Foul and Surface Water Management Strategy

Land at School Lane

Bapchild

Sittingbourne

ME9 9NJ

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1. Background and Introduction

The following Foul and Surface Water Management Strategy accompanies a planning application submitted to Swale Borough Council. The planning application is for residential development on land at School Lane, Bapchild, Sittingbourne, ME9 9NJ.

2. Development Description and Location

Development Location

The site is located at School Lane, Bapchild, Figure 1. The site is situated to the south of School Lane and to the west of Church Street. It is a greenfield site that covers 0.69ha.

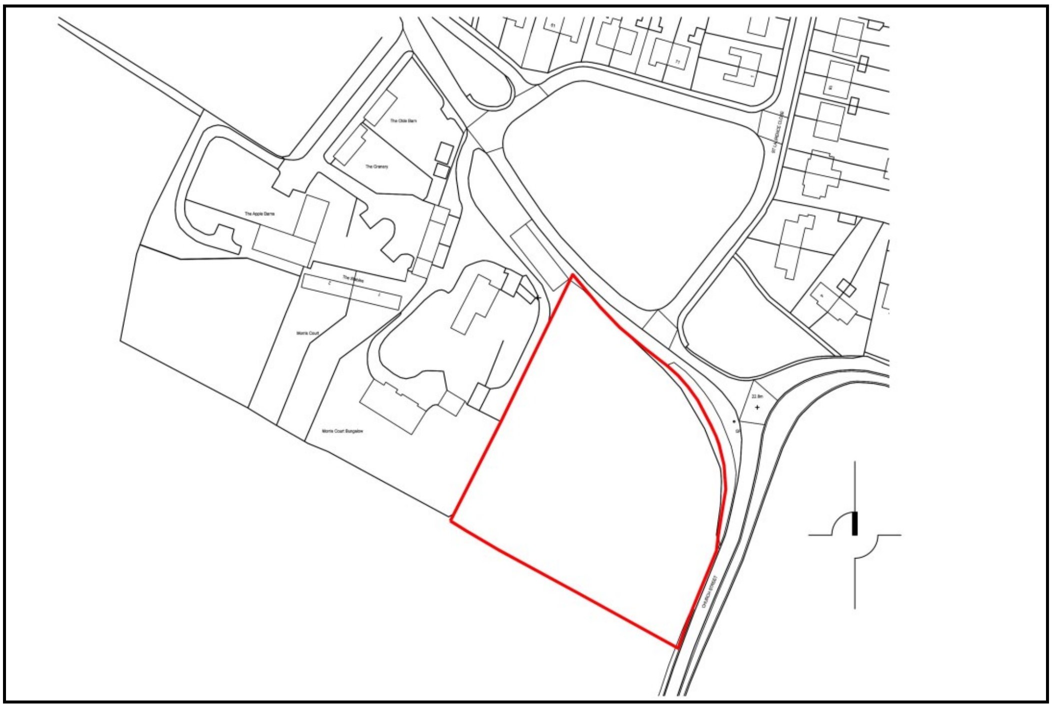


Figure 1. Site location plan.

Development Proposals

An outline planning application is proposed, with all matters except access reserved for future determination. An illustrative layout has been produced showing 14 dwellings, Figure 2.

Figure 2. Proposed development.

3. Policy Background

The management of surface water across the development has to comply with a number of local policy documents adopted by Swale Borough Council.

Swale Borough Council Strategic Flood Risk Assessment

Swale Borough Council published a Strategic Flood Risk Assessment in 2009. The SFRA states that:

The centre of Sittingbourne is predominantly located over chalk, but the surrounding area has sand, brickearth, gravel, alluvium and clay beds. As with Faversham, infiltration may be possible in most areas, particularly the chalk (assuming sufficient depth to the water table), but clay areas are typically very low permeability so it is likely that discharge into a watercourse may be necessary (unless the runoff can be infiltrated at a neighbouring site). Furthermore much of Sittingbourne lies over a Source Protection Zone which may potentially constrain infiltration depending on land use and treatment level achieved. SUDS devices are still appropriate, however, in order to attenuate runoff rates to avoid a sudden flush of large volumes of water into the watercourse and provide water quality treatment.

The application of SUDS in Swale Borough is heavily dependent upon the site characteristics, such as geology and topography of the site and surrounding areas. An indication of soil hydrological properties in Swale Borough is illustrated in the SFRA, Figure 3. Infiltration may not be viable in the soil areas of 47.2% and 49.6% SPR (Standard Percentage Runoff), but other soils areas are in principle sufficiently permeable to allow the infiltration of surface water runoff. The site lies within an area where the SPR is 29.2%.

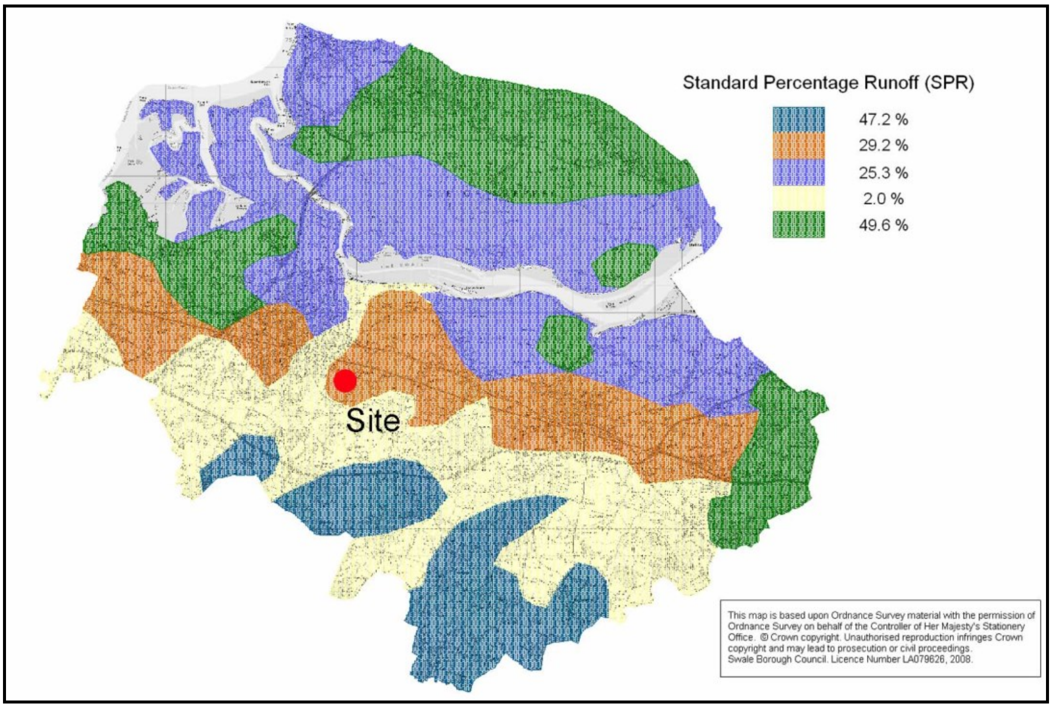


Figure 3. Soil hydrology for Swale Borough (© Swale Borough Council).

Swale Borough Council Local Plan 2008

Flooding and surface water feature within the policies of Swale Borough Council's Adopted Local Plan.

Policy E2 - Pollution states that all development proposals will minimise and mitigate pollution impacts including to water supply sources, groundwater aquifers, or local hydrology.

Policy E4 - Flooding and drainage states that The Borough Council will not grant planning permission where the development would give rise to increased risk to, human life, ecosystems, habitats and development from increased surface water run-off from the creation of large impermeable areas.

Bearing Fruits 2031 The Swale Borough Council Local Plan

The emerging Local Plan was placed on consultation in December 2014.

Policy DM 19 - Sustainable design and construction states that: *Until proposed Government changes to housing standards come into effect, all new residential developments will meet the full Code for Sustainable Homes standards Code Level 3 or above.*

Policy DM 21 - Water, flooding and drainage states that:

When considering the flooding and drainage implications of development, development proposals will:

1. *Accord with national planning policy and technical guidance;*
2. *Avoid inappropriate development in areas at risk of flooding and where development would increase flood risk elsewhere;*
3. *Provide site specific flood risk assessments, as required, carried out to the satisfaction of the Environment Agency and, if relevant, the Internal Drainage Board. These will, where necessary, include details of new flood alleviation and flood defence measures to be installed and maintained by the developer;*
4. *Include, where possible, sustainable drainage systems to restrict runoff to an appropriate discharge rate, maintain or improve the quality of the receiving watercourse, to enhance biodiversity and amenity and increase the potential for grey water recycling;*
5. *Integrate drainage measures within the planning and design of the project to ensure that the most sustainable option can be delivered, especially where, exceptionally, development is to be permitted in an area of flood risk;*
6. *Within areas at risk of flooding, submit a suitable flood warning and emergency plan that has been approved by the relevant emergency planning regime and, where appropriate, the emergency services;*
7. *Where necessary, demonstrate that adequate water supply and wastewater connection and treatment infrastructure is in place before construction commences and that these details have been approved by the appropriate water company and funded by the development where appropriate;*
8. *Ensure future unconstrained access to the existing and future sewerage and water supply infrastructure for maintenance and up-sizing purposes; and*
9. *Make efficient use of water resources and protect water quality, including, for new residential development, all homes to be designed to achieve a minimum water efficiency of 105 litres per person per day (equivalent to Code for Sustainable Homes Levels 3) in advance of any alternative national, mandatory, requirements which may be applied.*

4. Site Characteristics including Flood Risk Assessment

Topographical Survey - A detailed topographical survey has been carried out. The site slopes from a high point in the south of 32mAOD (Above Ordnance Datum), north to a level of 21mAOD, Figure 4, at a gradient of approximately 1 in 13.

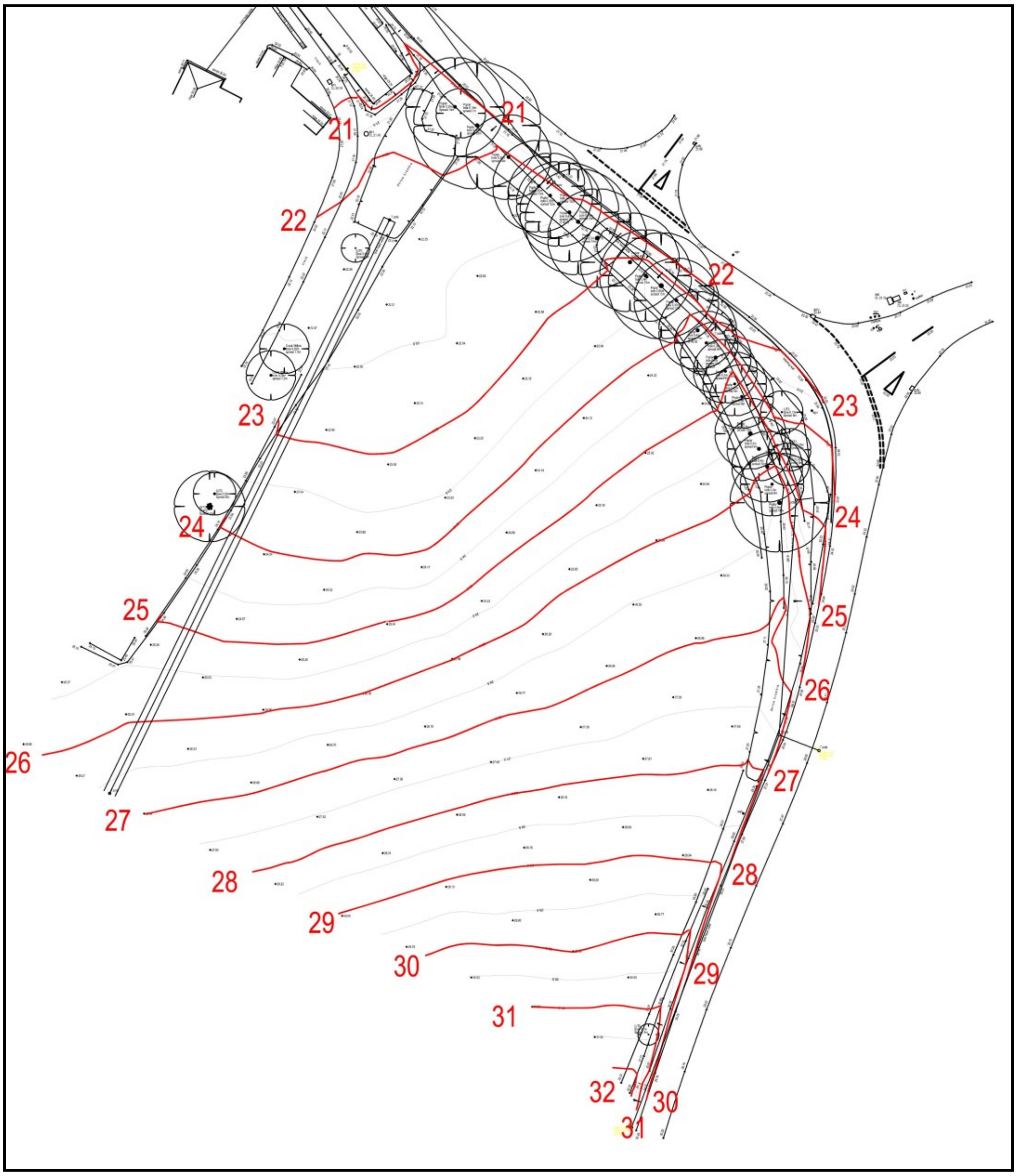


Figure 4. Local topography.

Geology and Soils - The bedrock geology consists of the Thanet Formation, sand, silt and clay. Superficial Head deposits, clay and silt are recorded over the south west corner of the site. Soils are classified as freely draining loamy soils.

Groundwater Protection Zone - The site lies within the outer groundwater source protection zone defined by a 400 day travel time from a point below the water table, Figure 5. The Thanet Formation is designated a secondary A bedrock aquifer defined as permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers, Figure 6. These are generally aquifers formerly classified as minor aquifers.

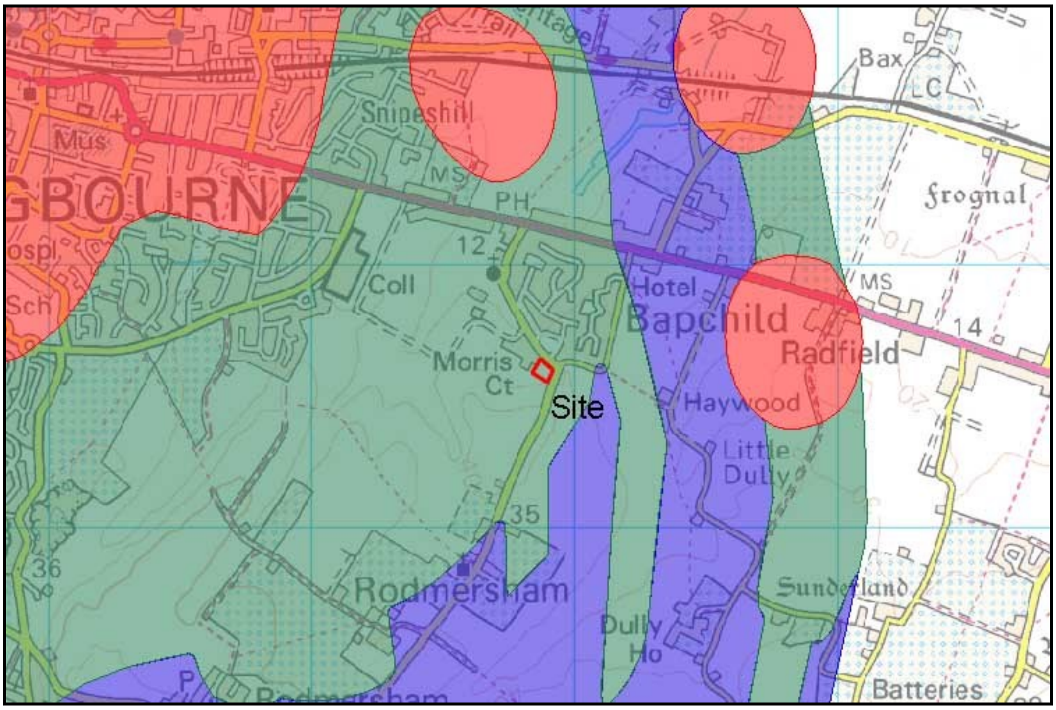


Figure 5. Groundwater source protection zone map showing zone 2 (green). (© Environment Agency)

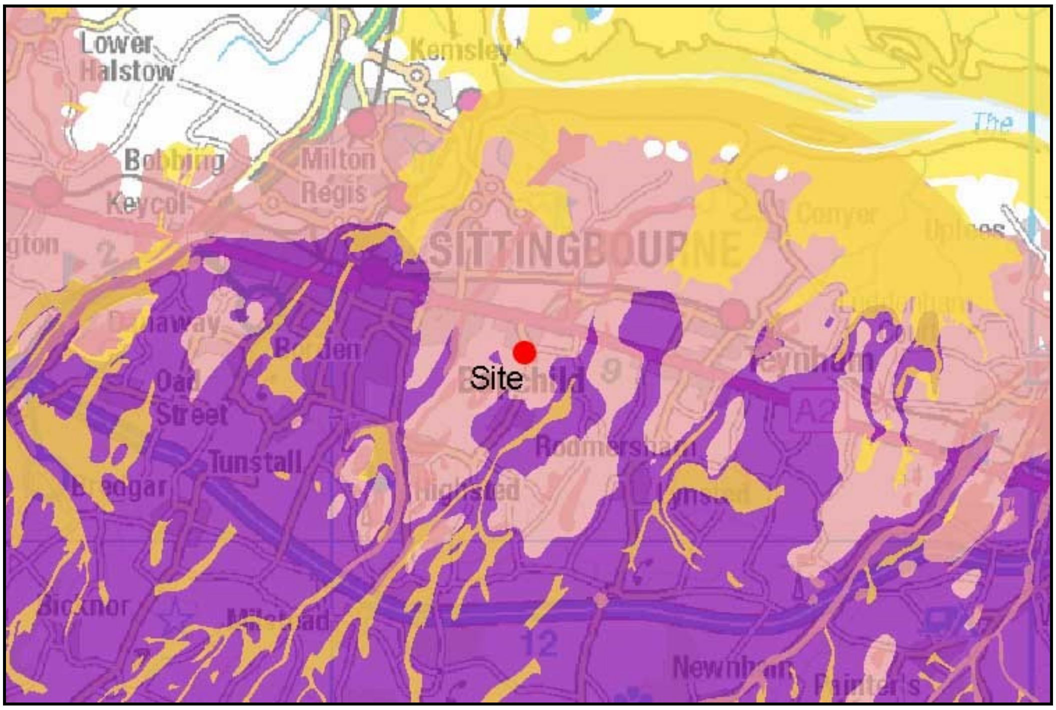


Figure 6. Aquifer map showing secondary A bedrock aquifer (pink). (© Environment Agency)

Infiltration Rates - Soakage testing has not been carried out at the site. Infiltration rates for common types of soil are shown in Table 1.

Soil Type	Infiltration Rate *f*
gravel	2.8×10^{-3} to 0.28 m/s
sand	2.8×10^{-5} to 0.028 m/s
loamy sand	2.8×10^{-6} to 2.8×10^{-4} m/s
sandy loam	1.4×10^{-5} to 1.4×10^{-4} m/s
loam	2.8×10^{-7} to 2.8×10^{-5} m/s
silt loam	1.4×10^{-7} to 2.8×10^{-5} m/s
chalk	2.8×10^{-7} to 0.028 m/s
sandy clay loam	2.8×10^{-7} to 2.8×10^{-5} m/s
clayey gravels	1.0×10^{-8} to 1.0×10^{-6} m/s
clayey sands	1.0×10^{-9} to 1.0×10^{-6} m/s

Table 1. Infiltration rates for typical soils.

An infiltration rate of 1.0 x 10^{-5} m/s has been assumed for infiltration within the Thanet Formation. This assumed rate will need to be verified before the design and construction of any infiltration devices.

Existing Surface Water Drainage Patterns - The site slopes from south to north at a gradient of approximately 1 in 13. The site is part of a wider catchment that drains to the northeast via watercourses that discharge to the sea northeast of Sittingbourne, Figure 7.

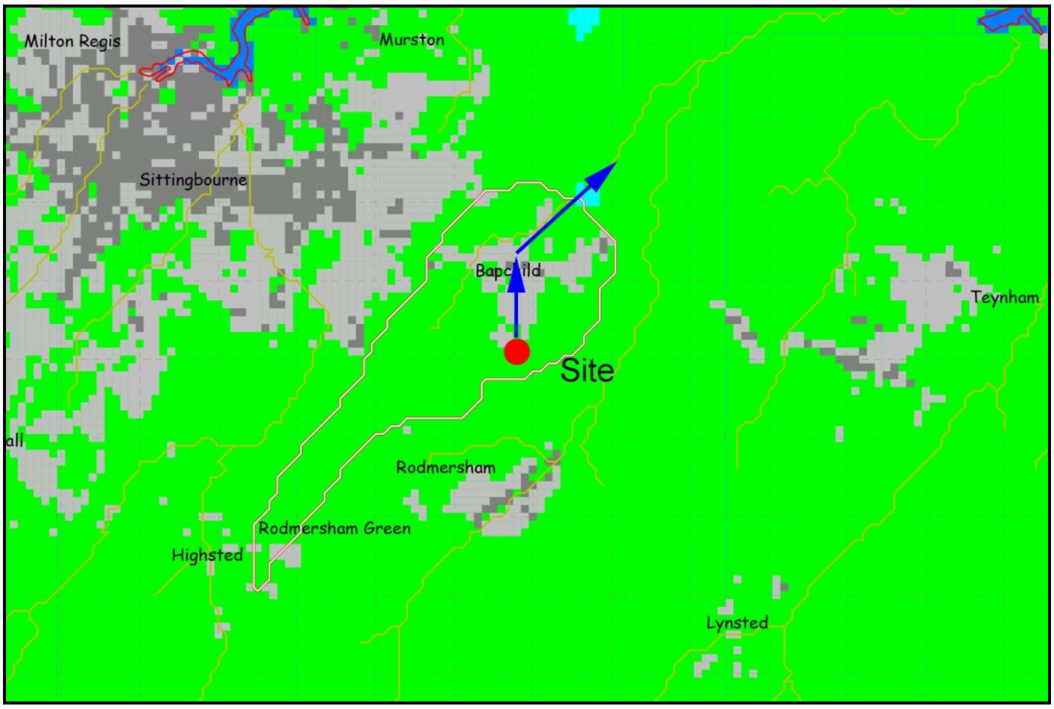


Figure 7. Local drainage catchment.

Sewer Record - The nearest public foul sewer is within School Lane, 70m from the proposed site access, Figure 8. The sewer is a 100mm diameter vitrified clay pipe with a cover level of 18.57mAOD and an invert level of 18.07mAOD. There are foul and surface water sewers serving the development north and west of Panteney Lane.

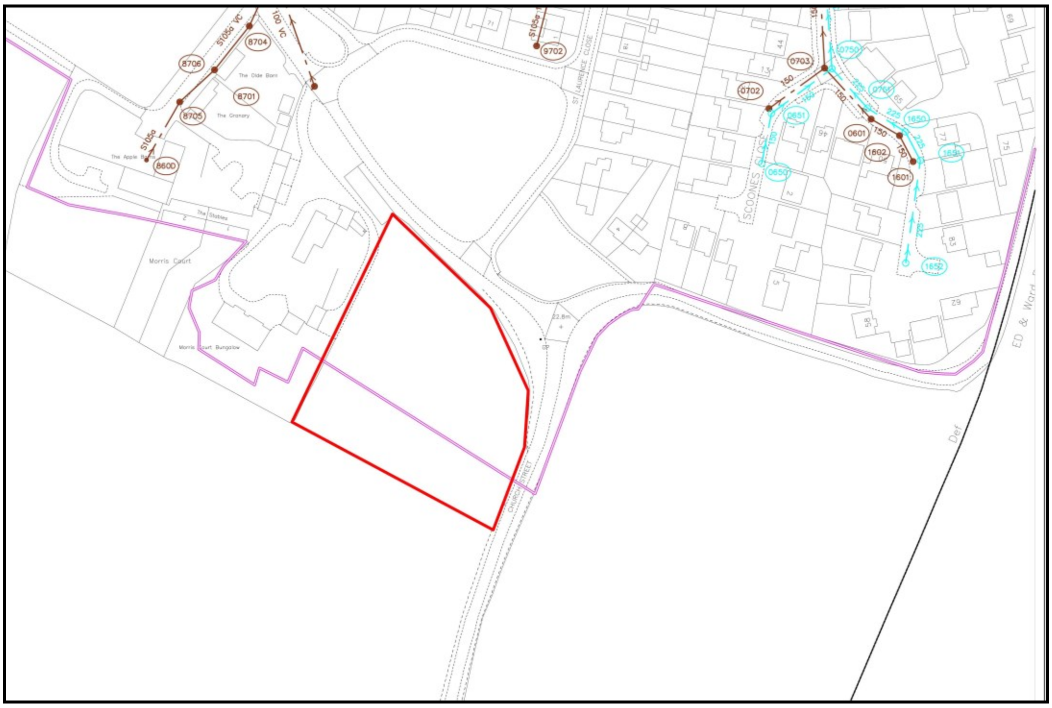


Figure 8. Public sewer record with the site edged red.

Flood Risk - The NPPF states that inappropriate development in areas at risk of flooding should be avoided by directing development away from areas at highest risk. Local Plans should apply a sequential, risk-based approach to the location of development to avoid where possible flood risk to people and property and manage any residual risk, taking account of the impacts of climate change by applying the Sequential Test.

Flood zones are the starting point for the Sequential Test. These zones are a broad assessment of flood risk as given below.

Zone 1 Low Probability - land assessed as having a less than 1 in 1000 annual probability of river or sea flooding in any year (<0.1%).

Zone 2 Medium Probability - land assessed as having between a 1 in 100 and 1 in 1000 annual probability of river flooding (1% - 0.1%) or between 1 in 200 and 1 in 1000 annual probability of sea flooding (0.5% - 0.1%) in any year.

Zone 3a High Probability - land assessed as having a 1 in 100 or greater annual probability of river flooding (>1%) or a 1 in 200 or greater annual probability of flooding from the sea (>0.5%) in any year.

Zone 3b The Functional Floodplain - land where water has to flow or be stored in times of flood, land which would flood with an annual probability of 1 in 20 (5%) of greater in any year or designed to flood in an extreme flood.

The site lies within flood zone 1, Figure 9 and therefore residential development is appropriate.

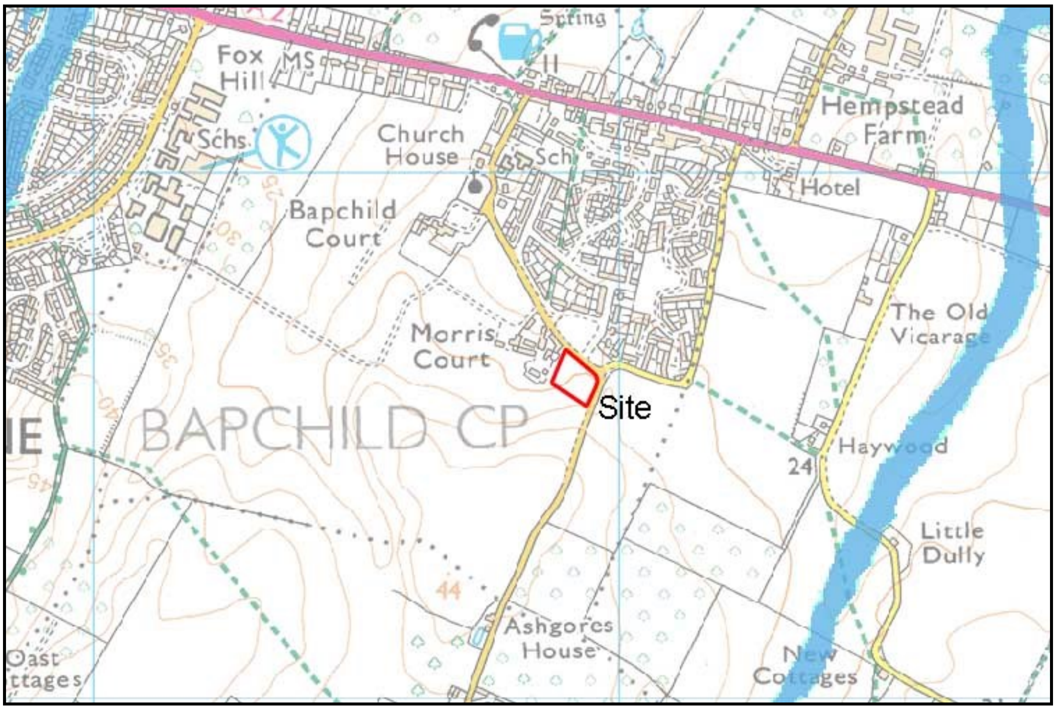


Figure 9. Environment Agency's Flood Map with the site circled red. (© Environment Agency)

Surface Water - The Environment Agency has published surface water flooding maps. These show the site to be at very low risk of surface water flooding, Figure 10. The definition of each category is given below:

Very Low (white) a chance of flooding of less than 1 in 1000 (0.1%)
Low (pale blue) a chance of flooding of between 1 in 1000 (0.1%) and 1 in 100 (1%)
Medium (mid blue) a chance of flooding of between 1 in 100 (1%) and 1 in 30 (3.3%)
High (dark blue) a chance of flooding of greater than 1 in 30 (3.3%)

The depth of water associated with the low risk event is shown in Figure 11. The definition of each colour is given below:

Below 300mm (light blue)
300-900mm (medium blue)
Over 900mm (dark blue)

The surface water flood maps also give an indication of velocity and direction of flow, Figure 12. The definition of each colour is given below:

Over 0.25 m/s (dark blue)
Less than 0.25 m/s (light blue)

The arrows indicate the direction of flow.

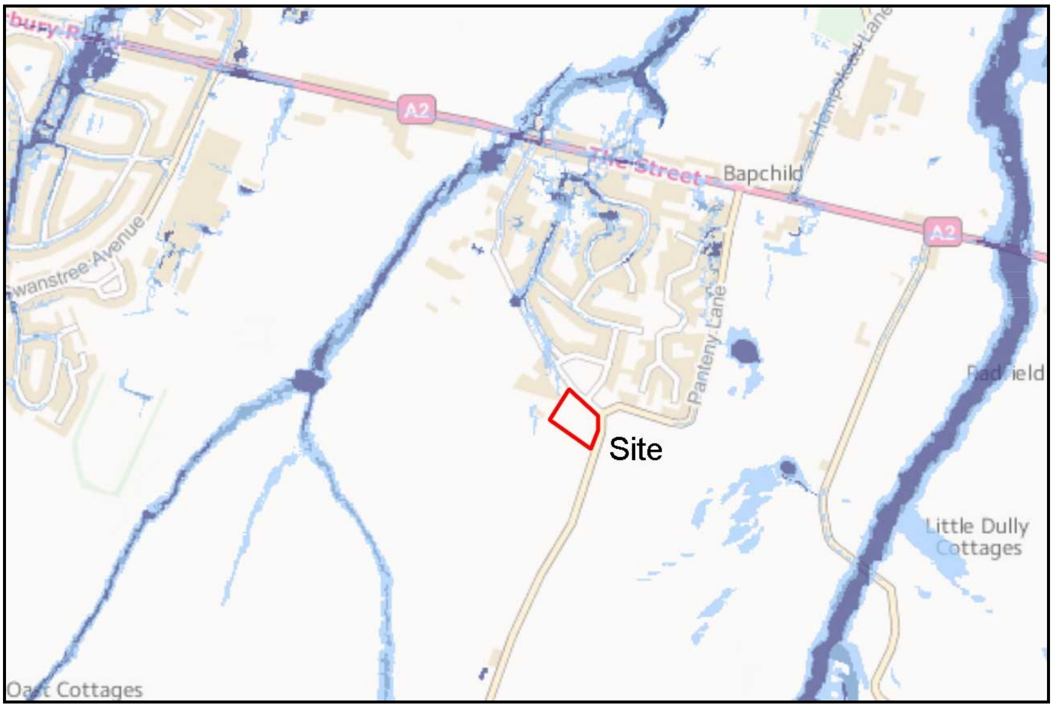


Figure 10. Environment Agency's surface water flood map with the site edged red. (© Environment Agency)

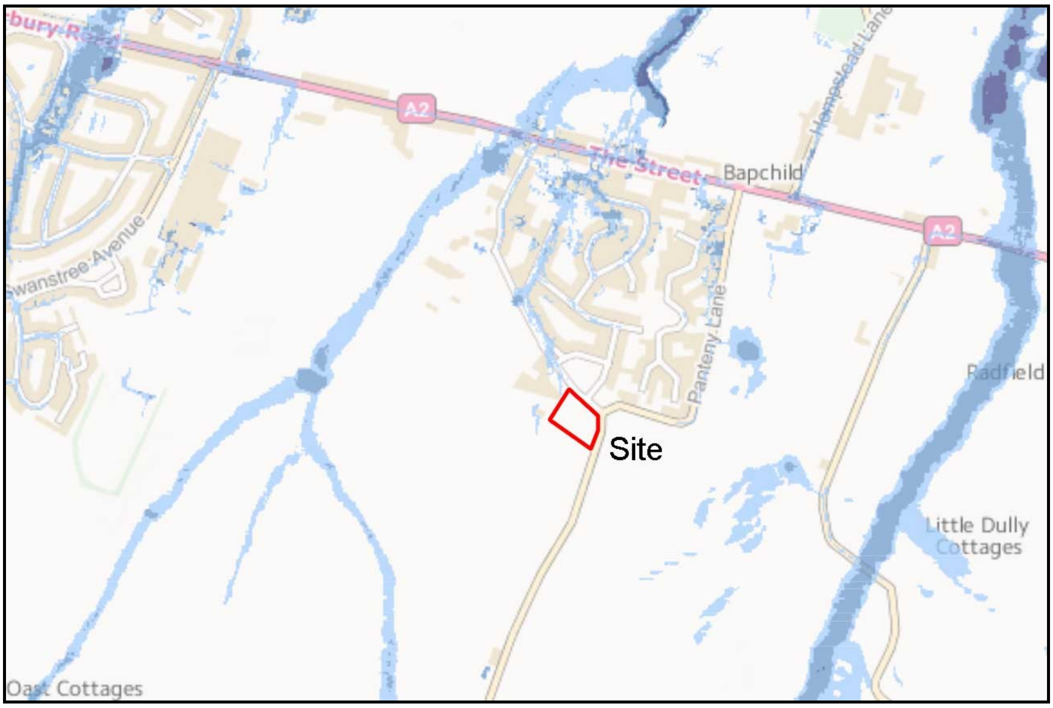


Figure 11. Surface water flood depth map for low risk of flooding category with the site edged red. (© Environment Agency)

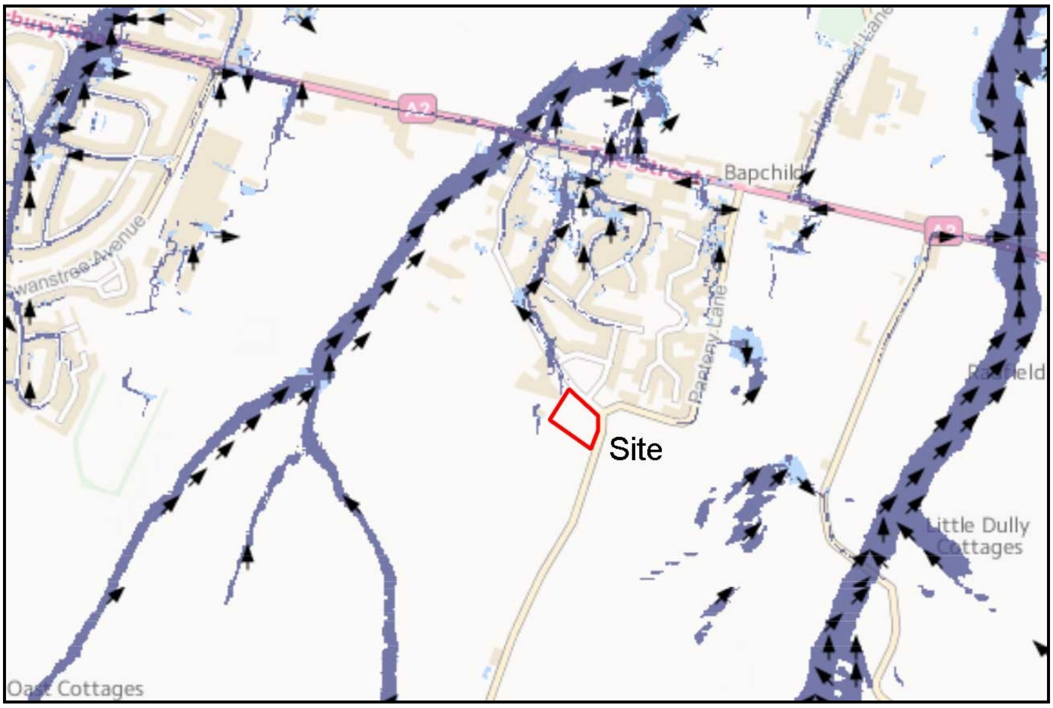


Figure 12. Surface water flood velocity map for low risk of flooding category with the site edged red. (© Environment Agency)

The site is at very low risk from surface water flooding. The velocity map confirms the general direction of flow from the site to the north.

The flood risk from surface water runoff from the development can be managed through the implementation of this surface water management strategy.

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.

The risk of groundwater flooding at the site has been considered in the Surface Water Management Plan (SWMP) published by Kent County Council, Figure 13. The site is in an area not considered susceptible to groundwater flooding.

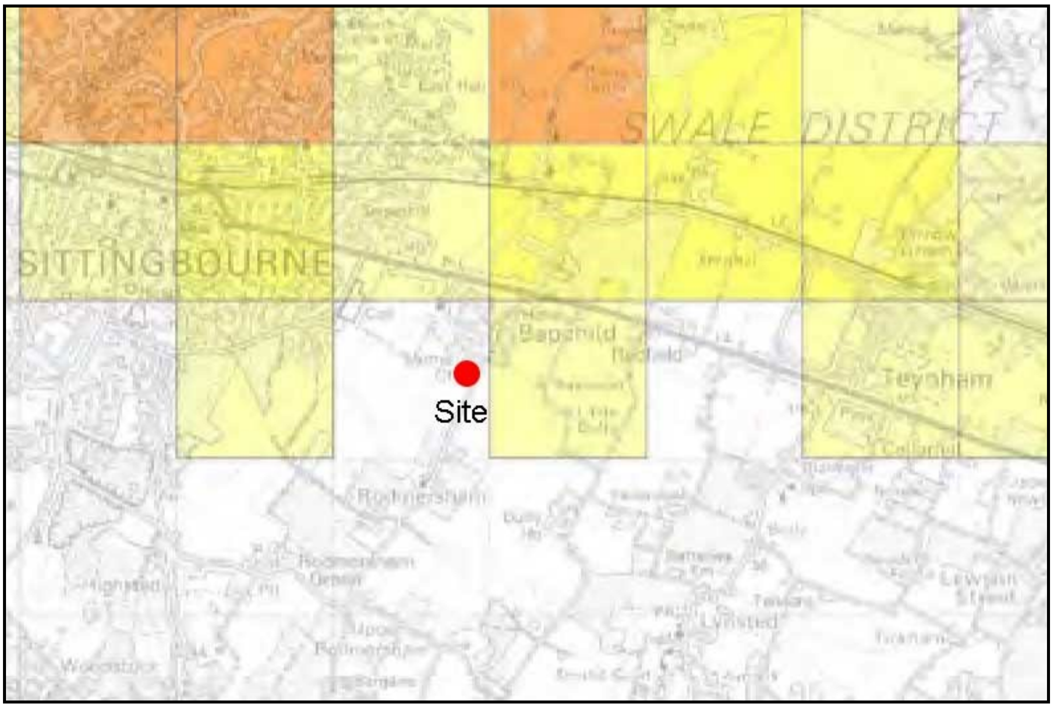


Figure 13. Groundwater flood susceptibility (© Kent County Council).

The SFRA states that:

It should be noted that the Groundwater Emergence Maps are not necessarily indicative of groundwater flooding, but only of areas where groundwater levels may be close to the surface. Local factors, such as an overlying impermeable area, or well adapted drainage systems may serve to prevent groundwater flooding from occurring.

A borehole sunk at the A2, east of Bapchild indicates that groundwater was struck at approximately 9mAOD. This is 12m below the level of the site. The risk of groundwater flooding at the site is considered to be low as any rise in groundwater would result in water emerging at lower levels along the A2 and flowing northwards away from the site.

Infrastructure - The SWMP identifies localised flooding incidents reported in Swale, Figure 14. There are no incidents recorded at the site. The site is not currently served by public sewers and there are no reservoirs in the vicinity of the site. The risk of infrastructure flooding at the site is considered to be low.

Figure 14. Historic flooding incidents showing KCC highways flooding (black circle), Southern Water flooding (green circle) and Southern Water flooding hotspots (green diamond). (© Kent County Council).

Existing Site

The site is a greenfield site. The peak greenfield runoff for the critical storm duration for the pre-development site, is shown in Table 2.

Return Period	Q l/s	
	per ha.	Site (0.69 ha)
1	1.4	1.0
30	3.7	2.6
100	5.2	3.6
100+30%	6.8	4.7

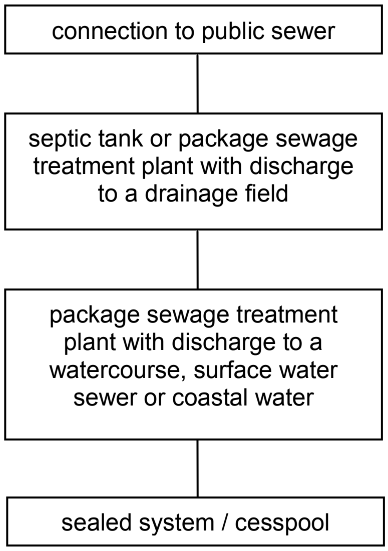
Table 2. Pre-development greenfield runoff rate for the site.

5. Foul Water Management Strategy

Choosing the right sewage treatment and disposal method is essential for the protection of public health and the environment and ensures effective long term performance of the system.

Sewage treatment and disposal can be provided by a sewerage undertaker or by a private treatment system. Pollution Prevention Guidelines (PPG4), published by the Environment Agency in 2006 states that developments proposing the use of private sewage treatment systems are usually only acceptable where connection to the public sewer is not possible. Private treatment systems may however offer a more sustainable solution to the overall water management of the site.

There is therefore a hierarchy of methods for disposing of foul sewage.



Connection to Public Sewer

The nearest public sewer is within School Lane, 70m west of the proposed site access. The sewer record indicates that the manhole (ref. 8701) is only 0.5m deep at this location with an invert level of 18.07mAOD. The proposed site access is at 21.07mAOD, 3m above the invert level of the public sewer. Providing sufficient protection measures are provided to the pipe it is possible to provide a gravity fed connection from the development to the existing public sewerage system.

Foul Sewage Flows

Existing Flows

Manhole 8701 is at the head of the public sewer run. It only serves buildings within Morris Court. According to the Royal Mail postcode finder only 10 addresses have the ME9 9NJ postcode. The sewer is therefore assumed to take flows from 10 dwellings. Sewers for Adoption 7th Edition states that design flow rates for dwellings should be 4,000 litres per dwelling per day. The existing foul flows entering manhole 8701 are therefore 0.5 l/s.

Proposed Flows

The proposed development creates an additional 14 dwellings. Based on flows of 4,000 litres per dwelling per day the foul flows from the proposed development will be 0.7 l/s.

Foul flows to manhole 8701 will increase from 0.5 l/s to 1.2 l/s. The maximum capacity for a 100mm diameter pipe laid at a gradient of 1 in 80 is 6.3 l/s. There is sufficient capacity within the local network to accommodate flows from the proposed development.

The proposals are therefore acceptable from a foul drainage perspective.

6. Climate Change

The global climate is constantly changing, but it is widely recognised that we are now entering a period of accelerating change. Climate change will result in an increase in sea levels, rainfall intensity and river flows.

The impact of climate change will be to reduce the standard of protection provided by current defences with time and increase the risk of flooding in undefended areas. The Planning Practice Guidance to the National Planning Policy Framework (NPPF) recommends using the following increases due to climate change to 2115 in any assessment:

Peak rainfall intensity	+30%
Peak river flow	+20%
Offshore wind speed	+10%
Extreme wave height	+10%

The surface water calculations include an increase of 30% on peak rainfall intensity in accordance with the NPPF for a development life of 100 years.

7. Detailed Development Proposals

The proposed development consists of 14 dwellings. The application is for outline planning approval and therefore a detailed layout has not been designed. Analysis of the illustrative layout indicates that the development area will be approximately 0.69ha and that potentially impermeable surfaces will cover approximately 44% of this, 3,050m^2. The nature of the impermeable areas has been estimated from the indicative layout, Figure 15 and Table 3.

Figure 15. Potential impermeable development areas.

Type	Area (m^2)
Impermeable Roof	1,460
Impermeable Paved	920
Impermeable Total	**2,380**
Permeable Paved	670

Table 3. Potential impermeable development areas.

The peak runoff for the critical storm duration for the post-development site, based on the runoff from an area of 2,380m^2, is shown in Table 4.

Return Period	Q l/s
1	20
30	48
100	63
100+30%	82

Table 4. Post-development runoff rate for the site.

8. Surface Water Management Strategy

Objectives

The aim of the surface water management strategy is to replicate the existing drainage patterns by providing storage and infiltration to dispose of surface water on-site.

In addition the strategy seeks to;

- to maximise the use of SUDS,
- to enhance water quality.

Broad Strategy

The broad strategy is to use suitable SUDS elements to attenuate and dispose of surface water via infiltration.

Drainage Elements

The following drainage elements are identified as being appropriate to the site;

- water butts,
- permeable paving,
- infiltration basins/channels,
- piped systems.

Water Butts

The expectation is that all individual properties will have water butts. Water butts act as source control devices intercepting rainfall early in the management train. Water butts will be provided on all residential units. It is recognised that water butts may be full during critical rainfall conditions and not provide storage.

Permeable Paving

Permeable paving allows water to infiltrate through the surface into an underlying storage area. The base of the pavement can be open to allow surface water to infiltrate into the underlying subgrade or closed with the permeable paving providing storage only.

Permeable paving is proposed in private drives and parking areas. The permeable paving is assumed to provide full infiltration as the soils are freely draining. Check dams will be needed to maximise the storage available within the subbase due to the sloping site.

Infiltration Basin/Channels

Infiltration basins/channels are depressions that are usually dry but can accommodate water during extreme rainfall events. They provide temporary storage for storm water runoff and can act as large soakaways.

Piped Systems

Pipes will be used for conveyance and connections between SUDS elements.

Surface Water Management Strategy

The Strategy has been modelled using MicroDrainage software published by XP Solutions.

The Quick Design for Infiltration Systems from Source Control has been used to determine the range of storage volumes required for each storm scenario based on the depth of the infiltration basin, Table 5.

Depth (m)	**Return Period**			
	1	30	100	100+30%
0.2	35	76	98	128
0.4	38	81	104	136
0.6	41	86	111	144
1.0	45	94	121	157

Table 5. Storage volume required in m^3 for various scenarios.

There is sufficient space on the flatter land by the entrance to provide an infiltration basin covering $140m^2$ and 0.6m deep. This provides $84m^3$ of storage, sufficient to deal with water from the 1 in 30 year rainfall event. The additional storage can be provided by providing an overflow area and stepped ponds behind the tree belt. At an additional shallow depth of 0.2m and covering $400m^2$ in total this provides a further $80m^3$ of storage giving a total storage volume of $164m^3$, sufficient to deal with water from the 1 in 100 year plus climate change rainfall event.

A detailed analysis of this infiltration basin is included at Appendix A. An indicative layout is shown in Figure 16.

Figure 16. Indicative SUDS layout.

The private drives and parking areas are assumed to be laid with permeable paving. The parameters used for the assessment of the permeable paving are shown in Table 6. The assessment is presented in Appendix B.

Parameter	Permeable Paving
Rainfall return period	1 in 100 year + 30%
Infiltration rate	1×10^{-5} m/s
Factor of safety	5
sub-base depth	0.25m
Contributing area	670m^2
Maximum water depth	0.145m

Table 6. Permeable paving parameters.

9. Water Quality

The level of pollution associated with any runoff event depends on;

- the land use, with runoff from paved areas being more polluting than roof areas,
- the length of time since the last rainfall event, with runoff after long dry periods being more polluting and
- the duration and intensity of the rainfall.

Pollution concentration is higher near the beginning of a storm, known as the first flush, and it follows that frequent small events are more polluting than longer and larger events.

To remove the major proportion of pollution it is necessary to capture and treat runoff from frequent, small events and the initial runoff from larger events.

Including a number of components in the SUDS management train has the following benefits:

- Different components maximise the treatment efficiency for a wide range of pollutants.
- Pollution is contained within upper SUDS components, minimising risk to the receiving waters.
- Coarse sediments are removed through permeable paving and grassed channels/infiltration basins whilst finer sediments are removed through detention in permeable paving and through infiltration.

The number of treatment train components recommended by the SUDS Manual (c697) is shown in Table 7.

	Receiving Water Sensitivity		
Catchment characteristics	**Low**	**Medium**	**High**
Roofs	1	1	1
Roads and parking	2	2	2

Table 7. Treatment train components required for various development types.

The SUDS Manual indicates that the following can be used as treatment train components:

- Infiltration
- Permeable paving
- Vegetative filtering and detention (in open channels)
- Granular filtering and detention (in gravel filled filter trenches)

- Retention (permanent ponds)
- Proprietary oil/silt/debris traps

The development uses some of these components to provide a suitable treatment train for runoff from different parts of the development as shown in Table 8. The number refers to the stage of treatment for example surface water falling on drives receives the first stage of treatment by percolation through the permeable paving with the second stage being infiltration through the ground. In some instances there are alternatives stages.

Element	Permeable paving	Oil/silt/debris traps	Grassed basins	Infiltration
Roof			1	2
Drive/parking areas	1			2
Highway		1	1	2

Table 8. Treatment train components required for various development surfaces.

Using permeable paving, oil and silt traps and grassed infiltration basins/channels the runoff from all parts of the development receives an appropriate level of treatment in accordance with the SUDS Manual.

10. Conclusion

This Surface Water Management Strategy accompanies a planning application submitted to Swale Borough Council. The planning application is for residential development on land at School Lane, Bapchild, Sittingbourne, ME9 9NJ.

The site lies in flood zone 1, land assessed as having a less than 1 in 1000 annual probability of river or sea flooding in any year. It is also assessed as being at low risk from other sources of flooding.

The site is a greenfield site and covers 0.69 ha. The proposed development will include 2,380m^2 of impermeable area with a further 670m^2 of permeable paved area.

The surface water management strategy is to use infiltration basins and permeable paving to store and infiltrate surface water runoff. Sufficient storage is provided on site to retain runoff from rainfall events up to the 1in 100 year plus climate change event.

The surface water management strategy provides a treatment train of SUDS components including permeable paving, oil/silt/debris traps and grassed infiltration basins/channels allowing runoff from all areas of the development to receive the level of treatment recommended within the SUDS Manual.

Appendix A - Draft Infiltration Basin Design

Summary of Results for 100 year Return Period (+30%)

Half Drain Time : 492 minutes.

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Volume (m³)	Status
15 min Summer	21.590	0.390	0.8	54.6	O K
30 min Summer	21.712	0.512	0.8	71.7	Flood Risk
60 min Summer	21.829	0.629	1.5	88.9	Flood Risk
120 min Summer	21.879	0.679	2.8	102.1	Flood Risk
180 min Summer	21.892	0.692	3.2	106.8	Flood Risk
240 min Summer	21.895	0.695	3.3	108.1	Flood Risk
360 min Summer	21.899	0.699	3.4	109.3	Flood Risk
480 min Summer	21.900	0.700	3.4	110.0	Flood Risk
600 min Summer	21.900	0.700	3.4	110.0	Flood Risk
720 min Summer	21.900	0.700	3.4	109.7	Flood Risk
960 min Summer	21.896	0.696	3.3	108.3	Flood Risk
1440 min Summer	21.886	0.686	3.0	104.7	Flood Risk
2160 min Summer	21.871	0.671	2.6	99.7	Flood Risk
2880 min Summer	21.858	0.658	2.3	95.8	Flood Risk
4320 min Summer	21.837	0.637	1.7	90.7	Flood Risk
5760 min Summer	21.820	0.620	1.3	87.3	Flood Risk
7200 min Summer	21.797	0.597	0.8	83.6	Flood Risk
8640 min Summer	21.731	0.531	0.8	74.4	Flood Risk
10080 min Summer	21.670	0.470	0.8	65.9	O K
15 min Winter	21.637	0.437	0.8	61.2	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Time-Peak (mins)
15 min Summer	124.370	0.0	27
30 min Summer	82.042	0.0	41
60 min Summer	51.576	0.0	70
120 min Summer	31.324	0.0	126
180 min Summer	23.081	0.0	182
240 min Summer	18.470	0.0	228
360 min Summer	13.443	0.0	282
480 min Summer	10.730	0.0	344
600 min Summer	9.003	0.0	412
720 min Summer	7.796	0.0	480
960 min Summer	6.207	0.0	618
1440 min Summer	4.495	0.0	892
2160 min Summer	3.249	0.0	1300
2880 min Summer	2.578	0.0	1708
4320 min Summer	1.858	0.0	2548
5760 min Summer	1.472	0.0	3408
7200 min Summer	1.227	0.0	4464
8640 min Summer	1.058	0.0	5200
10080 min Summer	0.932	0.0	5960
15 min Winter	124.370	0.0	26

Summary of Results for 100 year Return Period (+30%)

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Volume (m³)	Status
30 min Winter	21.775	0.575	0.8	80.5	Flood Risk
60 min Winter	21.868	0.668	2.5	98.7	Flood Risk
120 min Winter	21.909	0.709	3.4	113.6	Flood Risk
180 min Winter	21.925	0.725	3.4	120.0	Flood Risk
240 min Winter	21.932	0.732	3.4	122.7	Flood Risk
360 min Winter	21.935	0.735	3.4	123.7	Flood Risk
480 min Winter	21.936	0.736	3.4	124.3	Flood Risk
600 min Winter	21.935	0.735	3.4	123.7	Flood Risk
720 min Winter	21.931	0.731	3.4	122.4	Flood Risk
960 min Winter	21.922	0.722	3.4	118.9	Flood Risk
1440 min Winter	21.903	0.703	3.4	111.1	Flood Risk
2160 min Winter	21.883	0.683	2.9	103.7	Flood Risk
2880 min Winter	21.868	0.668	2.5	98.6	Flood Risk
4320 min Winter	21.844	0.644	1.9	92.2	Flood Risk
5760 min Winter	21.826	0.626	1.4	88.3	Flood Risk
7200 min Winter	21.807	0.607	1.0	85.1	Flood Risk
8640 min Winter	21.724	0.524	0.8	73.4	Flood Risk
10080 min Winter	21.636	0.436	0.8	61.1	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Time-Peak (mins)
30 min Winter	82.042	0.0	41
60 min Winter	51.576	0.0	68
120 min Winter	31.324	0.0	122
180 min Winter	23.081	0.0	180
240 min Winter	18.470	0.0	234
360 min Winter	13.443	0.0	300
480 min Winter	10.730	0.0	372
600 min Winter	9.003	0.0	448
720 min Winter	7.796	0.0	524
960 min Winter	6.207	0.0	668
1440 min Winter	4.495	0.0	938
2160 min Winter	3.249	0.0	1344
2880 min Winter	2.578	0.0	1760
4320 min Winter	1.858	0.0	2596
5760 min Winter	1.472	0.0	3520
7200 min Winter	1.227	0.0	4608
8640 min Winter	1.058	0.0	5616
10080 min Winter	0.932	0.0	6360

Rainfall Details

Rainfall Model	FSR	Winter Storms	Yes
Return Period (years)	100	Cv (Summer)	0.750
Region	England and Wales	Cv (Winter)	0.840
M5-60 (mm)	19.600	Shortest Storm (mins)	15
Ratio R	0.390	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+30

Time Area Diagram

Total Area (ha) 0.238

Time From:	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**
0	4	0.079	4	8	0.079	8	12	0.080

Model Details

Storage is Online Cover Level (m) 22.000

Infiltration Basin Structure

Invert Level (m) 21.200 Safety Factor 2.0
Infiltration Coefficient Base (m/hr) 0.03600 Porosity 1.00
Infiltration Coefficient Side (m/hr) 0.03600

Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)
0.000	140.0	0.700	400.0	1.400	0.0	2.100	0.0
0.100	140.0	0.800	400.0	1.500	0.0	2.200	0.0
0.200	140.0	0.900	0.0	1.600	0.0	2.300	0.0
0.300	140.0	1.000	0.0	1.700	0.0	2.400	0.0
0.400	140.0	1.100	0.0	1.800	0.0	2.500	0.0
0.500	140.0	1.200	0.0	1.900	0.0		
0.600	140.0	1.300	0.0	2.000	0.0		

Appendix B - Draft Permeable Paving Design

Summary of Results for 100 year Return Period (+30%)

Half Drain Time : 185 minutes.

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Volume (m³)	Status
15 min Summer	21.763	0.063	1.3	11.8	Flood Risk
30 min Summer	21.786	0.086	1.3	16.1	Flood Risk
60 min Summer	21.807	0.107	1.3	20.0	Flood Risk
120 min Summer	21.822	0.122	1.3	22.8	Flood Risk
180 min Summer	21.825	0.125	1.3	23.4	Flood Risk
240 min Summer	21.825	0.125	1.3	23.5	Flood Risk
360 min Summer	21.823	0.123	1.3	23.1	Flood Risk
480 min Summer	21.819	0.119	1.3	22.4	Flood Risk
600 min Summer	21.814	0.114	1.3	21.4	Flood Risk
720 min Summer	21.809	0.109	1.3	20.4	Flood Risk
960 min Summer	21.798	0.098	1.3	18.4	Flood Risk
1440 min Summer	21.778	0.078	1.3	14.5	Flood Risk
2160 min Summer	21.756	0.056	1.3	10.5	Flood Risk
2880 min Summer	21.746	0.046	1.1	8.6	Flood Risk
4320 min Summer	21.735	0.035	0.9	6.6	Flood Risk
5760 min Summer	21.729	0.029	0.7	5.4	Flood Risk
7200 min Summer	21.724	0.024	0.6	4.6	Flood Risk
8640 min Summer	21.721	0.021	0.5	4.0	Flood Risk
10080 min Summer	21.719	0.019	0.5	3.6	Flood Risk
15 min Winter	21.773	0.073	1.3	13.6	Flood Risk

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Time-Peak (mins)
15 min Summer	124.370	0.0	18
30 min Summer	82.042	0.0	33
60 min Summer	51.576	0.0	62
120 min Summer	31.324	0.0	120
180 min Summer	23.081	0.0	156
240 min Summer	18.470	0.0	188
360 min Summer	13.443	0.0	252
480 min Summer	10.730	0.0	320
600 min Summer	9.003	0.0	388
720 min Summer	7.796	0.0	456
960 min Summer	6.207	0.0	586
1440 min Summer	4.495	0.0	836
2160 min Summer	3.249	0.0	1172
2880 min Summer	2.578	0.0	1524
4320 min Summer	1.858	0.0	2248
5760 min Summer	1.472	0.0	2952
7200 min Summer	1.227	0.0	3680
8640 min Summer	1.058	0.0	4408
10080 min Summer	0.932	0.0	5144
15 min Winter	124.370	0.0	18

Summary of Results for 100 year Return Period (+30%)

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Volume (m³)	Status
30 min Winter	21.799	0.099	1.3	18.6	Flood Risk
60 min Winter	21.823	0.123	1.3	23.0	Flood Risk
120 min Winter	21.841	0.141	1.3	26.4	Flood Risk
180 min Winter	21.845	0.145	1.3	27.2	Flood Risk
240 min Winter	21.844	0.144	1.3	26.9	Flood Risk
360 min Winter	21.839	0.139	1.3	26.1	Flood Risk
480 min Winter	21.833	0.133	1.3	24.9	Flood Risk
600 min Winter	21.825	0.125	1.3	23.4	Flood Risk
720 min Winter	21.816	0.116	1.3	21.8	Flood Risk
960 min Winter	21.799	0.099	1.3	18.5	Flood Risk
1440 min Winter	21.769	0.069	1.3	12.9	Flood Risk
2160 min Winter	21.746	0.046	1.2	8.6	Flood Risk
2880 min Winter	21.738	0.038	0.9	7.0	Flood Risk
4320 min Winter	21.728	0.028	0.7	5.2	Flood Risk
5760 min Winter	21.722	0.022	0.6	4.1	Flood Risk
7200 min Winter	21.718	0.018	0.5	3.4	Flood Risk
8640 min Winter	21.716	0.016	0.4	2.9	Flood Risk
10080 min Winter	21.714	0.014	0.3	2.6	Flood Risk

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Time-Peak (mins)
30 min Winter	82.042	0.0	32
60 min Winter	51.576	0.0	60
120 min Winter	31.324	0.0	118
180 min Winter	23.081	0.0	172
240 min Winter	18.470	0.0	218
360 min Winter	13.443	0.0	274
480 min Winter	10.730	0.0	350
600 min Winter	9.003	0.0	422
720 min Winter	7.796	0.0	494
960 min Winter	6.207	0.0	628
1440 min Winter	4.495	0.0	866
2160 min Winter	3.249	0.0	1188
2880 min Winter	2.578	0.0	1532
4320 min Winter	1.858	0.0	2248
5760 min Winter	1.472	0.0	2992
7200 min Winter	1.227	0.0	3744
8640 min Winter	1.058	0.0	4408
10080 min Winter	0.932	0.0	5144

Rainfall Details

Rainfall Model	FSR	Winter Storms	Yes
Return Period (years)	100	Cv (Summer)	0.750
Region	England and Wales	Cv (Winter)	0.840
M5-60 (mm)	19.600	Shortest Storm (mins)	15
Ratio R	0.390	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+30

Time Area Diagram

Total Area (ha) 0.067

Time From:	(mins) To:	Area (ha)
0	4	0.067

Model Details

Storage is Online Cover Level (m) 22.000

Porous Car Park Structure

Infiltration Coefficient Base (m/hr)	0.03600	Width (m)	25.0
Membrane Percolation (mm/hr)	1000	Length (m)	25.0
Max Percolation (l/s)	173.6	Slope (1:X)	0.0
Safety Factor	5.0	Depression Storage (mm)	5
Porosity	0.30	Evaporation (mm/day)	3
Invert Level (m)	21.700	Cap Volume Depth (m)	0.200