Client: F D Attwood & Partners

Flood Risk Assessment for the
Proposed Development at
Darland Farm, Chatham,
Kent

June 2016

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1 Background and Scope of Appraisal

Flooding is a major issue in the United Kingdom. The impacts can be devastating in terms of the cost of repairs, replacement of damaged property and loss of business. The objectives of the Flood Risk Assessment are therefore to establish the following:

- whether a proposed development is likely to be affected by current or future flooding from any source
- whether the development will increase flood risk elsewhere within the floodplain
- whether the measures proposed to deal with these effects and risks are appropriate
- whether the site will be safe to enable the passing of the Exception Test (where appropriate)

Herrington Consulting has been commissioned by F D Attwood & Partners to prepare a Flood Risk Assessment (FRA) for the proposed development at **Darland Farm, Chatham, Kent, ME5 7PP**.

This appraisal has been undertaken in accordance with the requirements of the National Planning Policy Framework (March 2012) and the accompanying Planning Practice Guidance Suite. To ensure that due account is taken of industry best practice, it has been carried out in line with the CIRIA Report C624 ‘Development and flood risk - guidance for the construction industry’.

Reference is also made to the National Planning Practice Guidance Suite (March 2014) that has been published by the Department for Communities and Local Government. The *Flood Risk and Coastal Change* planning practice guidance included within the Suite represents the most contemporary technical guidance on preparing FRAs.

2 Development Description and Planning Context

2.1 Site Location and Existing Use

The site is located at OS coordinates 578153, 165760, off Pear Tree Lane in Chatham. In total the site covers an area of approximately 4.18 hectares and currently comprises undeveloped farmland. The location of the site in relation to the surrounding area is shown in Figure 2.1.

The site plan included in Appendix A.1 of this report provides more detail in relation to the site location and layout.

Figure 2.1 – Location map (Contains Ordnance Survey data © Crown copyright and database right 2016)

2.2 Proposed Development

The proposals for development comprise 44 residential dwellings, associated car parking and hard standing.

Drawings of the proposed scheme are included in Appendix A.1 of this report.

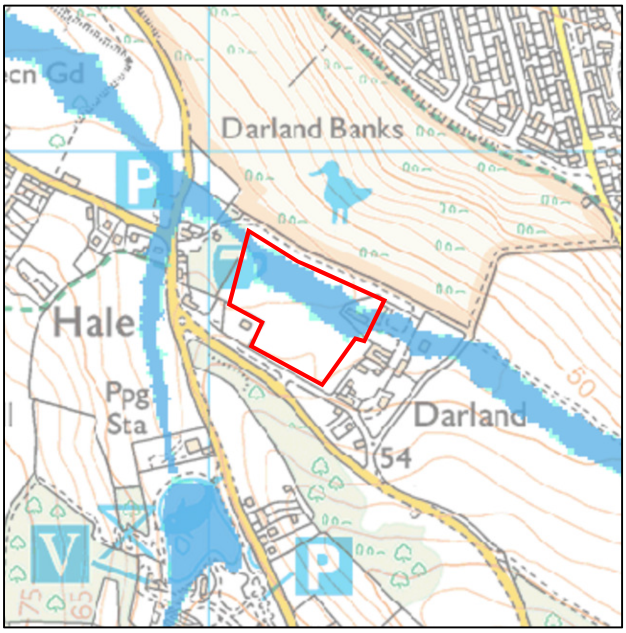
2.3 The Sequential Test

Local Planning Authorities (LPA) are encouraged to take a risk-based approach to proposals for development in areas at risk of flooding through the application of the Sequential Test and the objectives of this test are to steer new development away from high risk areas towards those at lower risk of flooding. However, in some areas where developable land is in short supply there can be an overriding need to build in areas that are at risk of flooding. In such circumstances, the application of the Sequential Test is used to ensure that the lower risk sites are developed before the higher risk ones.

The National Planning Policy Framework (NPPF) requires the Sequential Test to be applied at all stages of the planning process and generally the starting point is the Environment Agency's flood zone maps. These maps and the associated information are intended for guidance, and cannot provide details for individual properties. They do not take into account other considerations such as existing flood defences, alternative flooding mechanisms and detailed site based surveys. They do, however, provide high level information on the type and likelihood of flood risk in any particular area of the country. The flood zones are classified as follows:

> Zone 1 – *Low probability of flooding* – This zone is assessed as having less than a 1 in 1000 annual probability of river or sea flooding in any one year.
>
> Zone 2 – *Medium probability of flooding* – This zone comprises land assessed as having between a 1 in 100 and 1 in 1000 annual probability of river flooding or between 1 in 200 and 1 in 1000 annual probability of sea flooding in any one year.
>
> Zone 3a – *High probability of flooding* - This zone comprises land assessed as having a 1 in 100 or greater annual probability of river flooding or 1 in 200 or greater annual probability of sea flooding in any one year.
>
> Zone 3b – *The Functional Floodplain* – This zone comprises land where water has to flow or be stored in times of flood and can be defined as land which would flood during an event having an annual probability of 1 in 20 or greater. This zone can also represent areas that are designed to flood in an extreme event as part of a flood alleviation or flood storage scheme.

The location of the site is shown on the Environment Agency's flood zone map in Figure 2.2 and the information provided by this map has been interrogated and summarised in Table 2.2 below.



Key to flood map

Zone 3 - Extent of flooding from the sea by a flood that has a 0.5% (1 in 200) or greater chance of happening each year or from a river by a flood that has a 1% (1 in 100) or greater chance of happening each year.

Zone 2 - Additional extent of an extreme flood from rivers or the sea. These outlying areas are likely to be affected by a major flood, with up to a 0.1% (1 in 1000) chance of occurring each year.

Flood defences

Areas benefiting from flood defences

Main rivers

Location of development site

Figure 2.2 – Flood zone map showing the location of the development site (© Environment Agency)

The above mapping shows the development site to be located partially within Flood Zones 1, 2 and 3, thereby indicating that the site is potentially at risk of flooding from fluvial and/or tidal sources. However, inspection of OS mapping identifies that that the River Medway is the closest fluvial or tidal source to the development site.

The River Medway is located over 3km from the site and approximately 34m below the site elevation. This change in elevation is considered greater than any potential rise in the tide or water level in the river, even when considering an increase as a result of climate change throughout the anticipated lifetime of the development (100 years).

Furthermore, there is no evidence to suggest that the pathway shown in the EA mapping is an ephemeral river (i.e. one which flows seasonally, or even after extreme prolonged and heavy periods of rainfall), nor are there any fluvial/tidal sources in the upper valley, in which the site in located.

It is therefore concluded that the extent of flooding delineated on the flood maps is generated due to the depression in the topography, caused by the dry valley in which Darland Farm is sited. This is not, however, attributed to a fluvial or tidal watercourse and as such, it is concluded that the site is incorrectly classified as being located within either Flood Zone 2 or Flood Zone 3. Consequently, for the purpose of this assessment, and in the absence of a direct challenge to the Flood Zone maps, the site is assumed to be located within Flood Zone 1.

As it is not possible to locate the proposed development in an area classified as being at a lower risk of flooding from tidal/fluvial sources, it is determined that the site meets the requirements of the Sequential Test.

It is recognised that the pathway indicated by the Environment Agency mapping is due topography of the site and surrounding area and therefore, it is acknowledged that there is the potential for an overland flow of water to be directed towards the site during an extreme pluvial event. Consequently, this report examines the risk of flooding from this source in detail in Section 5.

In accordance with the objectives of the Sequential Test, it is possible consider the natural topography of the site and the proposed development uses, in order to minimise the impact of flooding from all sources. This could comprise locating more vulnerable buildings on the higher parts of the site, whilst siting less vulnerable elements of the development, such as car parking or recreational use, in the areas exposed to higher risk of flooding. This is referred to as the Sequential Approach and is examined later on in this FRA (Section 7.1).

2.4 The Exception Test

As defined in paragraph 102 of the NPPF, where the requirements of the Sequential Test are not met due to the unavailability of alternative sites within an area of low risk, the Exception Test should be applied to ensure that the risk of flooding to the site and surrounding area will be managed.

The Exception Test comprises two main objectives: firstly, to demonstrate that the site will be safe for its lifetime, without increasing the risk of flooding elsewhere. The second is to provide wider sustainability benefits to the community that outweigh the risk of flooding. Both elements of the test have to be passed for development to be allocated or permitted.

When determining whether the Exception Test is applicable, the type and nature of different development classifications in the context of their flood risk vulnerability is considered in addition to the likelihood of flooding at the site. This is summarised in Table 2.1 below.

Flood Risk Vulnerability Classification	**Zone 1**	**Zone 2**	**Zone 3a**	**Zone 3b**
Essential infrastructure – Essential transport infrastructure, strategic utility infrastructure, including electricity generating power stations	–	–	e	e
High vulnerability – Emergency services, basement dwellings caravans and mobile homes intended for permanent residential use	–	e	×	×
More vulnerable – Hospitals, residential care homes, buildings used for dwelling houses, halls of residence, pubs, hotels, non-residential uses for health services, nurseries and education	–	–	e	×
Less vulnerable – Shops, offices, restaurants, general industry, agriculture, sewerage treatment plants	–	–	–	×
Water compatible development – Flood control infrastructure, sewerage infrastructure, docks, marinas, ship building, water-based recreation etc.	–	–	–	–

Key :

– Development is appropriate

× Development should not be permitted

e Exception Test required

Table 2.1 – Flood risk vulnerability and flood zone compatibility

Based on the current (incorrect flood zone maps), part of the development site would be located within Flood Zones 2 and 3. As the development proposals comprise the construction of 44 residential dwellings, from Table 2.1 above it can be seen that the development would fall into a classification that would normally require the Exception Test to be applied.

However, as demonstrated in Section 2.3 above, based on the true definition of Flood Zone 2 and 3 (i.e. tidal/fluvial flooding), it is evident that the site is not subject to flooding from either of these sources and therefore, the development site is considered to be, by definition, located within Flood Zone 1. Given that the site meets the requirements of the Sequential Test, it would not be subject to the Exception Test by default.

Notwithstanding this, for all sites greater than 1.0 hectare, the NPPF requires that a flood risk assessment be prepared so that other flood risk issues such as surface water run-off, overland flow and groundwater flooding can be appraised to ensure that not only is the development safe, but that it does not increase the risk of flooding elsewhere. Consequently, appraising this risk is the primary focus of this report.

3 Definition of Flood Hazard

3.1 Site Specific Information

In addition to the high level flood risk information shown in the Environment Agency (EA) flood zone maps, additional data from detailed studies, topographic site surveys and other information sources is referenced. This section summarises the additional information collected as part of this FRA.

High level information contained within the SFRA – Medway District Council SFRA (2006) contains detailed mapping of flood extents from a wide range of sources. This document has been referenced as part of this site-specific FRA.

Site specific topographic surveys – A topographic survey has been undertaken for the site and a copy of this is included in Appendix A.1. From this it can be seen that the level of the site varies between 37.3m and 47.9m Above Ordnance Datum Newlyn (AODN). Land levels fall across the site from south to north-west.

Geology – Reference to the Geological Survey map shows that the underlying solid geology in the location of the subject site is Lewes Nodular Chalk Formation. Overlying this are superficial deposits of Head (Clay and Silt).

Historic flooding – Inspection of the Medway SFRA identifies that there have been no recorded flooding incidents at the site, from any source. No further information on historic flooding in this area has been provided or revealed through desktop searches.

3.2 Potential Sources of Flooding

The main categories of flooding have been assessed as part of this appraisal. The specific issues relating to each one and its impact on this particular development are discussed below. Table 3.1 at the end of this section summarises the risks associated with each of the flooding sources.

Flooding from Main Rivers, Ordinary or Man-made Watercourses – The Environment Agency's Flood Zone mapping identifies areas at risk of flooding from Rivers or the Sea. This mapping indicates that the site is located partially within Flood Zones 2 and 3. However, inspection of OS mapping reveals that the nearest watercourse to the site is the River Medway, which is located over 3km north of the site.

On closer inspection of the Environment Agency Flood Zone mapping it is evident that the source-pathway-receptor model used to create these maps has identified that the pathway of the predicted flooding follows the contours of the land, rather than the flow path of a specified ordinary watercourse or main river. This indicates that a fluvial watercourse is not the source of flooding at this location.

The site is, however, located within a dry valley and it is this feature that the Flood Zone maps are depicting as a flow path passing through the site. Although the risk of flooding from this pathway does need further investigation (refer to Section 5), it is considered that this pathway is not an ephemeral river, i.e. one which flows seasonally or even after extreme prolonged and heavy periods of rainfall. In addition, there is no historic evidence that suggests there have ever been any above-ground flows in this valley.

In summary, considering there is no evidence to suggest that the subject site is at risk of fluvial flooding from any main rivers or ordinary watercourses, flooding via this mechanism is discounted from any further analysis.

Flooding from Land (overland flow and surface water run-off) – Overland flooding typically occurs in natural valley bottoms as normally dry areas become covered in flowing water and in low spots where water may pond. This flooding mechanism can occur almost anywhere, but is likely to be of particular concern in any topographical low spot, or where the pathway for run-off is restricted by terrain or man-made obstructions.

However, the prediction of flooding from surface water can be difficult, as it is hard to forecast the exact intensity and extent of rainfall of a storm. Under the Flood Risk Regulations 2009, the Environment Agency was therefore tasked with producing and publishing flood maps for surface water.

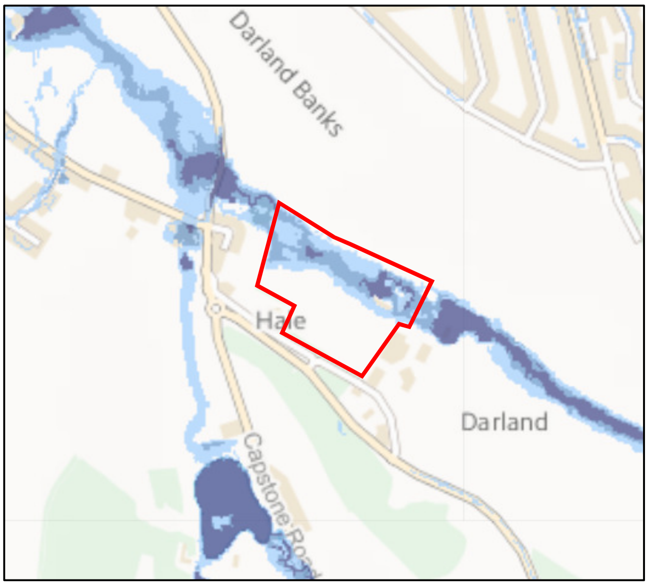
Maps showing the risk of flooding, and the associated approximate depth and velocity have been produced using information from Lead Local Flood Authorities, such as drainage rates, percentage run-off rates and critical storm durations. The maps pick out natural drainage channels, rivers, low areas within the floodplain and flow paths between buildings. In addition, the maps also consider the influence of buildings, roads and other structures within the floodplain which could obstruct flows, and account for a reduction in rainfall due to drains, sewers and infiltration. They do not, however, take into account individual property threshold heights and assume a single drainage rate for all urban areas.

Consequently, the surface water maps and the associated information are intended for guidance only, and cannot provide details for individual properties. They do, however, provide high level information and indicate areas in which surface water flooding issues should be investigated further. The risk categories are classified as follows:

- *Very low probability of flooding* – This zone is assessed as having less than a 1 in 1000 annual probability of surface water flooding.
- *Low probability of flooding* – This zone comprises land assessed as having between a 1 in 100 and 1 in 1000 annual probability of surface water flooding.
- *Medium probability of flooding* - This zone comprises land assessed as having between a 1 in 30 and 1 in 100 annual probability of surface water flooding.

- *High probability of flooding* – This zone is assessed as having greater than a 1 in 30 annual probability of surface water flooding.

Figure 3.1 below is an extract of the Environment Agency's 'Risk of Flooding from Surface Water' map and identifies the location of the site. This map has been interrogated to assist in this review, helping to identify whether the site is located in an area at specific risk of surface water flooding.



Key to flood map

Probability of flooding

High – Extent of flooding from surface water that has a 3.3% (1 in 30) or greater chance of happening each year.

Medium - Extent of flooding from surface water that has between a 3.3% (1 in 30) and 1% (1 in 100) chance of happening each year.

Low - Extent of flooding from surface water that has between a 1% (1 in 100) and 0.1% (1 in 1000) chance of happening each year.

Location of development site

Figure 3.1 – Surface water flooding map showing the location of the development site (© Environment Agency)

The above mapping shows the development site to be located in area predicted to be affected by an extreme pluvial event with a return period of greater than and including 1 in 30 years. Inspection of the LiDAR elevation data reveals that the site is located within a valley, with land levels falling towards the north west of the site. In locations with steep topography (such is the case at this location), heavy rainfall often results in the generation of surface water flow overland.

This characteristics of the local catchment can be seen by the similarity between the predicted extent of surface water flooding (shown in Figure 3.1) and the extent shown on the EA's fluvial/tidal flood zone map (Figure 2.2). It is therefore considered that the primary risk of flooding to the site is from the overland flow path identified in both of these maps.

This source is analysed in more detail in later sections of this report to ensure that the occupants of the site remain safe throughout the lifetime of the development, and that the risk of flooding to the surrounding area will not increase as a result of this development.

Flooding from the Sea – The Environment Agency Flood Zone mapping identifies that the site is located partially within Flood Zones 2 and 3a. However, inspection of OS mapping and aerial height data identifies the site to be located a significant distance inland and elevated well above predicted extreme tide levels. Consequently, the risk of flooding from this source is considered to be negligible and therefore the impacts of flooding from the sea are not considered further in this appraisal. The location of the site within a Flood Zone has been discussed previously in respect to the risk of flooding from Main Rivers, Ordinary and Man-Made Watercourses and is considered further in Section 5 of this report.

Flooding from Groundwater – Water levels below the ground rise during wet winter months, and fall again in the summer as water flows out into rivers. In very wet winters, rising water levels may lead to the flooding of normally dry land, as well as reactivating flow in 'bournes' (streams that only flow for part of the year). Where land that is prone to groundwater flooding has been built on, the effect of a flood can be very costly, and because groundwater responds slowly compared with rivers, floods can last for weeks or months. Groundwater flooding generally occurs in rural areas although it can also occur in more urbanised areas where the process known as groundwater rebound can cause localised flooding of basements. This increase in the water table level is occurring as a result of the decrease in groundwater extraction that has taken place since the decline in urban aquifer exploitation by heavy industry.

Data on groundwater flooding has been compiled by the British Geological Society and is illustrated on mapping, which is the product of integrating several datasets: a digital model of the land surface, digital geological map data and a water level surface based on measurements of groundwater level made during a particularly wet winter. This dataset provides an indication of areas where groundwater flooding may occur, but is primarily focussed on groundwater flooding potential over the Chalk of southern Britain as Chalk shows some of the largest seasonal variations in groundwater level, and is thus particularly prone to groundwater flooding incidents.

Inspection of this groundwater flood risk mapping data shows that the general area in which the development site lies is identified as being at low risk from groundwater flooding. The more detailed mapping on groundwater emergence provided as part of the Defra Groundwater Flood Scoping Study (May 2004), which shows areas where groundwater flooding has occurred in the past and also areas that are potentially vulnerable to groundwater emergence has also been referenced as part of this FRA. This shows that no groundwater flooding events were recorded during the very wet periods of 2000/01 or 2002/03 and that the site itself is not located within an area where groundwater emergence is predicted.

In addition to the information discussed above, the Environment Agency's Aquifer Designation maps and the British Geological Survey Groundwater Vulnerability mapping has been referenced. These maps, which are based on geological and hydrogeological information, identify areas where geological conditions could enable groundwater flooding. In this location, the bedrock (Lewes Nodular Chalk formation) is capable of supporting groundwater flows and the mapping shows that this is a highly productive aquifer.

Notwithstanding this, the more impermeable superficial deposits in this location (Head) will act as a cap, reducing the likelihood of groundwater emergence at the site. Given that the Medway SFRA identifies that there are no historical records of groundwater flooding at the site and that there are no subterranean elements to the development proposals, flooding from this mechanism is unlikely in this location. Consequently, based on the above information, the risk of flooding from this source is *low*.

Flooding from Sewers – In urban areas, rainwater is frequently drained into surface water sewers or sewers containing both surface and wastewater known as “combined sewers”. Flooding can result when the sewer is overwhelmed by heavy rainfall, becomes blocked, or is of inadequate capacity; this will continue until the water drains away. When this happens to combined sewers, there is a high risk of land and property flooding with water contaminated with raw sewage as well as pollution of rivers due to discharge from combined sewer overflows.

The undeveloped site is not currently thought to be in close proximity to any existing sewer connections. Given that surface water is unlikely to discharge into the public sewer, the risk of the sewer surcharging is greatly reduced. Additionally, there are no known records of flooding from sewers in this area, and therefore, based on the evidence available, the risk of flooding from this source is considered to be *low*.

Flooding from Reservoirs, Canals and other Artificial Sources – Non-natural or artificial sources of flooding can include reservoirs, canals and lakes where water is retained above natural ground level, operational and redundant industrial processes including mining, quarrying and sand and gravel extraction, as they may increase floodwater depths and velocities in adjacent areas. The potential effects of flood risk management infrastructure and other structures also need to be considered. Reservoir or canal flooding may occur as a result of the facility being overwhelmed and/or as a result of dam or bank failure.

Inspection of the Ordnance Survey mapping for the area shows that there are no artificial sources of flooding within close proximity to the site. In addition, the Environment Agency’s ‘Risk of Flooding from Reservoirs’ website shows that the site is not within an area considered to be at risk of flooding from reservoirs.

A summary of the overall risk of flooding from each source is provided in Table 3.1 below.

Source of flooding	Initial level of risk	Appraisal method applied at the initial flood risk assessment stage
Rivers	N/A	Environment Agency flood zone map, OS mapping and aerial height data
Ordinary and man-made watercourses	N/A	Site based appraisal, OS mapping and aerial height data
Sea/Estuaries	N/A	Environment Agency flood zone map, OS mapping and aerial height data
Overland flow	Examined further in Section 5.	Site based appraisal, aerial height data, and Environment Agency 'Risk of Flooding from Surface Water' and Flood Zone maps
Groundwater	Low	BGS groundwater flood hazard maps, Defra Groundwater Flood Scoping Study and site-specific geological data
Sewers	Low	Site based appraisal and Southern Water historic sewer records contained within the SFRA
Artificial sources	Low	Site based appraisal and Environment Agency 'Risk of Flooding from Reservoirs' flood map

Table 3.1 – Summary of flood sources and risks

4 Climate Change

When the impact of climate change is considered it is generally accepted that the standard of protection provided by current defences will reduce with time. The global climate is constantly changing, but it is widely recognised that we are now entering a period of accelerating change. Over the last few decades there have been numerous studies into the impact of potential changes in the future and there is now an increasing body of scientific evidence which supports the fact that the global climate is changing as a result of human activity. Past, present and future emissions of greenhouse gases are expected to cause significant global climate change during this century.

The nature of climate change at a regional level will vary: for the UK, projections of future climate change indicate that more frequent short-duration, high-intensity rainfall and more frequent periods of long-duration rainfall of the type responsible for the recent UK flooding could be expected.

These effects will tend to increase the size of flood zones associated with rivers, and the amount of flooding experienced from other inland sources. The rise in sea level will change the frequency of occurrence of high water levels relative to today's sea levels. It will also increase the extent of the area at risk should sea defences fail. Changes in wave heights due to increased water depths, as well as possible changes in the frequency, duration and severity of storm events are also predicted.

To ensure that any recommended mitigation measures are sustainable and effective throughout the lifetime of the development, it is necessary to base the appraisal on the extreme flood level that is commensurate with the planning horizon for the proposed development. The NPPF and supporting Planning Practice Guidance Suite state that residential development should be considered for a minimum of 100 years, but that the lifetime of a non-residential development depends on the characteristics of the development. For commercial development, a 60 year design life is assumed. The development that is the subject of this FRA is classified as residential.

4.1 Potential Changes in Climate

Peak Rainfall Intensity

The recommended allowances for increases in peak rainfall intensity were updated in February 2016 and although the allowance is applicable nationally, there is a range of values provided which correspond with the central and upper end percentiles (the 50th and 90th percentile respectively) over three time epochs corresponding with the planning horizons defined within the NPPF. The recommended allowances are shown in Table 4.1 below.

Allowance Category (applicable nationwide)	Total potential change anticipated for each epoch		
	2015 to 2039	**2040 to 2069**	**2070 to 2115**
Upper End	+10%	+20%	+40%
Central	+5%	+10%	+20%

Table 4.1 – Recommended peak rainfall intensity allowance for small and urban catchments (1961 to 1990 baseline)

All of the above recommended allowances for climate change should be used as a guideline and can be superseded if local evidence supports the use of other data or allowances. Additionally, in the instance where flood mitigation measures are not considered necessary at present, but will be required in the future (as a result of changes in climate), a "managed adaptive approach" may be adopted whereby development is designed to allow the incorporation of appropriate mitigation measures in the future.

4.2 Impacts of Climate Change on the Development Site

Due to the sites location in a dry valley, detailed flood modelling has not been undertaken as part of this FRA, or by the EA. Consequently, the EA has not quantified the risk of flooding at the site. Notwithstanding this, with the predicted increases in peak rainfall intensity, it is evident that the risk of flooding is likely to increase over the lifetime of the development, therefore, based on Table 4.1 above, an increase of 20% in peak rainfall intensity has been used to account for 100 years of climate change at the site.

In addition to the impact on fluvial flood risk at the site, climatic changes will also impact on the way in which the proposed development affects flood risk elsewhere. These impacts are primarily linked to the surface water discharge from the site; therefore potential increases in future rainfall need to be taken into account when designing surface water drainage systems.

For a residential development a design life of 100 years is assumed and therefore an increase of 20% in peak rainfall intensity has been used in the calculations in the outline surface water management strategy (refer to Section 8).

5 Probability and Consequence of Flooding

5.1 The Likelihood of Flooding

When appraising the risk of flooding to new development it is necessary to assess the impact of the 'design flood event' to establish depths, velocities and the rate of rise of floodwater under such conditions. Flood conditions can be predicted for a range of return periods and these are expressed in either years or as a probability, i.e. the probability that the event will occur in any given year, or Annual Exceedance Probability (AEP). The design flood event is taken as either the 1 in 100 year (1% AEP) event for fluvial flooding or the 1 in 200 year (0.5% AEP) event for sea or tidal flooding.

Reference to the Environment Agency's Flood Zone mapping shows the site to be located partially within Flood Zone 2 and 3. As discussed in Section 3.2, the site is located a sufficient distance from both the sea and any significantly sized watercourse, and has therefore been shown to remain unaffected by both fluvial and tidal sources of flooding. It can therefore be concluded that the pathway shown on the Flood Zone maps is more likely to be attributed to the generation of overland flow as a result of an extreme pluvial event.

Aerial height data for the site reveals that the site is located at the bottom of a dry valley. The velocity mapping published as part of the Environment Agency's 'Risk of Flooding from Surface Water' (Figure 5.1) mapping identifies that the surface water run-off is generated higher up in the catchment in Hempstead and is subsequently channelled by the valley towards the subject site.

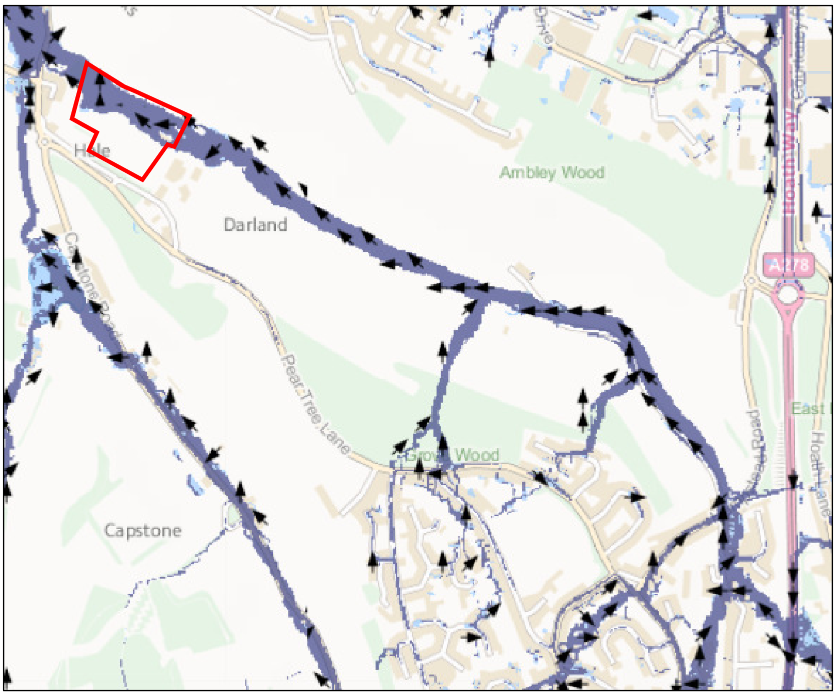


Figure 5.1 – Maximum predicted extent of flooding and dominant flow direction shown by the Environment Agency's Risk of flooding from Surface Water mapping. (© Environment Agency). Site outlined in red.

Although the above mapping indicates that the site is located within the predicted flood extents, further analysis has been undertaken in order to quantify the likelihood of such an event occurring and to gain an understanding of the potential impact that any overland flow of surface water could have on the development.

Unlike the mapping in Figure 5.1 above, the method adopted to quantify the risk in more detail does account for the impact of climate change over the lifetime of the development. This methodology is discussed in the following sections of this report.

5.2 Catchment Characteristics

This report has identified that the site is located within a dry valley which falls from south to north west, from Hampstead towards Luton. Inspection of the aerial height data, shown in Figure 5.2 below, clearly delineates the path of the valley.

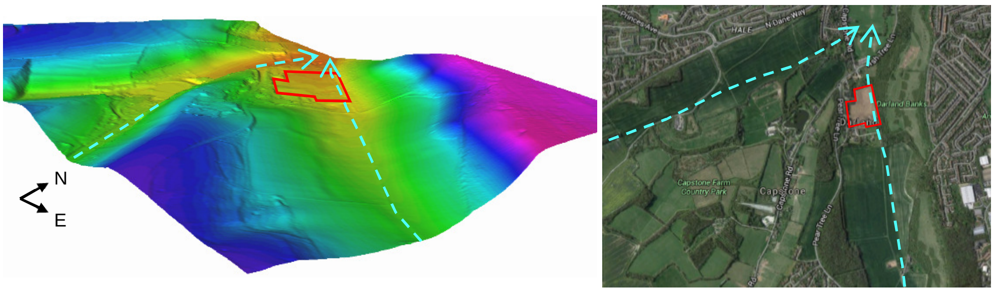


Figure 5.2 – Left: A 3d image of the aerial height data. Right: Google Aerial Imagery, Both images show the location of the development site (outlined in red) and the dominant flow paths (dashed blue arrow).

From the elevation data shown in Figure 5.2 above it is possible to determine the gradient of the valley along its length. This gradient has been calculated to be a 1:50 slope, which is relatively steep. The 3d image also shows that there is a clearly defined cross-section across the valley which would direct any water flowing overland from higher up in the catchment into the bottom of the valley.

Inspection of the aerial height data in combination with OS mapping reveals that there are no topographic features downslope of the site which would otherwise encourage floodwater to pond at the site. It is therefore concluded that any surface water run-off generated higher up in the catchment would be channelled at the base of valley, where it would travel through the lowest part of the site unobstructed, towards the town of Luton.

In order to quantify the magnitude of flooding under an extreme pluvial event, these characteristics, in addition to other catchment descriptors extracted from the Flood Estimation Handbook (FEH), have been applied to hydrological prediction methods (such as ReFH2) to calculate the peak flow within the valley under the design event. This hydrograph has subsequently been used to estimate the potential flood level at the site.

5.3 FEH Methodology

FEH represents the culmination of a five-year research programme at the Institute of Hydrology intended to develop and implement new procedures for rainfall and flood frequency estimation. The Handbook largely supersedes the earlier Flood Studies Report (FSR). Over 40 years have elapsed since the publication of the FSR and a principal element of developing the FEH was to consolidate research in rainfall and flood frequency analysis and to present new procedures for flood estimation.

The FEH aims to provide clear guidance to practitioners concerned with flood frequency estimation. Much of the relevant information, including catchment descriptors and the depiction of catchment boundaries by digital terrain model, is provided in digital format.

The first stage in the process is to define the catchment boundaries, which is a relatively straight forward process using the digital terrain model contained within the FEH CD-ROM. The catchment which the development site is located in is shown in Figure 5.3 below and covers an area of 5.5 sq km.

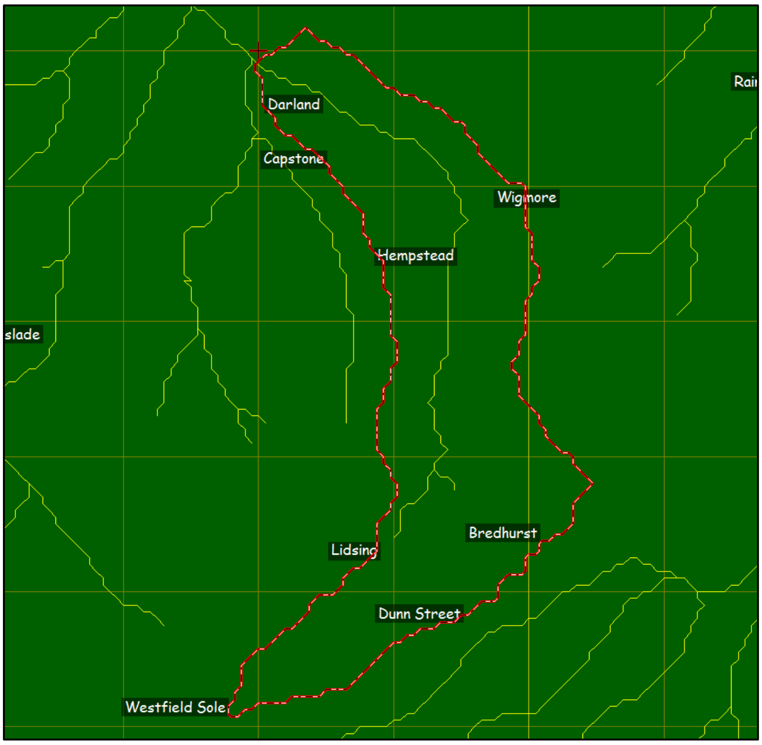


Figure 5.3 – Catchment boundaries from FEH CD-ROM

The FEH software then generates 'catchment descriptors' and these are incorporated into the ReFH2 model. Using the ReFH2 model, design flood hydrographs were generated for a specified initial soil moisture content and a design rainfall event. Both soil moisture and rainfall are specified on a seasonal basis depending on the degree of urbanisation of the catchment under consideration.

To account for 100 years of climate change, the 1 in 100 year peak rainfall intensity was further increased by 20% (refer to Section 4.1). The calculation audit sheets for the ReFH2 analysis are included in Appendix A.2 of this report; however, in summary the peak flows derived from the analysis are shown in Table 5.1.

Return Period in years (AEP)	Peak flow rate Q (m^3/s)
100 (1%)	2.22
100+20%cc (1%+CC)	2.66

Table 5.1 – Values of flow rate Q (m^3/sec)

5.4 Manning's Equation

Having established the peak overland flow rate for the upper part of the valley, it is possible to apply these values to the wider valley using the Manning's Equation. This method is a widely adopted method of calculating flow in open channels and has been shown to produce reasonably accurate results for a large range of natural and artificial channels. However, in order to investigate the impact that and extreme event could have on the subject site it is necessary to apply the same methodology for the wider valley.

Input parameters for the Manning's Equation comprise dimensions of the valley cross-section and the gradient from the point of flow (in the upper catchment) to the subject site. These parameters have been derived, primarily, by striking a cross section through 1m LiDAR elevation data. Given that a large proportion of the land within the flood compartment is vegetated, a global Manning's n roughness coefficient of 0.04 has been applied.

The predicted depth of flooding under the design flood event has been calculated as **0.06m**.

5.5 Extent and Depth of Flooding

Due to the slope of the valley, the predicted depth of flooding that has been determined using the above method is a dynamic flood depth, and does not represent a ponded flood depth. This flow will be confined to the centreline of the valley, at the lowest elevation. Therefore, by applying this flood depth to a range of cross sections along the length of the valley and interpolating between these cross sections, it is possible to estimate the area that could be affected during the design event. Figure 5.3 below assumes that the 60mm of floodwater would pond in the lowest points of the valley as it flows towards the north west.

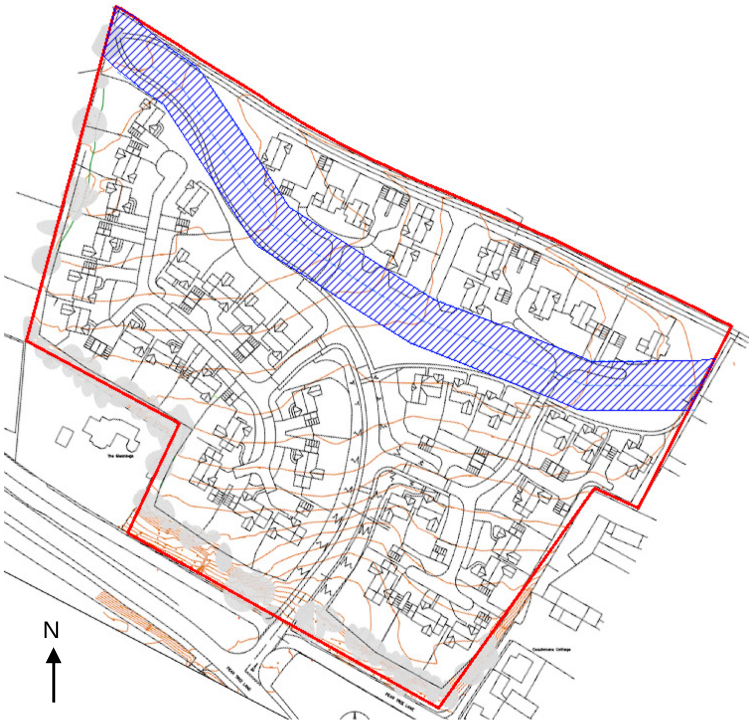


Figure 5.4 – the predicted extent of flooding resulting from an extreme pluvial event overlain onto the proposed scheme. Site boundary shown in red.

The above image has been derived by applying the surface water run-off which is generated higher in the catchment, but it does not take into consideration the rainfall landing on the site itself. Instead, the management of the surface water run-off within the site boundary as a result of the new development is considered independently as part of the surface water management strategy, discussed later in this report (refer to Section 8). The proposed drainage system has been designed to ensure that the design rainfall event can be managed in a sustainable way, without increase the risk of flooding offsite.

From the image above it can be seen that the proposed dwellings have been located outside of the predicted overland flow path of water arriving further up the valley. Additionally, the thresholds of the proposed properties will be raised a minimum of 150mm above the ground level to further minimise the risk of any internal flooding.

5.6 Rate of Rise and Velocity of Floodwater

The outputs from the analysis indicates that maximum flow velocities associated with the 1 in 100 year return period event at this location would be typically less than 0.5m/s.

The rate of rise will be directly linked to the design rainfall event, although it is recognised that there may be some time lag between the peak of the rainfall event and any overland flow of water reaching the site. The critical rainfall duration from the design event has been calculated using Micro Drainage and this is shown to be a very short duration rainfall event of just 15 minutes (summer event).

Although this type of event can create a large volume of surface water very quickly, as the event is over in a very short period of time the opportunity for water to build up and create overland flooding is limited.

Conversely, a prolonged rainfall event has the potential to cause water to accumulate, creating an overland flow of surface water. However, as the rainfall under this type of event is less intense than a short duration event, it provides the opportunity for the water to infiltrate into the ground, and/or for the drainage network to remove the water from the urbanised areas. Consequently, the water flowing overland towards the site would be limited.

6 Offsite Impacts and Other Considerations

6.1 Overland Flow Paths, Flow Regimes, and Displacement of Floodwater

The construction of a new building within the floodplain has the potential to displace water from that area and to increase flood risk elsewhere by raising flood levels. In this instance, the primary risk of flooding to the development site has been shown to be from an extreme pluvial event, and therefore it has been established that the site is not located within a *fluvial* floodplain. The potential source of flooding identified by the mapping is considered to arise from a natural overland flow path, and given that there are no topographic low points on the site in which floodwater can pond, the development will not displace floodwater.

Notwithstanding this, locating buildings within an overland flow path does have the potential to obstruct the flow of surface water run-off and change flow regimes, and therefore this requires further consideration.

Inspection of the proposed scheme drawings identifies that the development has been designed to locate all of the buildings outside of the lowest areas, where a natural overland flow path could be formed during an extreme rainfall event. As there is sufficient, unobstructed space between the proposed buildings, the buildings will not impede the natural flow in the unlikely event that floodwater does propagate towards the site as a shallow overland sheet flow of water.

The proposed SuDS system (refer to Section 8) will have the potential to reduce both the rate and volume that water is passed on downstream from the development site itself and therefore, it is concluded that the proposed development will not have a negative impact on flood flow regimes.

6.2 Public Safety and Access

The NPPF states that, where required, safe access and escape should be available to/from new development in flood risk areas. The Practice Guide goes on to state that access routes should be such that occupants can safely access and exit their dwellings in design flood conditions and that vehicular access to allow the emergency services to safely reach the development will also normally be required.

Although the site has been shown to be located outside of the fluvial floodplain, this FRA has indicated that part of the Darland Farm site could be subject to minor flooding under the design pluvial event. Although the proposed buildings have been sited outside of the natural flow path, there is the possibility that access to/from a number of the proposed dwellings could be affected.

Reference to the Practice Guide shows that in circumstances where it is not possible to provide dry access, the flood hazard to people under the design flood conditions needs to be quantified.

In the report 'Flood Risks to People' (R&D output FD2320/TR2) a methodology for quantifying flood hazard is set out using the following equation:

HR = ((v + 0.5) d) + DF

where,

HR = flood hazard rating
d = depth of flooding (m)
v = velocity (m/sec)
DF = debris factor (see Table 6.1)

Depths	Debris Factor (DF)
d = 0 to 0.25m	0.5
d > 0.25m	1.0

Table 6.1 - Guidance on the use of Debris Factor (DF)

When the topography of the surrounding area is examined with respect to the predicted flood extents, it can be seen that the safest route from the development site to an area outside of the floodplain is via Pear Tree Lane. The levels along this route have been established and using the design flood event conditions that include for climate change impacts, the following parameters are derived, i.e. d = 0.06m and v = 0.5m/sec. When these values are entered into the above equation a Hazard Rating of 0.56 is given.

When this value is compared to the threshold values given in Table 6.2 below it can be seen that the degree of hazard is classified as 'Low'. Access to and from the site during the design flood event is therefore considered to be safe.

Hazard Rating (HR)	Degree of flood hazard	Description
< 0.75	Low	Caution – shallow flowing water or deep standing water
0.75 to 1.25	Moderate	Dangerous for some, i.e. children – deep or fast flowing water
1.25 to 2.5	Significant	Dangerous for most people – deep fast flowing water
> 2.5	Extreme	Dangerous for all – extreme danger with deep and fast flowing water

Table 6.2 – Classification of Hazard Rating Thresholds

In the extremely unlikely instance that the events examined within this report are exceeded, occupants will be able to seek safe dry refuge on the upper floors of the development.

6.3 Proximity to Watercourse and Flood Defence Structures

Under the Water Resources Act 1991 and Land Drainage Byelaws, any proposals for development in close proximity to a tidal watercourse would need to take into account the Environment Agency's requirement for a 16m buffer zone between the river bank and any permanent construction such as buildings or car parking etc.

In this circumstance, it has been shown that the nearest main river is the river Medway which is over 3km from the development site. As such, the development proposals at Darland Farm will not compromise any of the Environment Agency's maintenance or access requirements.

7 Flood Mitigation Measures

The key objectives of flood risk mitigation are:

- to reduce the risk of the development being flooded
- to ensure continued operation and safety during flood events
- to ensure that the flood risk downstream of the site is not increased by increased run-off
- to ensure that the development does not have an adverse impact on flood risk elsewhere

Up to this point in the report the risks to the site have been appraised and the consequences of these risks occurring have been considered. The following section of this report examines ways in which flood risk can be mitigated.

Mitigation Measure	Appropriate	Comment
Careful location of development within site boundaries (i.e. Sequential Approach)	–	See Section 7.1
Raising floor levels	–	See Section 7.2
Land raising	x	See Section 7.2
Compensatory floodplain storage	x	See Section 6.1
Flood resistance & resilience	–	See Section 7.3
Alterations/ improvements to channels and hydraulic structures	x	Not required
Flood defences	x	Not required
Flood warning	x	See Section 7.4
Management of development run-off	–	See Section 8

Table 7.1 – Appropriateness of mitigation measures

7.1 Application of the Sequential Approach at a Local Scale

The sequential approach to flood risk management can also be adopted on a site based scale and this can often be the most effective form of mitigation. For example, on a large scheme this would mean locating the more vulnerable dwellings on the higher parts of the site and placing parking, recreational land or commercial buildings in the lower lying and higher risk areas.

In this instance, the proposed dwellings have been located outside of the predicted design flood extents and therefore, is considered to take advantage of the higher ground at the site as much as the other site constraints allow.

7.2 Raising Floor Levels & Land Raising

Although it is not possible to accurately define the maximum extent of the flow path at the site under the design event (1 in 100 year plus climate change), the use of the Manning's Equation has provided an indicative flood depth at the lowest point of the site (~60mm).

The proposed dwellings have been shown to be located outside of the predicted flood extents, however, as a precautionary measure, it is recommended that the proposed dwellings are raised by a minimum of 150mm above the existing ground level. Raising the thresholds of the proposed dwellings will provide sufficient freeboard under the design flood event to prevent any internal flooding.

In addition, inspection of the scheme drawings identifies that only living accommodation is placed on the ground floor, with the more vulnerable sleeping accommodation located on the first floor and above.

7.3 Flood Resistance and Resilience

During a flood event, floodwater can find its way into properties through a variety of routes including:

- Ingress around closed doorways.
- Ingress through airbricks and up through the ground floor.
- Backflow through overloaded sewers discharging inside the property through ground floor toilets and sinks.
- Seepage through the external walls.
- Seepage through the ground and up through the ground floor.
- Ingress around cable services through external walls.

Since flood management measures only manage the risk of flooding rather than eliminate it completely, flood resilience and resistance measures may need to be incorporated into the design of the buildings. The two possible alternatives are:

Flood Resistance or 'dry proofing', where flood water is prevented from entering the building. For example using flood barriers across doorways and airbricks, or raising floor levels. These measures are considered appropriate for 'more vulnerable' development where recovery from internal flooding is not considered to be practical.

Flood Resilience or 'wet proofing', accepts that flood water will enter the building and allows for this situation through careful internal design for example raising electrical sockets and fitting tiled floors. The finishes and services are such that the building can quickly be returned to use after the flood. Such measures are generally only considered appropriate for some 'less vulnerable' uses and where the use of an existing building is to be changed and it can be demonstrated that no other measure is practicable.

It has been demonstrated as part of this FRA that the primary risk of flooding is from an extreme pluvial event with flood depths predicted to be ~0.060m. The raised threshold recommended in Section 7.2 should therefore be sufficient to prevent in the ingress of surface water run-off during an extreme pluvial event.

Nevertheless, in the unlikely instance of an exceedance event, flood resistance and resilience measures are recommended to be incorporated within the construction of the scheme as a precautionary measure.

When the cost of recovering from an exceedance flood event is compared to the cost of incorporating these mitigation measures, it can be seen that these low cost construction techniques are worth the benefit of reducing the damage to buildings and property. Typical examples of flood resilience measures which may be appropriate for the development site include (but are not limited to) the following:

- Raising floor slab level further
- Bringing the electrical supply in at first floor
- Placing boilers and meter cupboards on the first floor
- Water-resistant plaster/tiles on the walls of the ground floor
- Solid stone or concrete floors with no voids underneath
- Covers for doors and airbricks
- Non-return valves on new plumbing works
- Avoidance of studwork partitions on the ground floor

Details of flood resilience and flood resistance construction techniques can be found in the document 'Improving the Flood Performance of New Buildings; Flood Resilient Construction', which can be downloaded from the Communities and Local Government website.

7.4 Flood Warning

The site is located within an area which is not currently covered by any flood warnings issued by the Environment Agency.

However, during times of heightened flood alert it is likely that regular updates on local and regional flooding will be broadcast via a number of media (e.g. radio/television/online). Therefore, occupants of the site are encouraged to keep updated by watching local TV stations or listen to local radio for flood warning updates.

Monitoring of the Met Office “Weather Warnings” may also provide an indication of when flooding might be expected (http://www.metoffice.gov.uk/weather/uk/uk_forecast_warnings.html).

8 Surface Water Management Strategy

8.1 Background and Policy

As part of the Government's continuing commitment to protect people and property from flood risk, the Department for Environment, Food and Rural Affairs (Defra) consulted on a proposal to make better use of the planning system to secure sustainable drainage systems (2014).

These changes came into effect from 6 April 2015, and relate to The Floods and Water Management Act 2010 National Standards (Schedule 3 – paragraph 5) for design, construction, maintenance and operation of Sustainable Drainage Systems (SuDS). These (non-statutory) Technical Standards for SuDS specify criteria to ensure sustainable drainage is included within developments of 10 dwellings or more; or equivalent non-residential, or mixed development (as set out in Article 2(1) of the Town and Country Planning (Development Management Procedure) (England) Order 2010).

These Technical Standards (S1 -14) provide additional detail and requirements not initially covered by the NPPF. However, it is recognised that SuDS should be designed to ensure that the maintenance and operation requirements are economically proportionate.

In this instance, the proposed development is for in excess of 10 units. Consequently, the National Standards will apply.

Further to this, the current requirement of National Policy is that all new developments in areas at risk of flooding should give priority to the use of SuDS. Within this section of the FRA, reference is therefore made to the new SuDS criteria, ensuring the proposed scheme is compliant with the current planning standards for the lifetime of the development.

8.2 Surface Water Management Overview

The requirements for managing rainfall run-off from developments depends on the pre-developed nature of the site. For undeveloped greenfield sites, the impact of the proposed development will require mitigation to ensure that the run-off from the site replicates the natural drainage characteristics of the pre-developed site.

In the case of brownfield sites, drainage proposals will be measured against the existing performance of the site, although it is preferable for solutions (where practical) to provide run-off characteristics that are similar to greenfield behaviour.

The main characteristics of the site and the proposed development that affect the surface water drainage strategy are summarised in Table 8.1 below.

Site Characteristic	Value
Total area of site	4.2 ha
Impermeable area (existing)	**0 m²**
Impermeable area (proposed)	Roof area = 5370 m^2 Hardstanding = 7280 m^2 **Total = 12650 m^2**
Current site condition	Greenfield site
Greenfield run-off rate	0.4 l/sec/ha (based on IoH Report 124 methodology)
Infiltration coefficient	0.09m/hr - 0.28m/hr (Based on site-specific infiltration testing)
Standard Percentage Run-off (SPR)	27.8%
Current surface water discharge method	No formal drainage
Is there a watercourse within close proximity to site?	No
Is site within groundwater Source Protection Zone?	Yes

Table 8.1 – Site characteristics affecting rainfall run-off

Synthetic rainfall data has been derived using the variables obtained from the Flood Studies Report (FSR) and the routines within the Micro Drainage Source Control software. The peak surface water flows generated on site for the existing and post-development conditions have been calculated by using the Modified Rational Method. Run-off rates have been calculated for a range of annual return probabilities including the 100 year return period event with a 20% increase in rainfall intensity to account for future climatic changes.

These values are summarised in Table 8.2 for a range of return periods. The critical storm duration is shown in brackets.

Return period (years)	Peak run-off (l/sec)	
	Existing site	**Developed site**
1	Undeveloped	190 (15 mins)
30	Undeveloped	468 (15 mins)
100	Undeveloped	610 (15 mins)
100 + 20%	Undeveloped	730 (15 mins)

Table 8.2 – Summary of peak run-off

The total volume of water discharged from the site from the 100 year 6 hour event (including for a 20% increase for climate change) is summarised in Table 8.3 below for both the existing and proposed site conditions.

Site condition	Total volume discharged
Existing site	0 m^3
Proposed development (before mitigation)	942 m^3

Table 8.3 – Total volume discharged from the 100 yr+20%cc 6 hour event

Reference to Tables 8.2 and 8.3 above identify that the proposed development will increase the percentage of impermeable area within the boundaries of the site and consequently, this will increase the volume of surface water run-off from the site. It will therefore be necessary to provide mitigation measures to ensure the rate of run-off discharged from the site is not increased as a result of the proposed development.

As part of this process, the potential use of sustainable drainage techniques within the proposed development will be considered in order to assess the practicality of better replicating greenfield behaviour, in accordance with best practice guidance the National Technical Standards for SuDS.

The general surface water management requirement for all new development is to ensure that the peak discharge rate and the discharge volume of surface water run-off does not exceed that of the existing site. Additionally, surface water run-off up to the 100 year return period event should preferably be contained within the site at designated temporary storage locations unless it can be shown to have no material impact in terms of nuisance or damage, or increase river flows during periods of river flooding (Preliminary rainfall run-off management for developments - EA/DEFRA W5-074/A).

A detailed surface water drainage design has not been undertaken, however, it is necessary for the FRA to demonstrate that the surface water from the proposed development can be discharged safely and sustainably. The following calculations have therefore been undertaken to demonstrate that this is achievable. The proposed method of surface water discharge and the associated constraints is described below.

8.3 Existing Drainage

The exact nature of the existing drainage on site has not currently be confirmed, however, as the site is currently undeveloped it is likely that any surface water run-off is currently discharged informally, directly to the ground. This is supported by the soil conditions and bedrock geology in this location which suggest that surface water run-off from the site is discharged by infiltration. Any surface water run-off which is not infiltrated into the ground is likely to flow away from the site following the natural contours of the land, towards the north west.

8.4 Opportunities to Discharge Surface Water Run-Off

For any given development, the National Standards in relation to SuDS state that the preferred option for discharging surface water run-off from the site is to **infiltrate** water into the ground as this deals with the water at source, and serves to replenish groundwater. If this is not viable (due to a high water table, local impermeable soils, contamination issues including source protection zones etc.), then the next option of preference is for the run-off to be discharged into a **watercourse**. Only if neither of these options is possible should the water be conducted into the **public sewer** system.

Infiltration – The Standard Percentage Run-off (SPR) value has been established for this site from the Flood Estimation Handbook (FEH) database. This parameter is used to indicate the percentage of rainfall which becomes direct response run-off to a watercourse. A higher run-off percentage means that less rainfall is infiltrated into the soil, indicating lower permeability soil.

The SPR for this site is 27.8%, suggesting that the soils have relatively moderate permeability. This is supported by the mapped geology and soil characteristics for this area, which show the site to be located on permeable chalk from the Lewes Nodular Chalk Formation, overlain by semi-permeable clay and silt Head deposits. On this basis, the percolation rate of the soils in this area is considered to be sufficient for traditional infiltration techniques to be utilised.

In order to confirm the infiltration characteristics of the Head and Lewis Chalk, site-specific ground investigations, including infiltration testing, have been undertaken in a number of locations. The results of this testing have confirmed variable infiltration characteristics for the soils and underlying geology across the site. Whilst the bedrock chalk deposits were not intercepted during the trial investigations, infiltration rates into the overlying Head deposits ranged between 0.09m/hr and 0.23m/hr. This range of infiltration rates suggest that the use of infiltration SuDS will be suitable at this location.

<u>Consequently, on the basis of the information above, it has been assumed that infiltration will be the most suitable method for discharging surface water run-off from the site.</u>

As there was considerable variation in the infiltration rates measured across the site, the development has been split into 4 distinct drainage zones. The extent of these zones is delineated in Figure 8.1 below. The infiltration rate within each zone has been based on the corresponding trial pit located within that zone (refer to Table 8.4). This approach ensures that the variability in the infiltration rate is accounted for within the proposed SuDS design. It may be necessary to further confirm the infiltration rate at the exact location for each proposed infiltration SuDS feature.

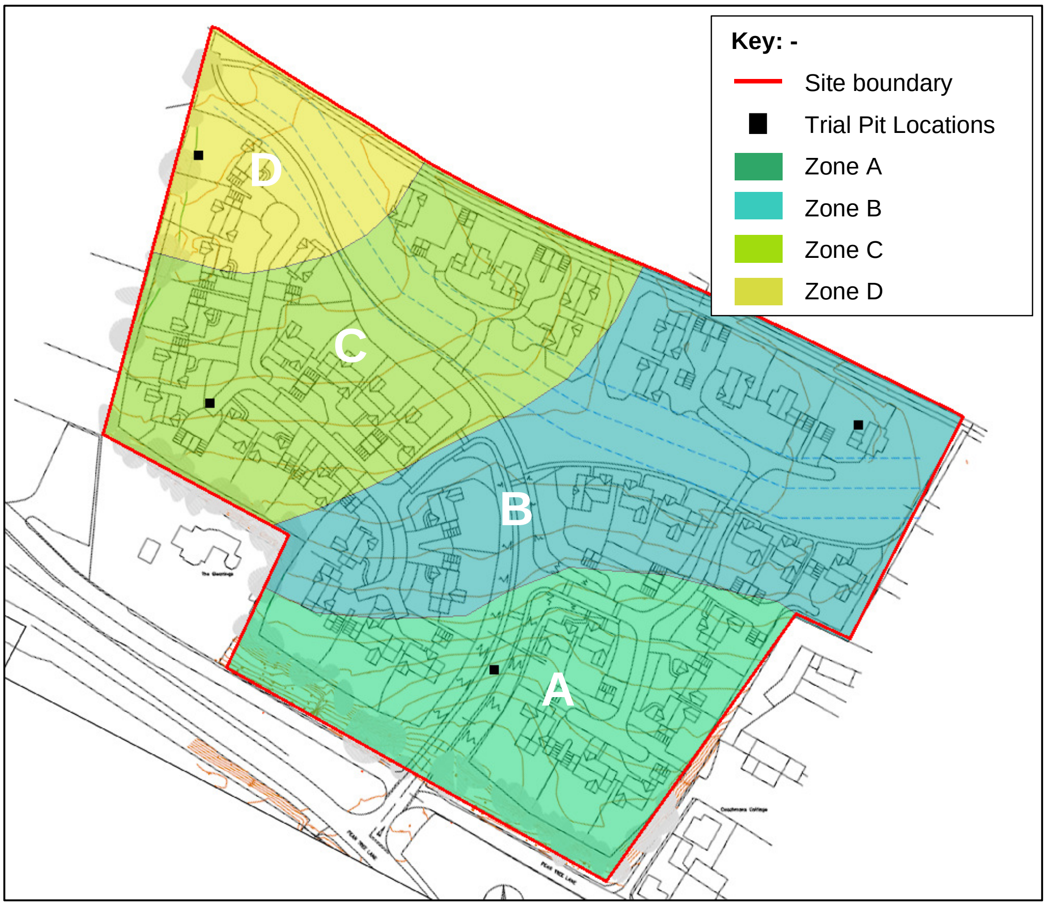


Figure 8.1 – Extent of drainage zones based upon infiltration testing results taken at a number of testing locations (as indicated).

Zone	Infiltration Rate
A	0.09m/hr
B	0.24m/hr
C	0.16m/hr
D	0.12m/hr

Table 8.4 – Infiltration rates for each drainage zone.

Whilst the infiltration rate at the site has been confirmed to be sufficient for the use of infiltration SuDS it is necessary to take a number of other factors into consideration. These are listed below:

- Infiltration SuDS shall not be constructed through contaminated material.
- Any infiltration features which result in a concentrated discharge of surface water run-off to the ground such as soakaways should not normally be located within 5.0 metres of any existing, or proposed (adjacent) buildings. For features constructed in low density chalk deposits geotechnical investigations are often required to determine suitability and this buffer zone is extended to 10.0 metres.
- The depth of any infiltration basin or soakaway should normally not exceed 2.0 metres and under no circumstances shall be permitted to intersect the water table.
- A minimum of a 1.0 metre unsaturated zone shall be maintained between the base of any infiltration basins or soakaways and the maximum seasonal water table for that site.
- Soakaways within an Inner Source Protection Zone for a Public Water Supply shall only be permitted for the sole use of clean roof water drainage.
- Infiltration SuDS intended to drain highway or parking areas will usually require additional safeguards such as seal-trapped gullies or a suitably sized oil/grit separator.
- Soakaways designed to receive clean roof water should be kept separate from those receiving surface water run-off from adoptable highway or parking areas.
- The use of borehole soakaways is always subject to written agreement from the Environment Agency.

In this case the site is shown by the Environment Agency's groundwater Source Protection Zone maps to be located within an area where infiltration is restricted. Figure 8.2 below shows the site in relation to the surrounding Source Protection Zones outlined by the Environment Agency.

Site investigations, undertaken by others, have been carried out in order to demonstrate that an unsaturated zone will be available between the discharge point and the groundwater table at all times of the year.

The results of these investigations have confirmed groundwater levels in this area to be at least 3m below ground level. It is therefore concluded that groundwater levels are at a sufficient depth below the surface to enable the use of infiltration SuDS, including the use of traditional soakaways.

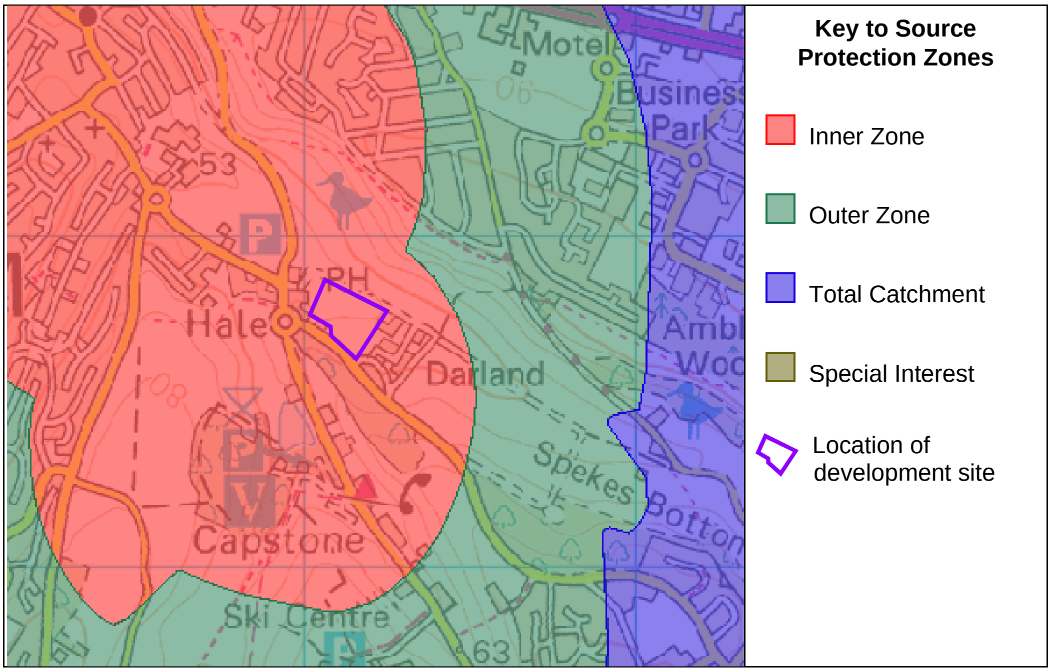


Figure 8.2 – Groundwater map showing the Environment Agency's Source Protection Zones (Contains Ordnance Survey data © Crown copyright and database right 2016)

If infiltration SuDS features are used to discharge surface water from the site, it will be necessary to demonstrate that the design rainfall event (100 year+20%cc) can be managed on site. It may not, however, be practical to design features to accommodate the design event. In this case, it will be necessary to find an alternative method of managing surface water run-off, which maximises the potential for infiltration, whilst also providing the required storage on site.

In addition, any adopted system will need to ensure that, if the capacity of the infiltration system is exceeded, then the impact of any overland flow is considered appropriately. Ideally, surface water run-off should be contained within the site at designated temporary storage locations. If this is not possible it will be necessary to demonstrate that flooding within the site or any floodwater leaving the site can be shown to have no material impact in terms of nuisance or damage, or increase river flows during periods of river flooding. This therefore discussed in more detail in the later sections of this report.

Discharge to Watercourses – There are no known watercourses or ditches within close proximity of the site to permit a direct connection. Consequently, there is no opportunity to utilise a direct connection to an existing watercourse as a means of managing surface water run-off from the proposed development.

Discharge to Public Surface Water Sewer & Existing Connections – The undeveloped site is not currently thought to be in close proximity to any existing sewer connections. Whilst a solution for managing foul waste discharged from the development will be required, it is highly unlikely that capacity will be available within the foul sewers in this area to permit any additional surface water run-off discharged from the site. Consequently, it is unlikely it will be possible to discharge surface water run-off directly into the public sewer system.

8.5 Foul Drainage

With regard to foul drainage, it is likely that the proposed development will require a new connection into the foul sewer network in close proximity to the site. At the detailed design stage, it will be necessary to confirm that there is adequate capacity in the existing foul sewers at this location to accommodate any additional foul waste from the new residential units.

8.6 Constraints and Further Considerations

Although testing undertaken at the site has confirmed a good infiltration. Additional investigations to refine the known infiltration rates in the location of any proposed infiltration SuDS, as well as confirm the depth below the ground level of the groundwater table, may be required at the detailed design stage. At this 'strategic' stage, the surface water management strategy has been based upon the confirmed infiltration testing results and drainage zones outlined in Section 8.4 of this report.

Analysis of the BGS bedrock and superficial geological mapping shows the site to be located on bedrock strata of chalk. When building soakaways in strata subject to modification or dissolution such as chalk, there is the potential for issues to arise with regards to subsidence, structural instability and modification when wetted. Care should therefore be taken to ensure the location of the soakaway is far away from proposed structures.

Consequently, the proposed drainage plan must take into consideration the 5m mandatory buffer zone for soakaways. It is also recommended that specialist advice is sought from an engineering geologist at the detailed design stage with regard to building soakaways in the chalk strata.

Due to the sensitive nature of the aquifer resources directly beneath the site, care should also be taken to ensure the discharge of surface water run-off to the ground is from clean sources which will not result in pollution of the underlying aquifer and source protection zone. As a result, it will not be permissible to discharge surface water run-off from the highway areas directly to the ground via soakaways. Nonetheless, the use of oil interception devices, sediment catch pits and other pollution control measures should be explored further at the detailed design stag and the use of permeable paving is still likely to be suitable.

Inspection of the site and scheme layout shows that whilst there are opportunities for the inclusion of Sustainable Drainage Systems (SuDS), there is very little open space in which to incorporate SuDS features that require significant areas of land such as wetland areas and large detention basins etc. The SuDS options are discussed in more detail in the following section.

8.7 Sustainable Drainage Systems (SuDS)

Appropriately designed SuDS can be utilised such that they not only attenuate run-off but also provide a level of improvement to the quality of the water passed on to watercourses or into the groundwater table. This is known as source control and is a fundamental part of the SuDS philosophy.

A range of typical SuDS components that can be used to improve the environmental impact of a development is listed in Table 8.5 below along with the relative benefits of each feature and the appropriateness for the subject site.

SuDS Feature	Environ-mental benefits	Water quality improve ment	Suitability for low permeability soils (k<10-6)	Ground-water recharge	Suitable for small/ confined sites?	Site-specific restrictions	Appropriate for subject site?
Wetlands	–	–	–	x	x	Insufficient space	No
Retention ponds	–	–	–	x	x	None	Yes
Detention basins	–	–	–	x	x	Insufficient space	No
Infiltration basins	–	–	x	–	x	None	Yes
Soakaways	x	–	x	–	–	None	Yes
Underground storage	x	x	–	x	–	None	Yes
Swales	–	–	–	–	x	None	Yes
Filter strips	–	–	–	–	x	None	Yes
Rainwater harvesting	x	–	–	–	–	None	Yes
Permeable paving	x	–	–	–	–	None	Yes
Water butts	–	x	–	x	–	None	Yes
Green roofs	–	–	–	x	–	Dependant on proposed roof construction	Unknown at this stage

Table 8.5 – Suitability of SuDS

From Table 8.5 it can be seen that there are a number of SuDS elements that are potentially suitable for this site. However, at this stage in the planning process, it is envisaged that a combination of soakaways and permeable paving will be used to discharge the surface water run-off via infiltration.

8.8 Proposed Surface Water Management Strategy (SWMS)

The SWMS for each of the different elements of the scheme is set out below along with the calculations that have been undertaken to demonstrate how the overall objectives have been achieved. This does not represent a detailed surface water drainage design, it is simply an assessment to demonstrate that the objectives and requirements of the NPPF can be met at the planning stage.

Permeable Paving

For the roads, car parking and hardstanding areas, it is possible to incorporate permeable paving. Provided that this is laid onto a minimum of a 0.2m thick open-graded sub-base, this will provide sufficient storage for the run-off before discharging via infiltration such that the 100 year+20%cc event can be fully discharged.

The area of permeable paving proposed has been estimated from the scheme drawings provided, this has been based on the assumption that one third of the proposed highway will not be suitable for the use of permeable paving due to tyre scrub and the requirement for drainage access points and pathways.

To ensure a conservative estimate for the required sub-base depth across the site is provided, the calculations have been based upon the lowest infiltration rate of 0.09 m/hr determined from the site investigations. A summary of the Micro Drainage analysis for permeable paving is shown in Table 8.6 below.

Parameter	Value
Area draining to permeable paving	7280 m^2
Area of permeable paving	5000m^2
Critical storm duration	60 minutes
Maximum filtration	62.5 l/sec
Half drain time	21 minutes
Required sub-base depth	0.2m

Table 8.6 – Summary of Micro Drainage analysis for the permeable paving (100 yr+20%cc)

Ring Soakaways

The surface water run-off from the roofs of the buildings across the entire site can be discharge via a series of ring soakaways. The details for the proposed soakaways within each drainage catchment area (as detailed in Section 8.4) are outlined below:

Drainage Zone A - Roof Drainage

The surface water run-off from the roofs of the buildings in drainage Zone A can be discharged by ring soakaways, this is based upon the measured infiltration rate of 0.09m/hr.

Parameter	Value
Area draining to Soakaways	1420 m^2
Type of Soakaway	Ring Soakaways
Number of soakaways	11
Total Area Discharging to Each Soakaway	129 m^2
Assumed Infiltration Rate	0.09 m/hr
Maximum Filtration	2.0 l/sec
Critical storm duration	240 minutes
Half drain time	380 minutes
Dimensions	2m (diameter) x 1.5m (deep)

Table 8.7 – Summary of Micro Drainage analysis for the roof area (100 yr+20%cc)

Drainage Zone B - Roof Drainage

The surface water run-off from the roofs of the buildings in drainage Zone B can be discharged by ring soakaways, this is based upon the measured infiltration rate of 0.24m/hr.

Parameter	Value
Area draining to Soakaways	1740 m^2
Type of Soakaway	Ring Soakaways
Number of soakaways	14
Total Area Discharging to Each Soakaway	124 m^2
Assumed Infiltration Rate	0.24 m/hr
Maximum Filtration	5.8 l/sec
Critical storm duration	180 minutes
Half drain time	133 minutes
Dimensions	1.8m (diameter) x 1.5m (deep)

Table 8.8 – Summary of Micro Drainage analysis for the roof area (100 yr+20%cc)

Drainage Zone C - Roof Drainage

The surface water run-off from the roofs of the buildings in drainage Zone C can be discharged by ring soakaways, this is based upon the measured infiltration rate of 0.16m/hr.

Parameter	Value
Area draining to Soakaways	1870 m^2
Type of Soakaway	Ring Soakaways
Number of soakaways	16
Total Area Discharging to Each Soakaway	117 m^2
Assumed Infiltration Rate	0.16 m/hr
Maximum Filtration	4.6 l/sec
Critical storm duration	180 minutes
Half drain time	195 minutes
Dimensions	1.8m (diameter) x 1.5m (deep)

Table 8.9 – Summary of Micro Drainage analysis for the roof area (100 yr+20%cc)

Drainage Zone D - Roof Drainage

The surface water run-off from the roofs of the buildings in drainage Zone D can be discharged by ring soakaways, this is based upon the measured infiltration rate of 0.12 m/hr.

Parameter	Value
Area draining to Soakaways	330 m^2
Type of Soakaway	Ring Soakaways
Number of soakaways	3
Total Area Discharging to Each Soakaway	110 m^2
Assumed Infiltration Rate	0.12 m/hr
Maximum Filtration	0.6 l/sec
Critical storm duration	240 minutes
Half drain time	255 minutes
Dimensions	1.8m (diameter) x 1.5m (deep)

Table 8.10 – Summary of Micro Drainage analysis for the roof area (100 yr+20%cc)

Figure 8.3 (below) is an indicative drainage layout plan delineating the potential for ring soakaways to be incorporated into the scheme proposals. A higher resolution version of this plan can be found within Appendix A.3 of this report.

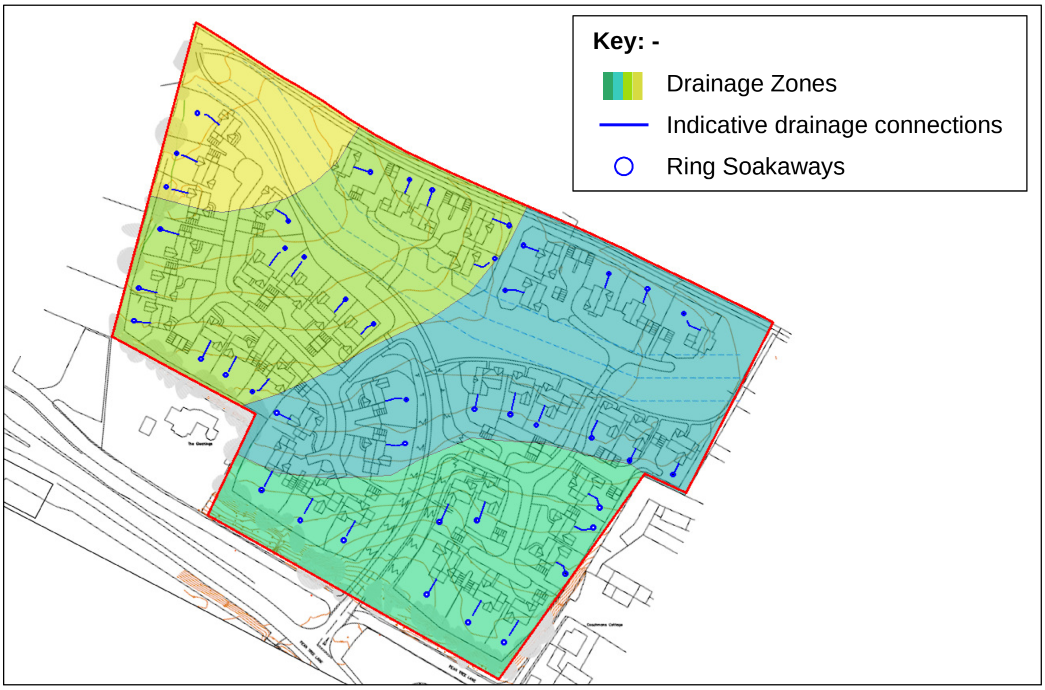


Figure 8.3 – Indicative drainage layout plan delineating the potential location for soakaways across the site.

8.9 Additional Opportunities for SuDS

Additional opportunities for the incorporation of SuDS within the proposed scheme are outlined below:

Swales – It may be possible to use swales adjacent to the highway areas or within some of the areas of green open space as conveyance features to redirect run-off from the highways into large crate soakaways or infiltration ponds instead of the proposed permeable paving. Swales would provide storage for run-off and an additional treatment system for filtering pollutants from the highway areas.

Rainwater Harvesters – Based on the proposed scheme there is potential to incorporate rainwater harvesting systems within each dwelling. Utilising rainwater harvesting would not only provide some additional storage for storm water, but would also help to reduce the developments reliance on potable water supplies. If rainwater harvesting is proposed, analysis of the potential demand and yield, as well as the cost effectiveness of utilising such a system, should be examined at the detailed design stage. At this stage the surface water management strategy simply outlines the potential possibility of incorporating rainwater harvesting within the scheme.

Rain Gardens – For small areas of isolated hardstanding such as garden paths and sheds, it may be possible to discharge run-off to dedicated areas of landscaped rain gardens. These rain gardens could be profiled to allow run-off to pond and infiltrate into a thin soil substrate of permeable sand or gravel.

Green Roofs – Surface water run-off from all or part of the roof areas across the proposed development could be discharged through a series of green roofs. The incorporation of green roofs will act to store and filter a large amount of run-off from the roof area within the soil substrate of the planted areas.

The incorporation of green roofs would, however, depend on whether the roof construction type is suitable. It will also be necessary to provide adequate drainage at the base of the green roof to avoid stagnation, as well as provide a means of attenuating and discharging run-off in the event that the roof is saturated prior to a rainfall event. Nonetheless, green roofs would provide an additional level of treatment for any surface water run-off discharging from the roofs of the proposed properties. At this stage the surface water management strategy simply outlines the potential possibility of incorporating green roofs within the scheme.

Water Butts – Given the nature of the development there is some scope for the incorporation of water butts within the proposed scheme. Typical sizes and dimensions of water butts are outlined below.

Typical House Water Butt Options	Dimensions of a typical house water butt	Volume of storage provided (litres)
Type 1 (wall mounted – Small)	1.22m high x 0.46m x 0.23m	100
Type 2 (Standard house water butt)	0.9m high x 0.68m diameter	210
Type 3 (Large house water butt)	1.26m high x 1.24m x 0.8m	510
Type 4 (Column tank – Very large)	2.23m high x 1.28m diameter	2000

Table 8.11 - Estimated storage capacity of available water butts

8.10 Management and Maintenance

In order for any surface water drainage system to operate as originally designed, it is necessary to ensure that it is adequately maintained throughout its lifetime. For commercial development this is generally taken as 60 years and residential 100 years is assumed. Therefore over the lifetime of a development there is a strong possibility that the system could either fail or its performance be reduced if it is not correctly maintained. This is even more important when SuDS form a part of the surface water management system, as these require a more onerous maintenance regime than a typical piped network.

The key requirement of any management regime is routine inspection and maintenance and therefore at the stage when the development is taken forward to the detailed design stage an 'owners manual' will need to be prepared. This will include:

- A description of the drainage scheme,
- A location plan showing all of the SuDS features and equipment such as flow control devices etc.
- Maintenance requirements for each element
- An explanation of the consequences of not carrying out the specified maintenance

For the SuDS features recommended by this assessment, the most obvious maintenance tasks will be the cleaning of the permeable paving and the de-silting of soakaways. For the latter, it is important to ensure that the design must recognise the need for this operation and thus incorporate silt traps and easy access for emptying.

At this point in time there are no formal arrangements for SuDS to be adopted; however, for developments such as this that rely to some extent on the ongoing inspection and maintenance of the SuDS features, it will be necessary to ensure that measures are in place.

One option would be to task the management company responsible for maintaining the rest of the site with the inspection and maintenance of the SuDS elements. An alternative option could be to task the individual residents with the maintenance responsibilities for their individual property and the associated drainage features. However, measures will need to be put in place to ensure occupants are made aware of maintenance schedules.

8.11 Residual Risk

The proposed surface water management strategy has been design for the 1 in 100 year event, including an allowance for climate change in line with the NPPF and National Technical Standards for SuDS. However, in line with the precautionary principle, the impact a scenario outside of these design parameters, such as an exceedance rainfall event or the failure of the surface water drainage system, has been evaluated. This is termed *residual risk*.

The mitigation measures discussed previously within this section of the report, such as the incorporation of flood resistance and resilience techniques and raising the threshold, will significantly reduce the risk of the development being affected by flooding from a residual risk event. They do not, however, completely remove the risk. The impact of a residual risk event has therefore been assessed in this part of the FRA.

Sensitivity testing has been undertaken for all elements of the proposed surface water drainage plan. In order to evaluate the impact of an event which exceeds the design event, the proposed drainage system has been tested for a 1 in 100 year event with a 40% increase in rainfall, which represents an additional 20% increase in the allowance for climate change applied in Section 8.8.

The results of the sensitivity testing demonstrate that both the proposed permeable paving and soakaways have sufficient capacity to deal with the 1:100+40%CC event. It has therefore been demonstrated that the proposed permeable paving and soakaways will provide additional flood storage, which is currently not available at the site, thereby minimising the risk of flooding offsite during an extreme flood event. This additional storage will act to reduce the rate of run-off contributing to the overland flow path previously identified in Section 5, and will therefore provide a betterment to any development downslope of the site.

Although it is not mandatory to design for the exceedance event, it is possible to increase the volume of storage available at the site by either increasing the depth of the sub-base for the proposed permeable paving, or incorporating any of the additional SuDS measures outlined in Section 8.4.

In conclusion, the proposed system has been shown to have sufficient capacity to deal with an additional 20% increase in the design rainfall event, and this ancillary storage will reduce the rate of run-off contributing to the overland flow path previously identified during an exceedance event. Thereby helping to minimise the risk of flooding offsite when compared to the existing situation.

8.12 Summary of Proposed Surface Water Management Strategy

The overarching objective of a SWMS is to identify a sustainable surface water drainage system that reduces the peak rate and volume of run-off from the site to a value that is less than would be experienced with the existing site condition. This helps to reduce the amount of surface water discharged from the site and passed onto systems further downstream and thus in doing so helps to reduce the risk of flooding.

This strategy recommends that the development utilises infiltration as much as is reasonably possible, which is in line with the hierarchical approach promoted by current best practice. Further to this, infiltration testing has been undertaken the site to confirm ground conditions at the site are suitable for the use of infiltration SuDS.

The strategy that has been identified at this early stage in the development design process achieves the aspirational objective of reducing peak discharge rates to the greenfield run-off value by utilising a combination of permeable paving and soakaways.

Other potential opportunities to incorporate SuDS measures within the scheme have been explored, including the use of swales, rainwater harvesting and green roofs. These options could be used to provide additional storage onsite, thereby providing additional pollution control benefits and reducing the required capacity within the proposed soakaways. Further detailed site investigations may be required at the detailed design stage to confirm which are the most suitable for incorporation into the scheme.

The above calculations are indicative only and whilst they do not comprise a detailed drainage scheme, they do at this stage demonstrate that the proposed strategy for managing surface water run-off is achievable.

9 Conclusions

The key aims and objectives for a development that is to be sustainable in terms of flood risk are summarised in the following bullet points:

- the development should not be at a significant risk of flooding, and should not be susceptible to damage due to flooding
- the development should not be exposed to flood risk such that the health, safety and welfare of the users of the development, or the population elsewhere, is threatened
- normal operation of the development should not be susceptible to disruption as a result of flooding and safe access to and from the development should be possible during flood events
- the development should not increase flood risk elsewhere
- the development should not prevent safe maintenance of watercourses or maintenance and operation of flood defences by the Environment Agency
- the development should not be associated with an onerous or difficult operation and maintenance regime to manage flood risk; the responsibility for any operation and maintenance required should be clearly defined
- the development should not lead to degradation of the environment
- the development should meet all of the above criteria for its entire lifetime, including consideration of the potential effects of climate change

In determining whether the proposals for development at Darland Farm are sustainable in terms of flood risk and are compliant with the NPPF and its Planning Practice Guidance, all of the above have been taken into consideration as part of this FRA.

The Environment Agency Flood Zone mapping has identified that the site is located partially in Flood Zones 2 and 3. However, further analysis has been undertaken to establish whether this mapping is accurate, given that there are no tidal/fluvial sources in close proximity which could impact the site.

It has subsequently been demonstrated that the EA flood zone maps are likely to be incorrect at this location and as such, this appraisal has been prepared on the assumption that the proposed development site is located within Flood Zone 1. Notwithstanding this, it is recognised that there is a natural flow path that could transport surface water across the site during an extreme pluvial event and therefore, the risk of flooding from this source has been considered in more detail.

Based on the assumption that the EA mapping is incorrect, the site would not be subject to the Sequential Test. Furthermore, if the site is considered to meet the requirements of the Sequential Test, then the Exception Test is not applicable by default.

However, as the potential exists for the site to be affected by minor surface water flooding and the subject site is larger than 1 hectare in size, it is still necessary to examine the impact of flooding from all sources over the lifetime of the development. This has therefore been the focus of this site-specific FRA.

The risk of flooding from a wide range of sources has been examined and it has been demonstrated that the pathway indicated by the Environment Agency mapping is likely to be the result of an overland flow path, which dissects the site.

In order to quantify the potential magnitude and depth of flooding from this source, the impact of an extreme pluvial event has been investigated using of a number of hydrological prediction methods. The results of these models have shown that the base of the dry valley in which the site is located could be affected by flood depths in region of 0.06m under the design event.

Nonetheless, the scheme has been designed to ensure that the proposed buildings are located on higher ground, away from the natural depressions within the site, i.e. outside of the extents predicted as a result of the hydrological assessment. This approach will also ensure that the identified natural overland flow path remains unobstructed.

Furthermore, additional mitigation measures have also been incorporated within the design to warrant that the risk of flooding to the occupants remains low. These measures include raising the thresholds of the proposed dwellings by 150mm, and incorporating flood resistant and resilient construction techniques where possible.

The predicted depth of flooding is a considered to be a conservative estimate, as it does not account for the volume of surface water run-off intercepted by the proposed surface water drainage system. A Surface Water Drainage Strategy has been prepared to ensure that the proposed development will not increase the risk of flooding (both on or offsite), as a result of additional surface water run-off discharged from the developed parts of the site.

The results of infiltration testing undertaken at the site have confirmed that the use of infiltration SuDS will be appropriate in this location. Based on the derived infiltration rates, the proposed drainage strategy utilises a combination of ring soakaways and permeable paving to discharge surface water run-off to the ground. This SuDS system will achieve the aspirational objective of reducing peak discharge rates to the greenfield run-off value.

Further to this, the system has been shown to have extra capacity, which will reduce the rate of run-off contributing to the overland flow path. This provides a potential betterment on the existing situation, minimising the amount of water passed on to the surrounding area. This has been shown to remain the case even when the allowance for climate change is increased to 40%.

In conclusion, this report has demonstrated that, not only the risk of flooding is significantly lower than that depicted by the coarse Environment Agency flood zone map, but with the incorporation of the measures recommended in this report, the occupants of the proposed dwellings will be safe and the proposals will not exacerbate the risk of flooding elsewhere.

10 Recommendations

The findings of this report conclude that the development will not increase flood risk at the site, or elsewhere. There are, however, a number of mitigation measures and recommendations that are required to reduce the risk to the development and other areas within the floodplain.

- The finished ground floor level for all buildings shall be set at least 150mm above the existing ground level.

- The flood resilience measures outlined in Section 7.3 of this report are to be incorporated into the design of the building where possible.

- The surface water management strategy for the development will need to be developed to a detailed design stage and this will need to take into account the requirements set out in Section 8.1 and 8.2.

- The use of appropriate SuDS techniques as discussed in Section 8 should be considered for incorporation into the scheme design. For this development the use of permeable paving and ring soakaways is recommended.

- At the detailed design stage, it may be necessary to undertake further site-specific investigations in order to further quantify; the groundwater level, infiltration characteristics and the level of contamination that may be present in the soils at specific locations of the proposed features.

- Further investigation into suitable pollution control measures such as, oil and petrol interceptors and silt traps should be undertaken at the detailed design stage to ensure the final design minimises the potential for contaminants to discharge into the proposed soakaways.

With the above mitigation measures incorporated into the design of the development the proposals will meet the requirements of the NPPF and its Planning Practice Guidance and will therefore be acceptable and sustainable in terms of flood risk.

11 Appendices

Appendix A.1 – Drawings

Appendix A.2 – ReFH2 Outputs

Appendix A.3 – Indicative Drainage Layout

Appendix A.4 – Soakage Test Report

Appendix A.5 – Surface Water Management Calculations