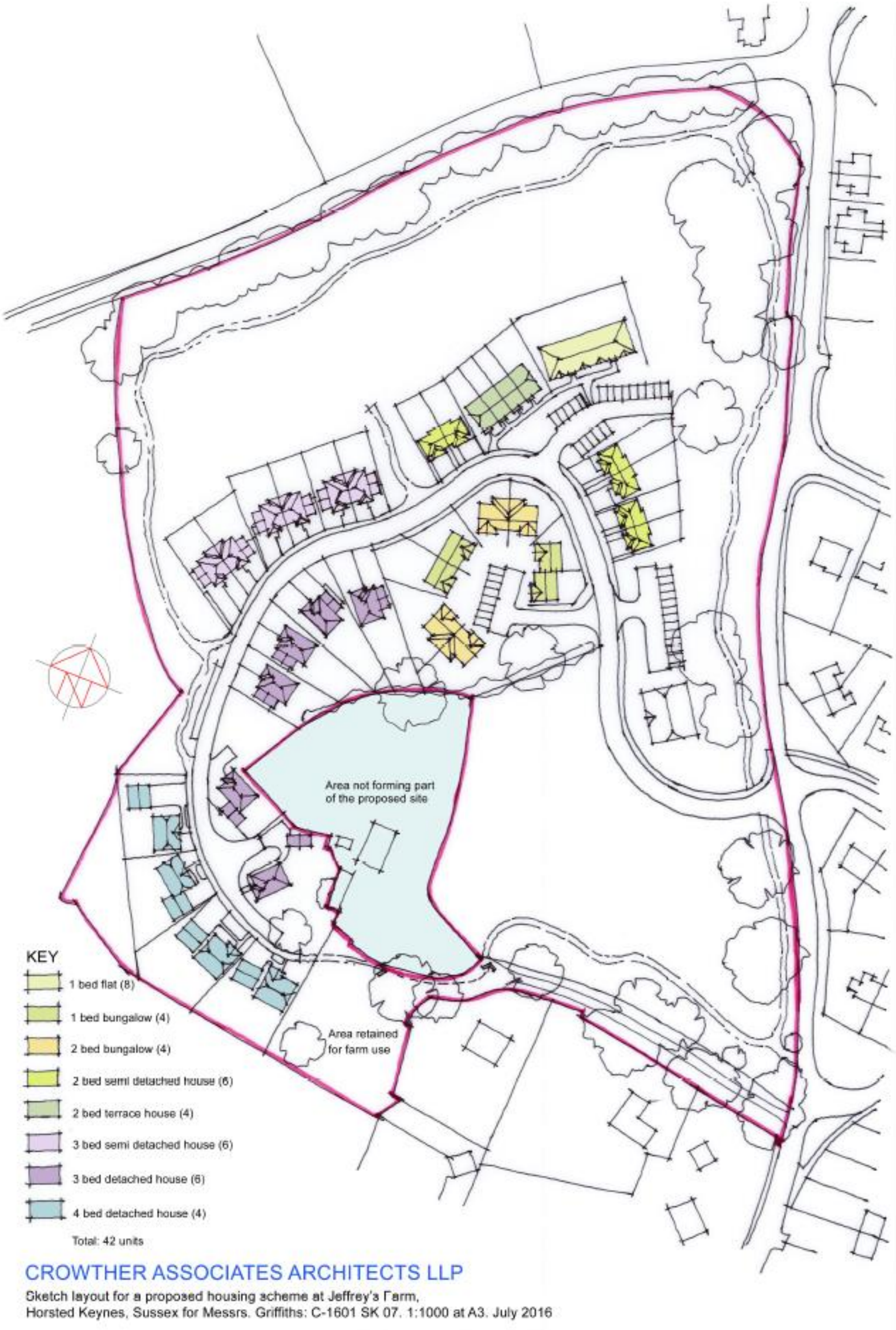
Dr. J. B. Butler
B.Sc., M.Phil., PhD.
Ambiental Technical Solutions Ltd. July 2016

Appendix 1 – Plans

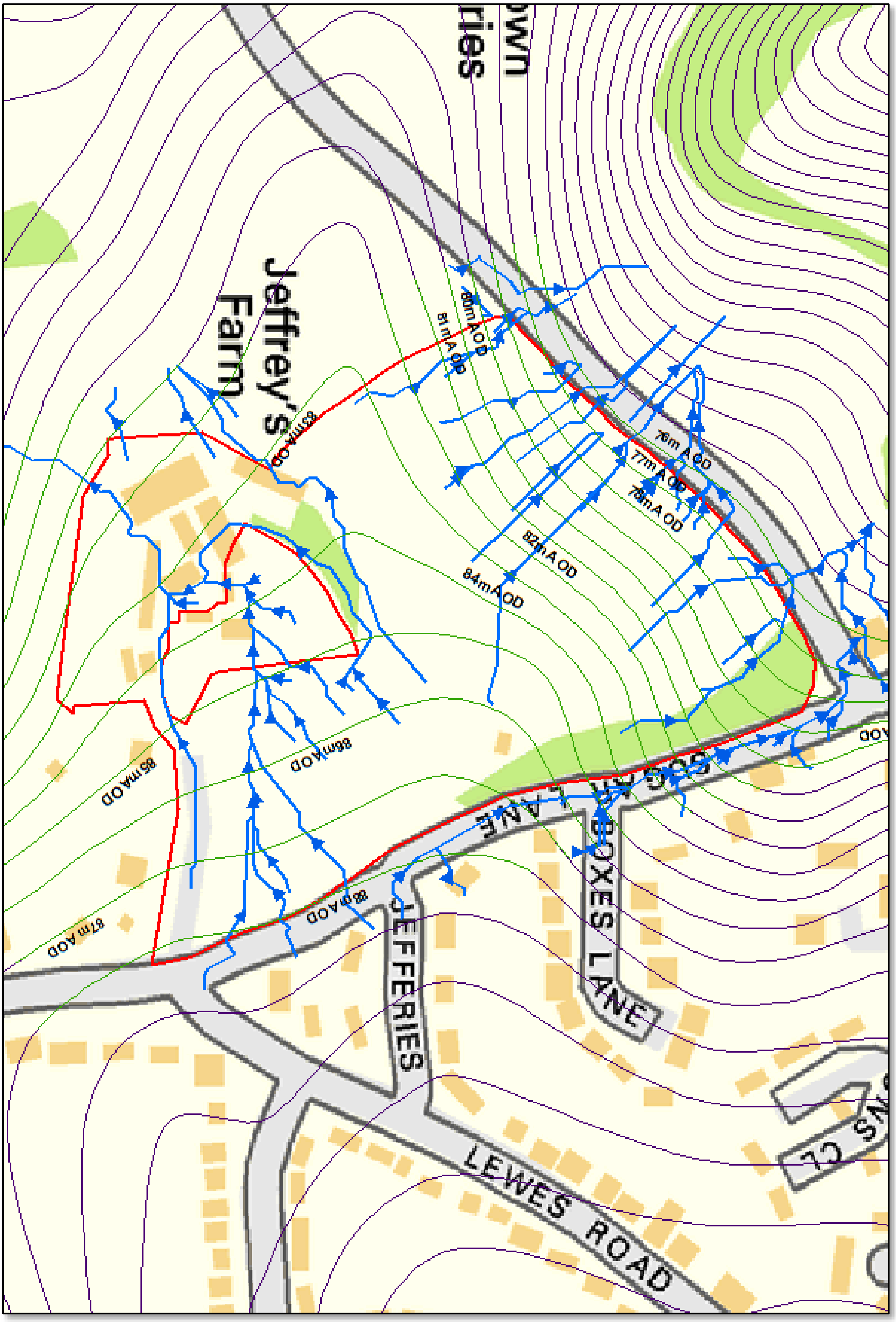
- *Appendix 1, Plan 1 – Site Location*
- *Appendix 1, Plan 2 – Proposed Site Location Plan*
- *Appendix 1, Plan 3 – Existing Flow Direction*

Promap

Appendix 1, Plan 1 – Site Location



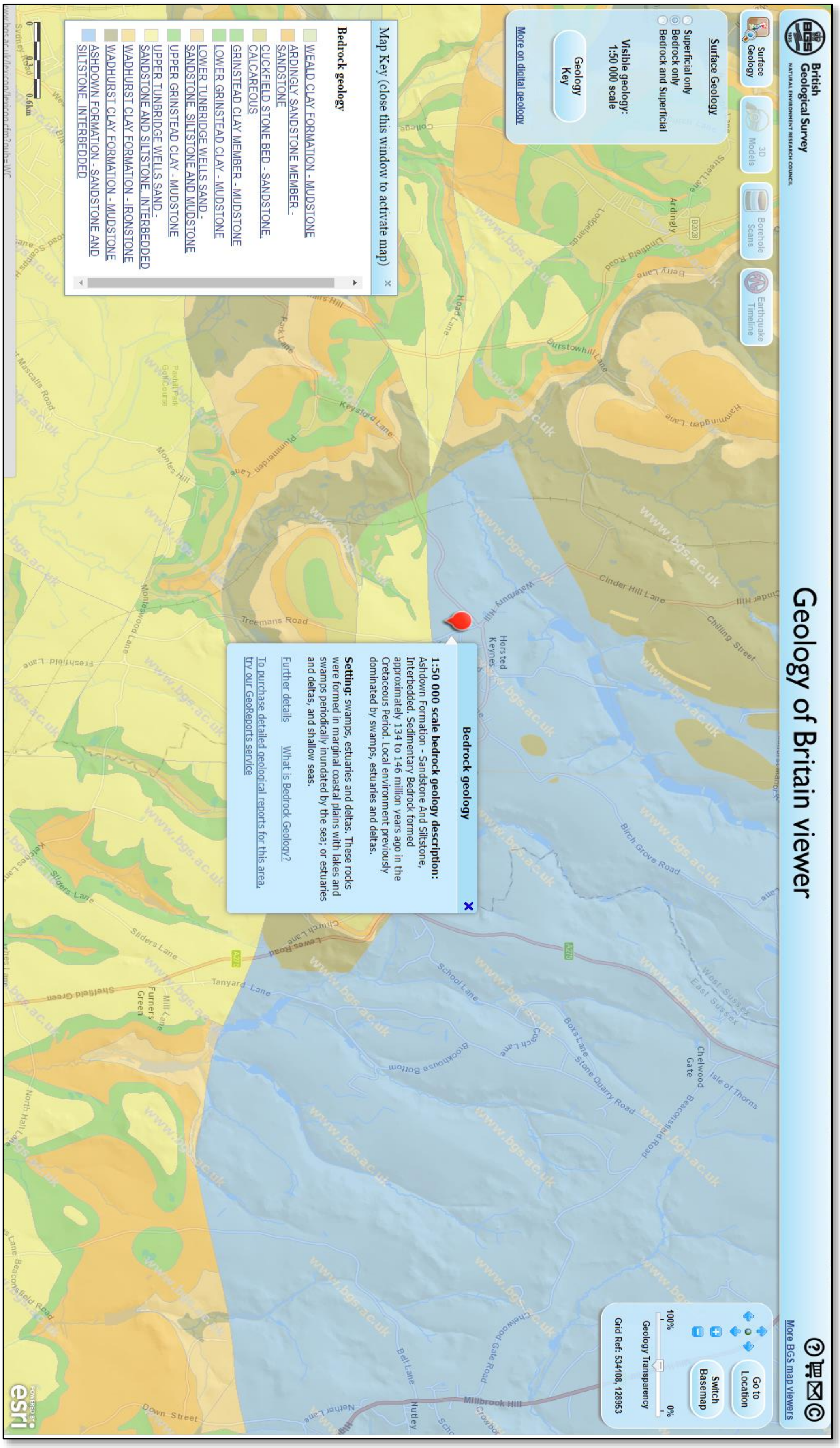
Appendix 1, Plan 2 – Proposed Site Location Plan



Appendix 1, Plan 3 – Existing Surface Water Flow Pathways

Appendix 2 – Site Geology Maps

- *Figure 1 – Bedrock Geology*
- *Figure 2 – Superficial Deposits*
- *Figure 3 – Soil Parental Material*
- *Figure 4 – Soil Texture*
- *Figure 5 – Hydrogeology*
- *Figure 6 – Groundwater Source Protection Zones*
- *Figure 7 – Groundwater Vulnerability Zones*



Appendix 2, Figure 1 - Bedrock Geology

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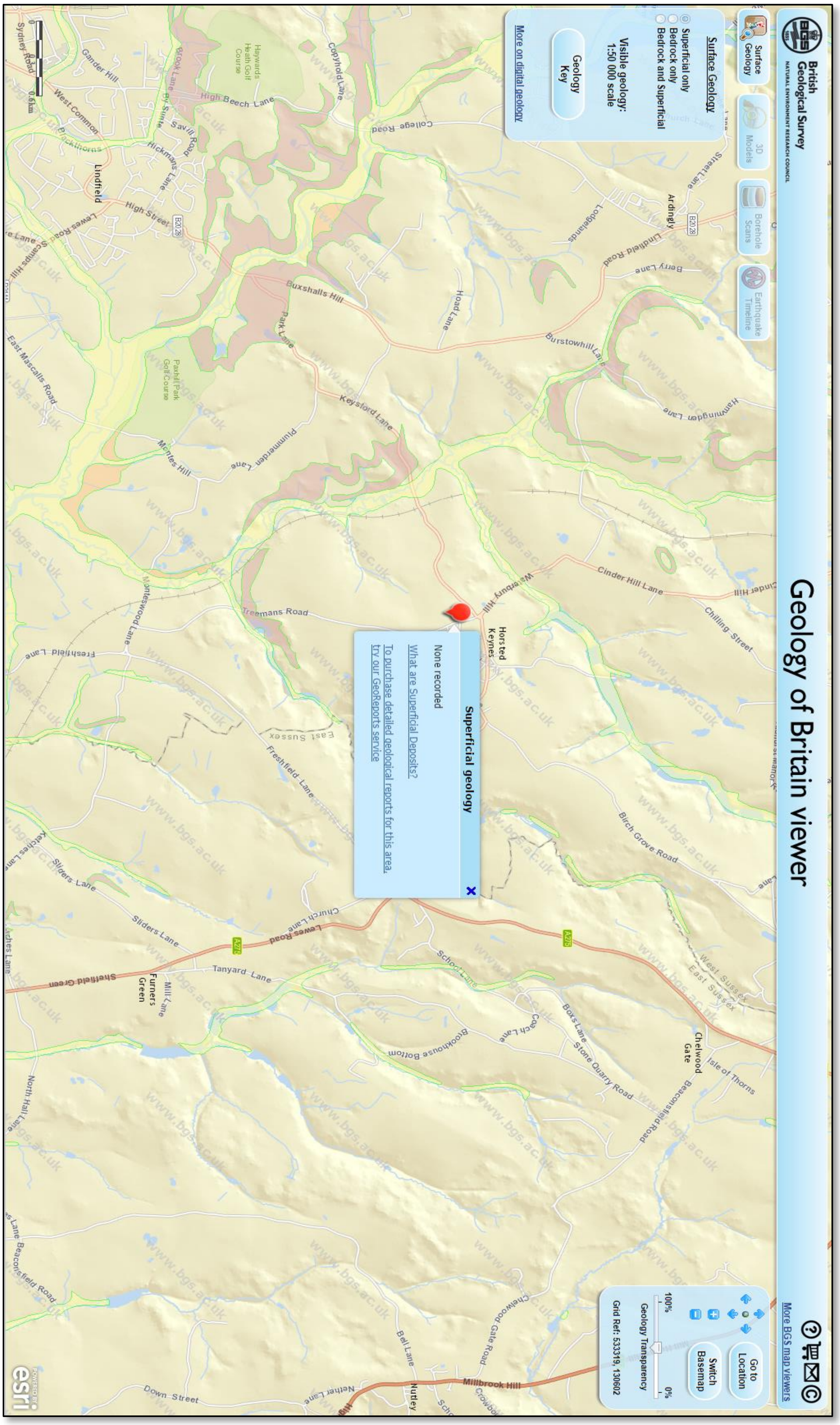
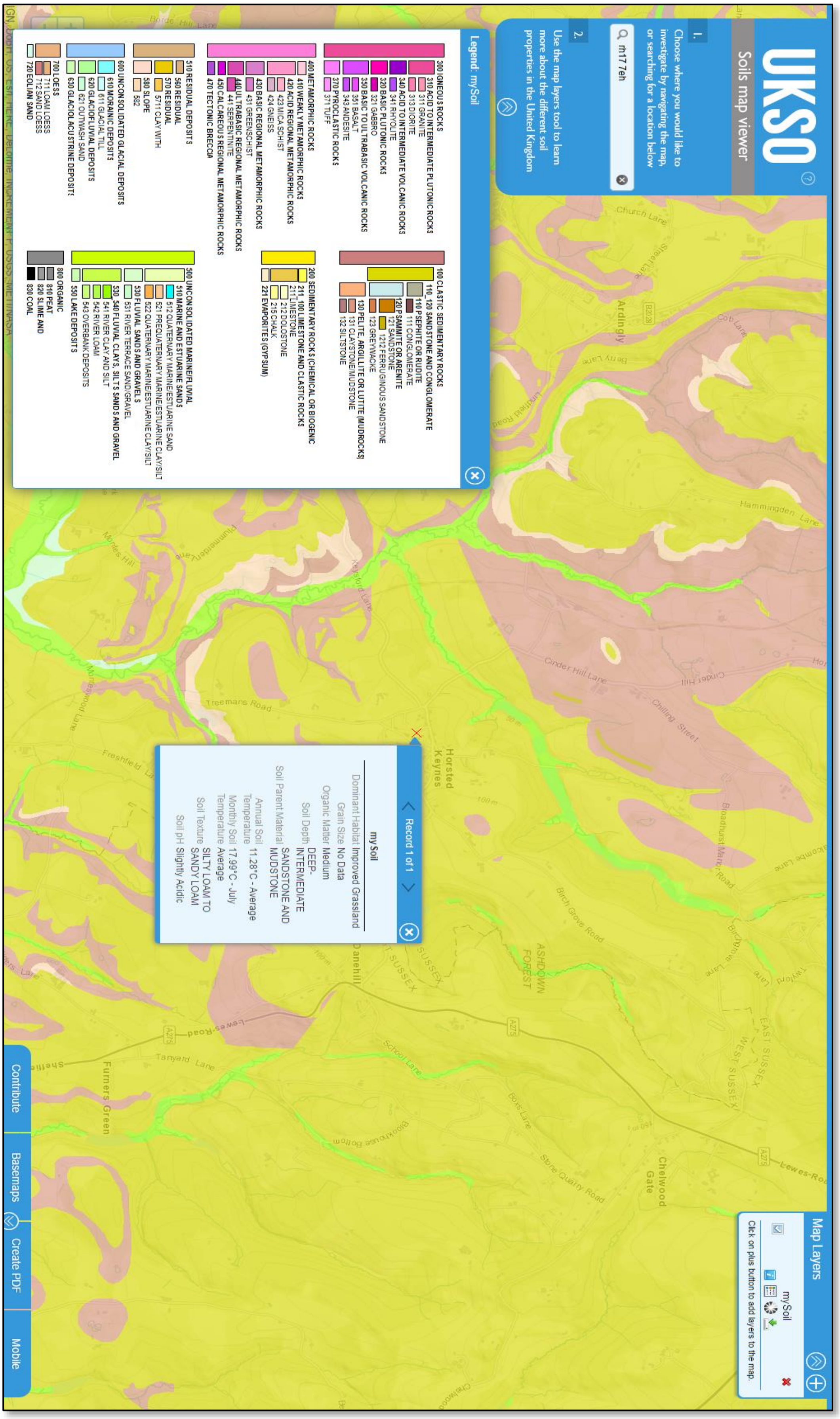
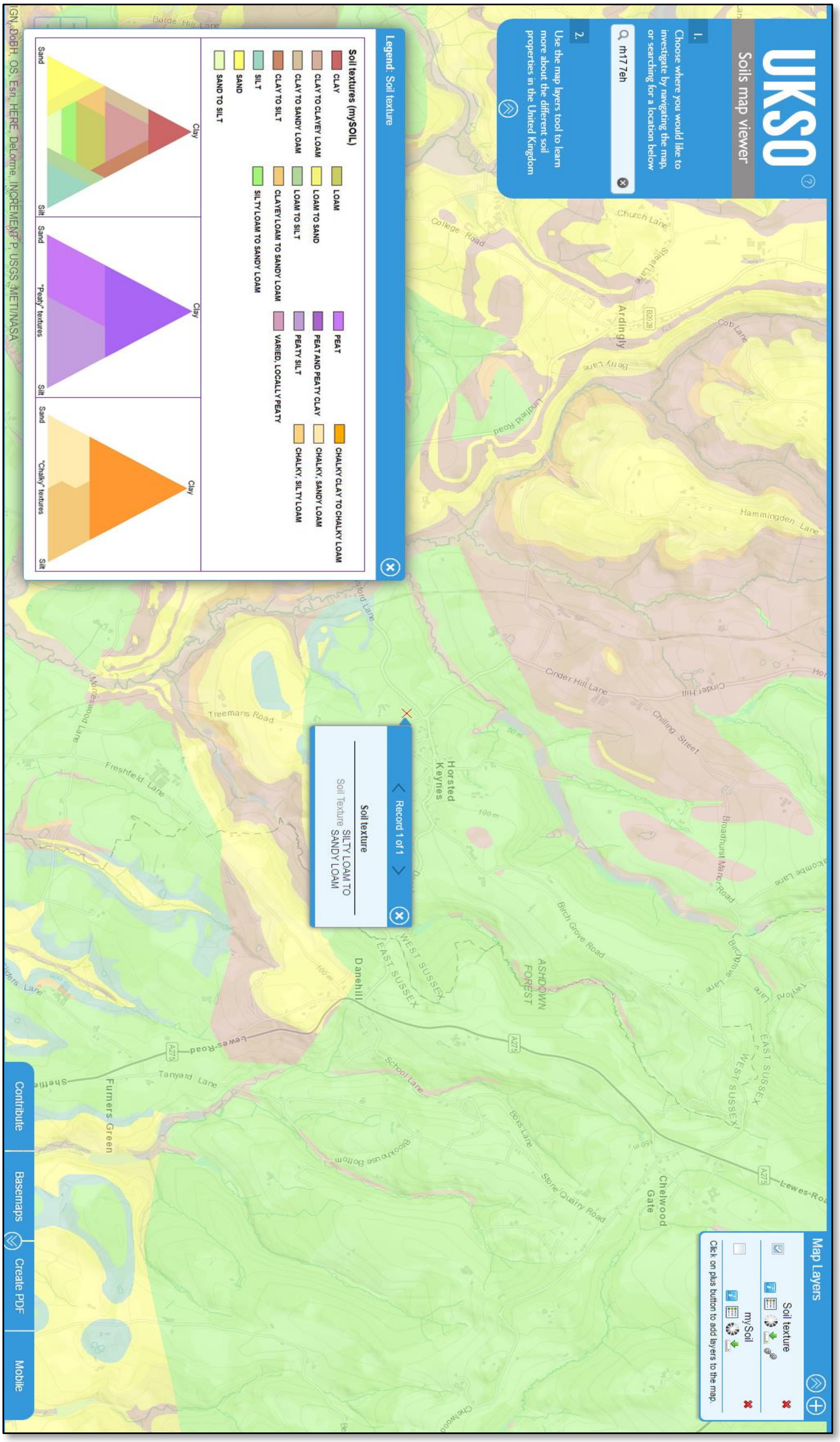


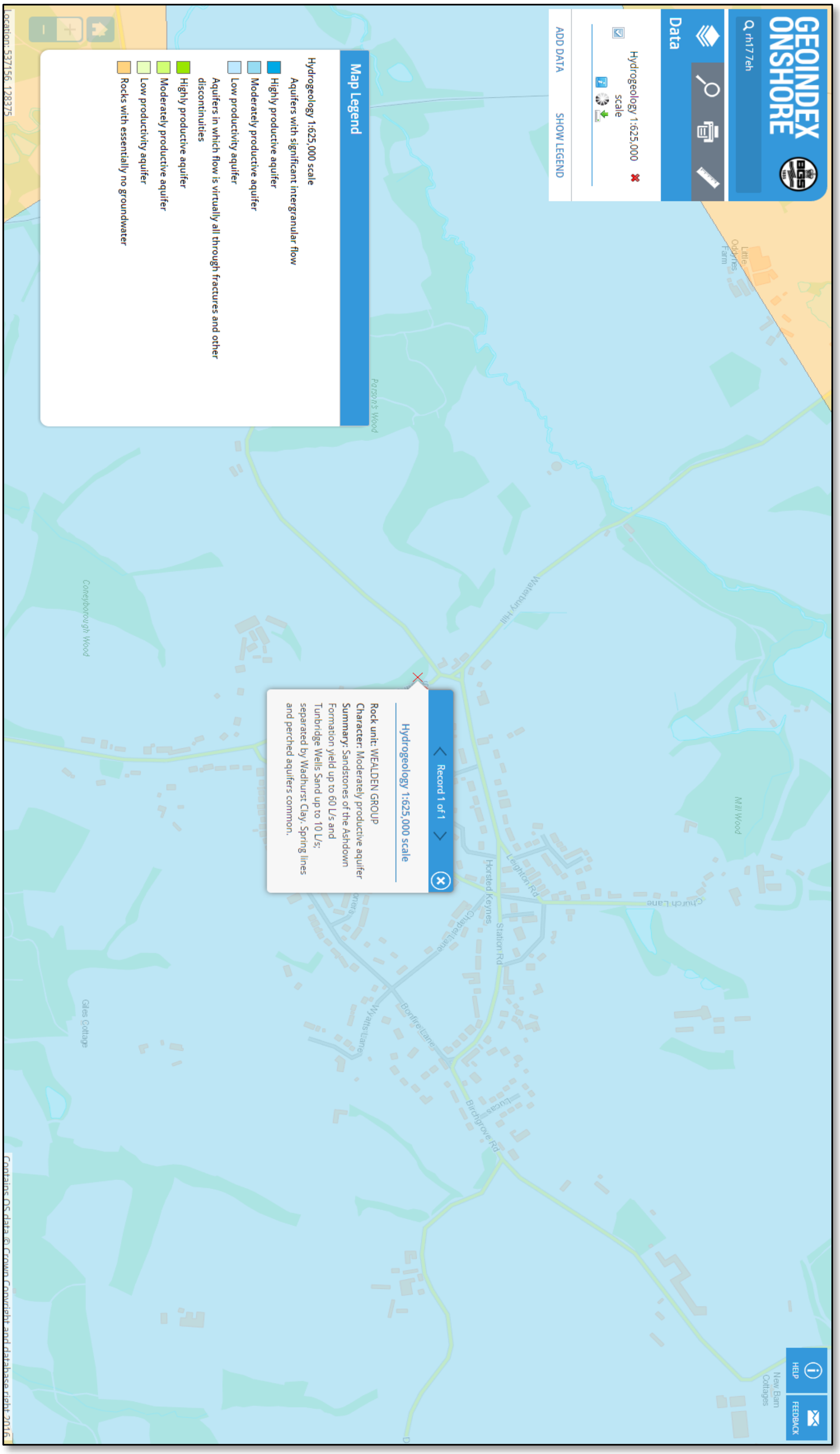
Appendix 2, Figure 2 - Superficial Deposits



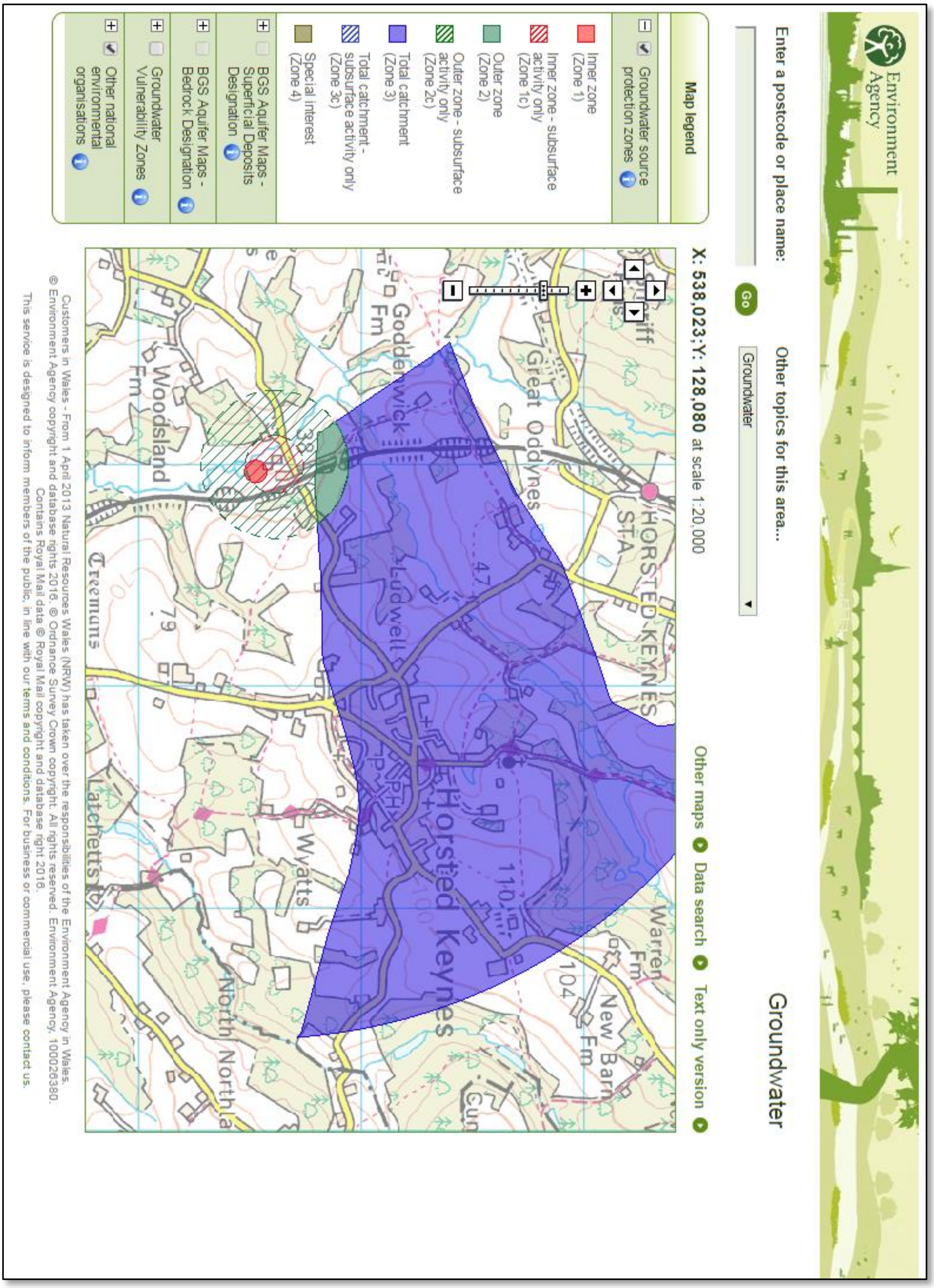
Appendix 2, Figure 3 - Soil Parental Material



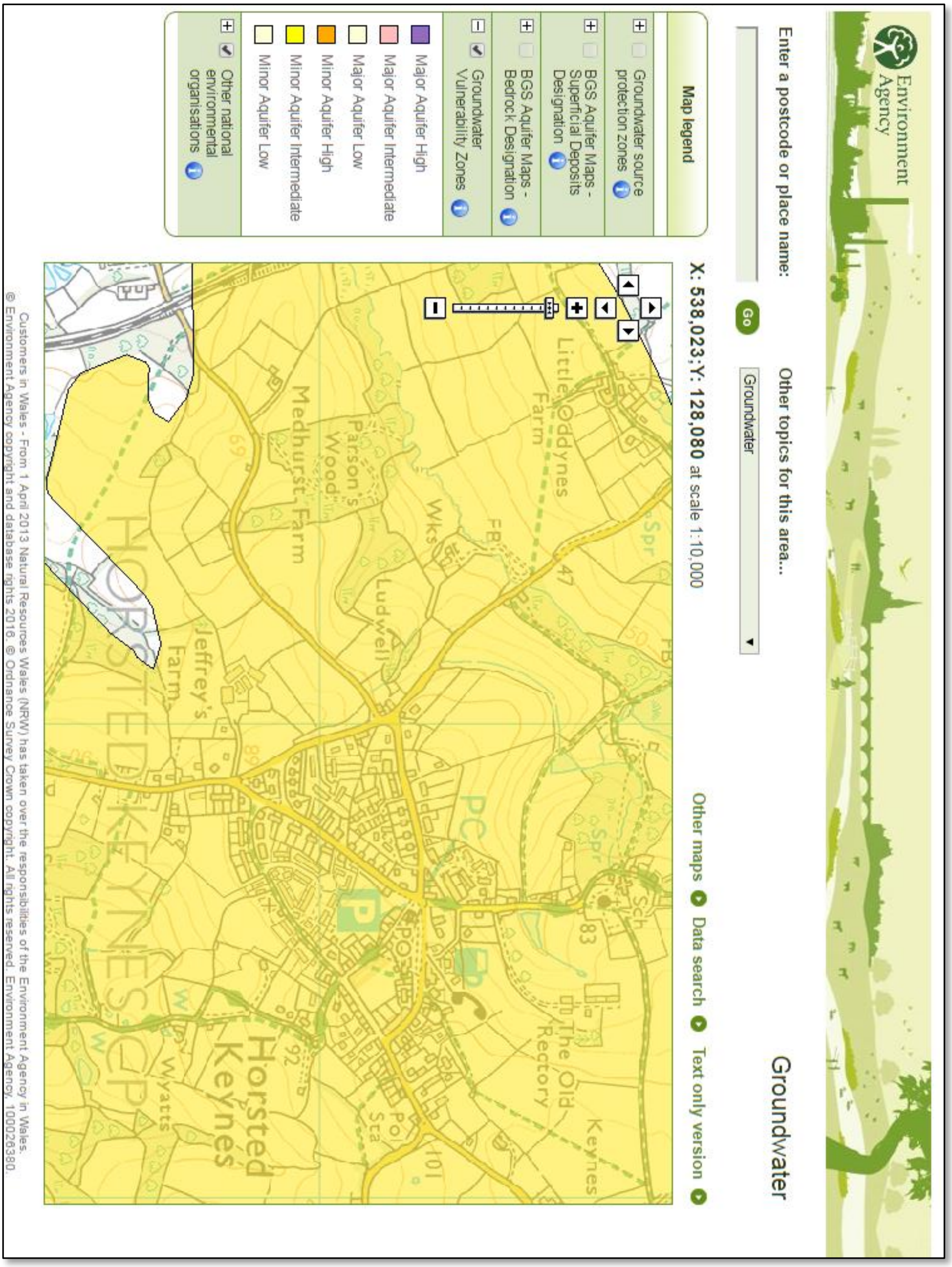
Appendix 2, Figure 4 – Soil Texture



Appendix 2, Figure 5 – Hydrogeology



Appendix 2, Figure 6 – Groundwater Source Protection Zones



Appendix 2, Figure 7 – Groundwater Vulnerability Zones

Appendix 3 – Calculations

- *Table 1 – Greenfield Runoff Rates Calculation Summary*
- *Table 2 – Summary of Attenuation Storage Estimation – 1 in 100 years + cc*
- *Graph 1 – Attenuation Storage Volume required for site estimated for Critical Duration (m^3 per m^2)*
- *Table 3 – Soakaway Summary Table: Preliminary Calculations Type A*
- *Table 4 – Soakaway Summary Table: Preliminary Calculations Type B*
- *Table 5 – Soakaway Summary Table: Preliminary Calculations Type C*
- *Table 6 – Soakaway Summary Table: Preliminary Calculations Type D*
- *Table 7 – Soakaway Summary Table: Preliminary Calculations Type E*

GREENFIELD RUNOFF RATES CALCULATION SUMMARY		
PARAMETERS		
Catchment Area	52416.61 m^2	5.24 ha
Open Public Space	26282.10 m^2	2.63 ha
Area Positively Drained	26134.51 m^2	261 ha
SAAR (mm)	853 mm	
SOIL	3	
SPR	0.37	
$Q_{BAR,rural}$ (l/s) for 50 Ha	**181.02 l/s**	
Hydrological Region	7	
Growth Curve Factor 1 year	0.85	
Growth Curve Factor 30 year	2.46	
Growth Curve Factor 100 year	3.19	
Return Period	**Greenfield Runoff per Hectare (l/s·ha)**	
QBAR	3.19	
1	3.08	
30	8.91	
100	11.55	
Return Period	**Greenfield Runoff (l/s)**	
QBAR	9.46	
1	8.04	
30	23.28	
100	**30.18**	

Appendix 3, Table 1 – Greenfield Runoff Rates Calculation Summary

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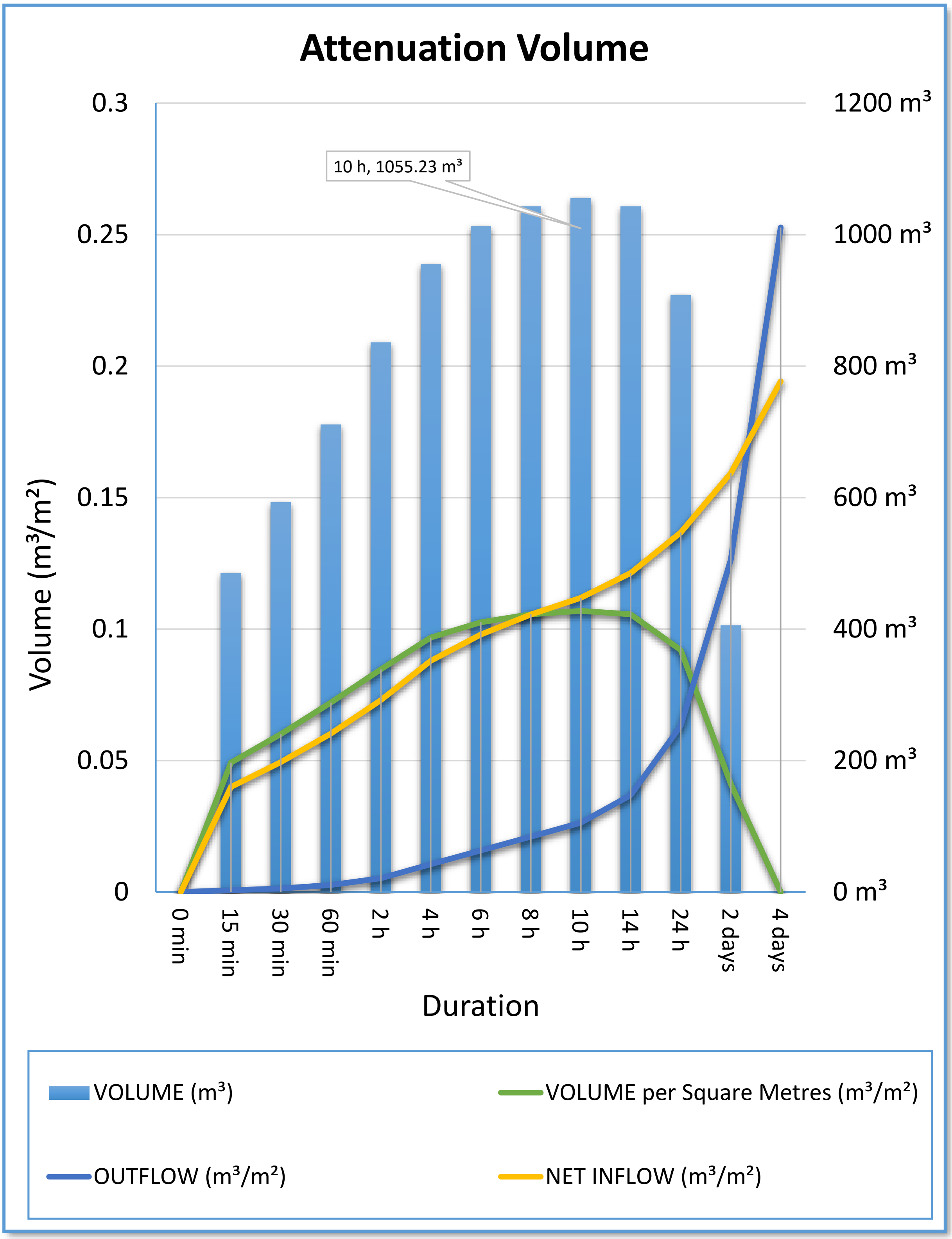
Storm Duration	RAINFALL DEPTH (mm)		NET INFLOW (l/m²)		OUTFLOW (l/m²)	VOLUME (m³/m²)	
	RETURN PERIOD		RETURN PERIOD			RETURN PERIOD	
	100 years	100 yr + CC (30%)	100 years	100 yr + CC (30%)		100 yr + CC (30%)	100 yr + CC (30%) Adjustment (+25%)
0					0.00		
15 min	30.76	39.99	24.62	33.85	0.66	0.0332	0.0415
30 min	37.96	49.35	31.82	43.21	1.32	0.0419	0.0524
60 min	46.34	60.24	40.20	54.10	2.63	0.0515	0.0643
2 h	56.15	73.00	50.01	66.85	5.27	0.0616	0.0770
4 h	67.66	87.96	61.52	81.82	10.53	0.0713	0.0891
6 h	75.3	97.89	69.16	91.75	15.80	0.0760	0.0949
8 h	81.19	105.55	75.05	99.40	21.06	0.0783	0.0979
10 h	86.04	111.85	79.90	105.71	26.33	0.0794	**0.0992**
14 h	93.35	121.36	87.21	115.21	36.86	0.0784	0.0979
24 h	105.21	136.77	99.07	130.63	63.18	0.0674	0.0843
48 h	122.49	159.24	116.35	153.09	126.37	0.0267	0.0334
4 days	149.41	194.23	143.27	188.09	252.74	-0.0646	No storage required

Appendix 3, Table 2 – Summary of Attenuation Storage Estimation – 1 in 100 years + cc



Appendix 3, Graph 1 – Attenuation Storage Volume required for site estimated for Critical Duration (m^3 per m^2)

SOAKAWAY SUMMARY TYPE A			
GEOMETRY			
Soakaway			
Perimeter		16.00 m	
Total			
SOAKAWAY BASE AREA (m^2)		16.00 m^2	
Effective depth, D_{eff} (m)		1.34 m	
PARAMETERS			
EFFECTIVE POROSITY		0.5	
Infiltration Coefficient, q (m/h)		0.036	
Factor of Safety		1.5	
Infiltration Coefficient Corrected, q (m/h)		0.024	
AREA TO BE DRAINED			
Contributing Area (m^2)		150.00	
Total Area (m^2)		52416.61	
DESIGN RAINFALL			
RAINFALL DEPTH (mm)		97.89	
DURATION (min)		360 min	
INTENSITY (m/h)		0.02	
Climate Change Factor		1.3	
Return Period (years)		100+CC	
Rainfall Duration		Intensity (mm/h)	Water Depth (m)
0.25 h	15 min	159.95	0.73
0.5 h	30 min	98.70	0.89
1 h	60 min	60.24	1.06
2 h	120 min	36.50	1.21
4 h	240 min	21.99	1.33
6 h	360 min	16.32	1.34
10 h	600 min	11.19	1.28
24 h	1440 min	5.70	0.84
RESULTS			
Maximum Water Depth (m)		1.3445 m	
Time for half-emptying (h)		7.04 h	
Storage Volume (m^3)		10.76 m^3	

Appendix 3, Table 3 – Soakaway Summary Table: Preliminary Calculations Type A

SOAKAWAY SUMMARY TYPE B			
GEOMETRY			
Soakaway			
Perimeter		18.00 m	
Total			
SOAKAWAY BASE AREA (m^2)		14.00 m^2	
Effective depth, D_{eff} (m)		1.11 m	
PARAMETERS			
EFFECTIVE POROSITY		0.5	
Infiltration Coefficient, q (m/h)		0.036	
Factor of Safety		1.5	
Infiltration Coefficient Corrected, q (m/h)		0.024	
AREA TO BE DRAINED			
Contributing Area (m^2)		115.00	
Total Area (m^2)		52416.61	
DESIGN RAINFALL			
RAINFALL DEPTH (mm)		87.96	
DURATION (min)		240 min	
INTENSITY (m/h)		0.02	
Climate Change Factor		1.3	
Return Period (years)		100+CC	
Rainfall Duration		Intensity (mm/h)	Water Depth (m)
0.25 h	15 min	159.95	0.64
0.5 h	30 min	98.70	0.77
1 h	60 min	60.24	0.91
2 h	120 min	36.50	1.04
4 h	240 min	21.99	1.11
6 h	360 min	16.32	1.10
10 h	600 min	11.19	1.01
24 h	1440 min	5.70	0.57
RESULTS			
Maximum Water Depth (m)		1.1103 m	
Time for half-emptying (h)		5.64 h	
Storage Volume (m^3)		7.77 m^3	

Appendix 3, Table 3 – Soakaway Summary Table: Preliminary Calculations Type B

SOAKAWAY SUMMARY TYPE C			
GEOMETRY			
Soakaway			
Perimeter		16.00 m	
Total			
SOAKAWAY BASE AREA (m^2)		16.00 m^2	
Effective depth, D_{eff} (m)		1.72 m	
PARAMETERS			
EFFECTIVE POROSITY		0.5	
Infiltration Coefficient, q (m/h)		0.036	
Factor of Safety		1.5	
Infiltration Coefficient Corrected, q (m/h)		0.024	
AREA TO BE DRAINED			
Contributing Area (m^2)		185.00	
Total Area (m^2)		52416.61	
DESIGN RAINFALL			
RAINFALL DEPTH (mm)		97.89	
DURATION (min)		360 min	
INTENSITY (m/h)		0.02	
Climate Change Factor		1.3	
Return Period (years)		100+CC	
Rainfall Duration		Intensity (mm/h)	Water Depth (m)
0.25 h	15 min	159.95	0.91
0.5 h	30 min	98.70	1.10
1 h	60 min	60.24	1.31
2 h	120 min	36.50	1.52
4 h	240 min	21.99	1.68
6 h	360 min	16.32	1.72
10 h	600 min	11.19	1.67
24 h	1440 min	5.70	1.19
RESULTS			
Maximum Water Depth (m)		1.7167 m	
Time for half-emptying (h)		7.91 h	
Storage Volume (m^3)		13.73 m^3	

Appendix 3, Table 5 – Soakaway Summary Table: Preliminary Calculations Type C

SOAKAWAY SUMMARY TYPE D			
GEOMETRY			
Soakaway			
Perimeter		18.00 m	
Total			
SOAKAWAY BASE AREA (m^2)		20.00 m^2	
Effective depth, D_{eff} (m)		1.77 m	
PARAMETERS			
EFFECTIVE POROSITY		0.5	
Infiltration Coefficient, q (m/h)		0.036	
Factor of Safety		1.5	
Infiltration Coefficient Corrected, q (m/h)		0.024	
AREA TO BE DRAINED			
Contributing Area (m^2)		235.00	
Total Area (m^2)		52416.61	
DESIGN RAINFALL			
RAINFALL DEPTH (mm)		97.89	
DURATION (min)		360 min	
INTENSITY (m/h)		0.02	
Climate Change Factor		1.3	
Return Period (years)		100+CC	
Rainfall Duration		Intensity (mm/h)	Water Depth (m)
0.25 h	15 min	159.95	0.92
0.5 h	30 min	98.70	1.12
1 h	60 min	60.24	1.34
2 h	120 min	36.50	1.55
4 h	240 min	21.99	1.72
6 h	360 min	16.32	1.77
10 h	600 min	11.19	1.74
24 h	1440 min	5.70	1.28
RESULTS			
Maximum Water Depth (m)		1.7728 m	
Time for half-emptying (h)		8.50 h	
Storage Volume (m^3)		17.73 m^3	

Appendix 3, Table 6 – Soakaway Summary Table: Preliminary Calculations Type D

SOAKAWAY SUMMARY TYPE E			
GEOMETRY			
Soakaway			
Perimeter		22.00 m	
Total			
SOAKAWAY BASE AREA (m^2)		30.00 m^2	
Effective depth, D_{eff} (m)		1.12 m	
PARAMETERS			
EFFECTIVE POROSITY		0.5	
Infiltration Coefficient, q (m/h)		0.036	
Factor of Safety		1.5	
Infiltration Coefficient Corrected, q (m/h)		0.024	
AREA TO BE DRAINED			
Contributing Area (m^2)		235.00	
Total Area (m^2)		52416.61	
DESIGN RAINFALL			
RAINFALL DEPTH (mm)		97.89	
DURATION (min)		360 min	
INTENSITY (m/h)		0.02	
Climate Change Factor		1.3	
Return Period (years)		100+CC	
Rainfall Duration		Intensity (mm/h)	Water Depth (m)
0.25 h	15 min	159.95	0.61
0.5 h	30 min	98.70	0.74
1 h	60 min	60.24	0.88
2 h	120 min	36.50	1.01
4 h	240 min	21.99	1.11
6 h	360 min	16.32	1.12
10 h	600 min	11.19	1.07
24 h	1440 min	5.70	0.67
RESULTS			
Maximum Water Depth (m)		1.1229 m	
Time for half-emptying (h)		7.27 h	
Storage Volume (m^3)		16.84 m^3	

Appendix 3, Table 7 – Soakaway Summary Table: Preliminary Calculations Type E

Appendix 4 – Proposed Drainage Strategy

- *Figure 1 – Preliminary Drainage Strategy Layout*

Appendix 4, Plan 1 – Preliminary Drainage Strategy Layout

Appendix 5 – Information

Surface Water Runoff Calculation Method

Rainfall data has been extracted from the FEH CD-ROM for several storm duration events for a number of return periods, including 1:1.01 year, 1:10 year and 1:100 year storm events. These return periods are industry standard, however it is important to be aware that return periods less than 1:2 years are not considered reliable and should not be used in detailed design calculations.

The 1:100 year with an allowance for climate change has been based on a 30% increase to the 1:100 year rainfall intensity and not the rainfall depth. This is to provide the most conservative runoff rates for the site possible.

Greenfield runoff rates have been calculated using The Institute of Hydrology Report 124 Marshall and Bayliss, 1994 method, as recommended in the SuDs Manual CIRIA (C753). In keeping with standard practice, the calculations are based on calculating the Greenfield runoff rates for a 50 Ha site and then factored to account for the actual site size.

Impermeable runoff rates have been calculated using the Modified Rational Method for the impermeable surfaces on site only.

Throughout the calculations a weighted co-efficient has been used, allowing different materials of surface covering on site to be taken into account.

These runoff rates have then been combined to provide the most accurate runoff rate possible for both the existing and proposed site.