Ian Pick Associates Ltd

Flood Risk Assessment and Surface Water Management Plan

Manor Farm, Haisthorpe, Driffield, YO25 4NX Report LL095 September 2021

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Summary

This document is a Flood Risk Assessment and Surface Water Management Plan for an agricultural development in the East Riding of Yorkshire, located in a rural part of the Yorkshire Wolds, between Driffield and Bridlington. The development site is drained by an informal system of ponds and ditches, with no record of flooding locally. In the text below, reference to documentation is provided by hyperlinks, which are shown as footnotes for clarity. The main findings of this assessment are as follows:

1. One storage shed has been approved and a workshop lean-to has been proposed at Manor Farm, within the East Riding of Yorkshire. The site is located in flood zone 1, beyond the limits of 1:1,000-year fluvial flooding.

2. The buildings are / would be located on land that is already used for agriculture, so there would be no change in vulnerability. Land and buildings used for agriculture are classified as “Less Vulnerable”, under NPPF guidelines.

3. The farm and the existing sheds are located on relatively flat land, sloping gently south eastward and shown on regional mapping to be at very low risk of surface water flooding. The only flood risk that could affect the site is from groundwater.

4. Although there is no record of groundwater flooding at the site, the strategic flood risk assessment suggests that there is a groundwater flood risk in this area, due to its location, bounding the chalk aquifer of the Yorkshire Wolds.

5. The low vulnerability land use at this site is considered appropriate in areas with a flood risk profile such as this, very low risk from fluvial and surface water flooding and a theoretical but unquantified flood risk from groundwater.

6. The Environment Agency suggests that surface water drainage systems should be designed to the central climate change allowance of 20% but tested to an upper end allowance of 40%.

7. As the Lead Local Flood Authority, the East Riding of Yorkshire Council prefer a 30% allowance to be applied in all hydraulic calculations. To illustrate a range of possible outcomes, the 30% and 40% allowances are examined in this assessment.

8. Regional soil mapping shows the soil to be slowly permeable and seasonally wet loams and clays. Geological mapping shows this to have developed from underlying Pleistocene till.

9. Existing sheds at the site use guttering and downpipes to convey runoff from their roofs to closed plastic pipes, located beneath the surface. These convey flow to a pond, located to the south of the site access road.

10. The existing pond has a three-inch outflow, which already provides some attenuation downstream. MicroDrainage has been used to design an attenuation system to fully comply with the flood risk provisions of the NPPF.

11. The FEH catchment covering the site was downloaded but found to be inappropriate, because it also covers freely draining areas to the north.

12. An adjacent FEH catchment was therefore downloaded, whose area is confined to the slowly permeable and seasonally wet loams and clays, developed over glacial till.

13. ReFH v.2.3 was used to calculate fully rural, Greenfield runoff rates for impermeable surfaces on the site at three return periods. These include the proposed and agreed developments and existing impermeable surfaces that already drain into the pond.

14. MicroDrainage was used to simulate rainstorms at these return periods and model an attenuation system that would discharge at or below Greenfield rates. It is assumed to discharge at or below Greenfield runoff rates at all return periods.

15. It is recommended that an outflow chamber should be built at the site of the existing pond overflow and that 50 mm orifice plates should be located within a perforated riser to provide the necessary attenuation and protection against blockage.

16. A maintenance schedule is recommended, based on advice in the SuDS Manual. This should be modified to include the maintenance of other structures, to produce a site-specific maintenance schedule for the whole site.

17. MicroDrainage modelling shows that the recommended attenuation system would limit pond level to some 228 mm above the existing resting pond level, during the 1:100-year rainstorm, with the recommended 30% allowance for climate change.

18. Residual risks include exceedance inflow and failure of the infiltration system. Exceedance could result from a rainstorm of greater magnitude than the 1:100-year design rainstorm and the infiltration system could fail due to blockage of the outflow.

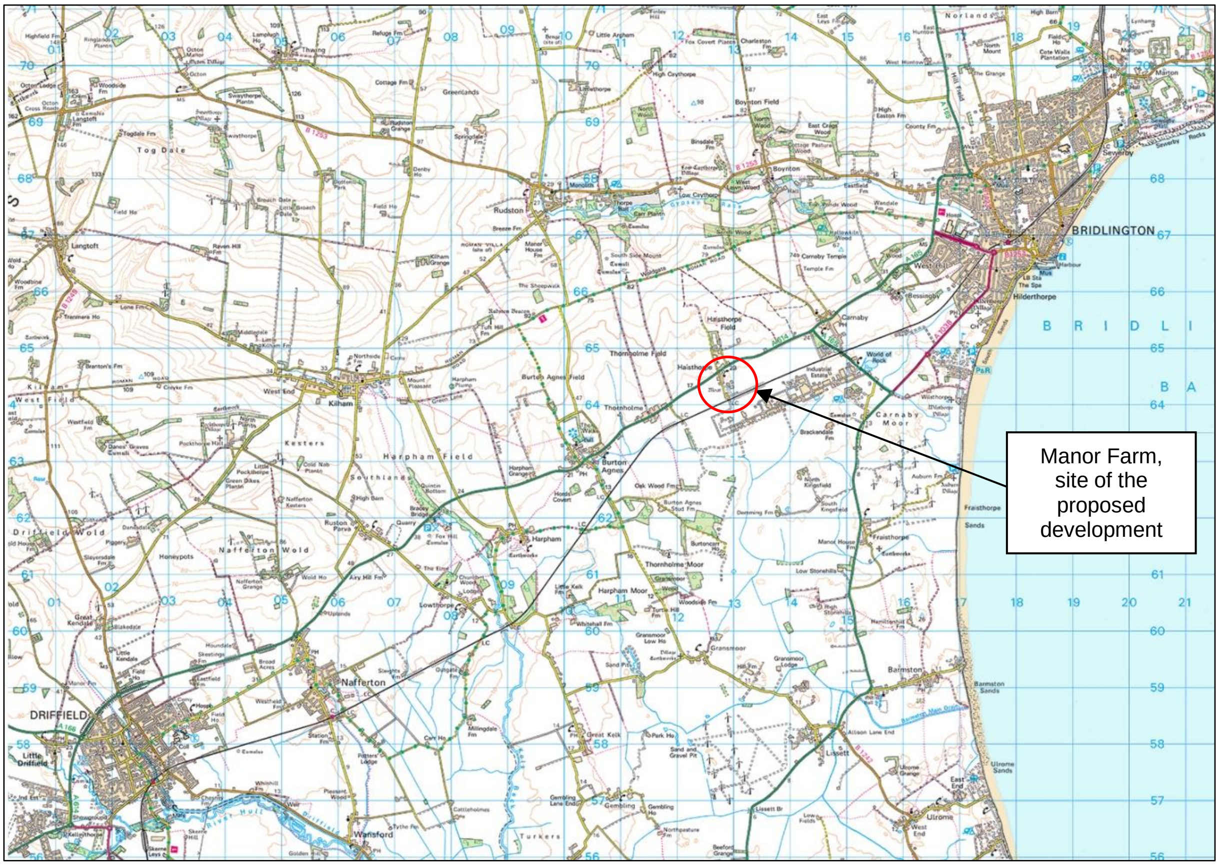
19. In order to manage either of these residual risks, it is recommended that a 1 m wide emergency overflow weir should be built into the pond margin, 300 mm above the existing outflow / resting pond level.

20. In summary, flood risk at the site is very low and a less vulnerable agricultural use is appropriate. Runoff from impermeable surfaces can be managed using a system based on attenuation. If the recommendations within this report are adopted, then the proposed new workshop, the agreed storage shed, associated infrastructure and the existing buildings on the site would fully comply with the flood risk provisions of the NPPF.

1 Development site and location

A commercial, agricultural development has been proposed within a rural part of the East Riding of Yorkshire, at Manor Farm, Haisthorpe YO25 4NX. The site is located south of the A614 trunk road, about 14 km north east of Driffield and 7 km south west of Bridlington (Figure 1). The development includes one new storage shed, which has already been approved and constructed and a lean-to, which would serve as a workshop and a store for machinery. Both buildings are or would be located within the existing sheds in the farmyard, referenced below as “the site”. The site (Figure 2, Figure 4) is on land already used for agriculture (Figure 3), at coordinates shown in Table 1.

Figure 1 Location of Manor Farm within the East Riding of Yorkshire

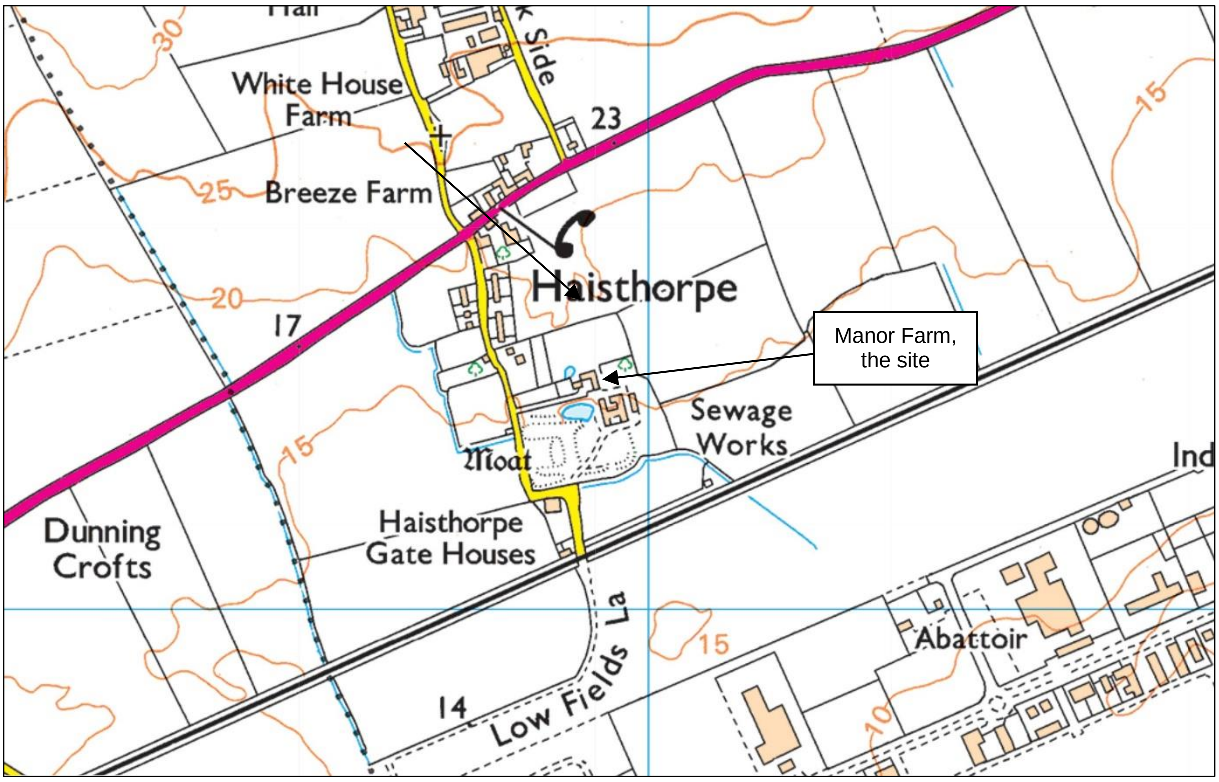


Source: https://maps.the-hug.net/

Table 1 Approximate location of the proposed new sheds

OS X (Eastings)	512900
OS Y (Northings)	464350
Nearest Post Code	YO25 4NX
Lat (WGS84)	54.06273
Long (WGS84)	W-0.27628
Nat Grid Ref	TA 12900 64350

Figure 2 Location of Manor Farm, in relation to the topography



Source: https://maps.the-hug.net/

Figure 3 Air photo of the site and surrounding area

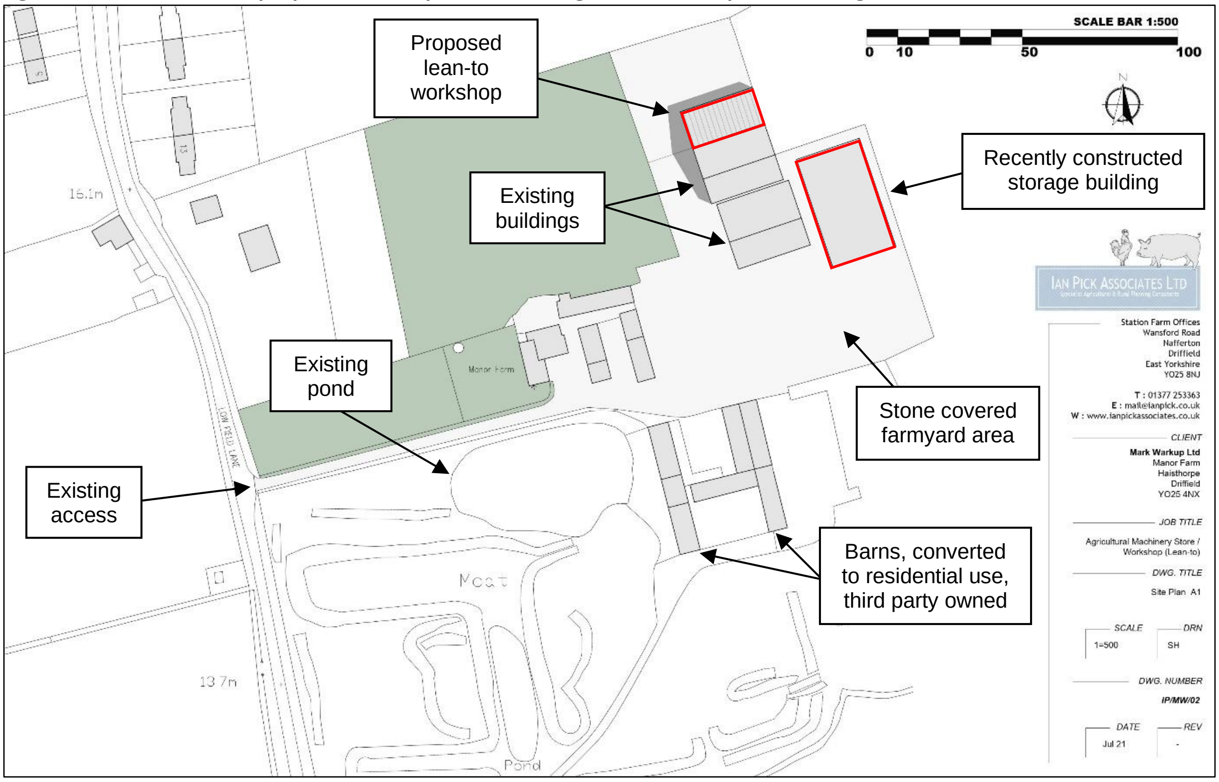
Source: https://satellites.pro/UK_map#54.054350,-0.274289,15

2 Development proposals

The layout of the site and its key features are shown in Figure 4. The development includes a storage building, approved 13th August 2018 (Ref: 18/01364/PLF)[1], already constructed and requiring a sustainable drainage system. An additional structure has been proposed (Ref: 21/02839/PLF), a lean-to extension to be used for agricultural machinery storage and repair. Both structures are outlined in red on Figure 4. The area around these buildings includes the existing farmyard surface and some areas which have been covered with an impermeable surface to facilitate operations. Further detail is given in Section 6.3, where site drainage arrangements are examined.

Having evolved long before the flood risk provisions of the NPPF came into force, most of the farmyard buildings and most of the farmhouse itself drain into the pond shown in Figure 4, with no explicit provision for outflow control. Although the pond will provide some degree of attenuation and consequent mitigation of flood risk downstream, this assessment seeks to instigate formal control arrangements, to ensure that flood risk elsewhere is minimised. Impermeable surfaces and their areas are calculated in Appendix B and listed in Table 9. This shows a total impermeable area of a little over 3,400 m^2 or 0.34 ha. Since it receives rainfall, the attenuation pond and filter drain that feeds into it are also included, to give a total catchment area of some 5,400 m^2 (Table 9). As a commercial development, the storage building and the lean-to are regarded as having a design life of 60 years.

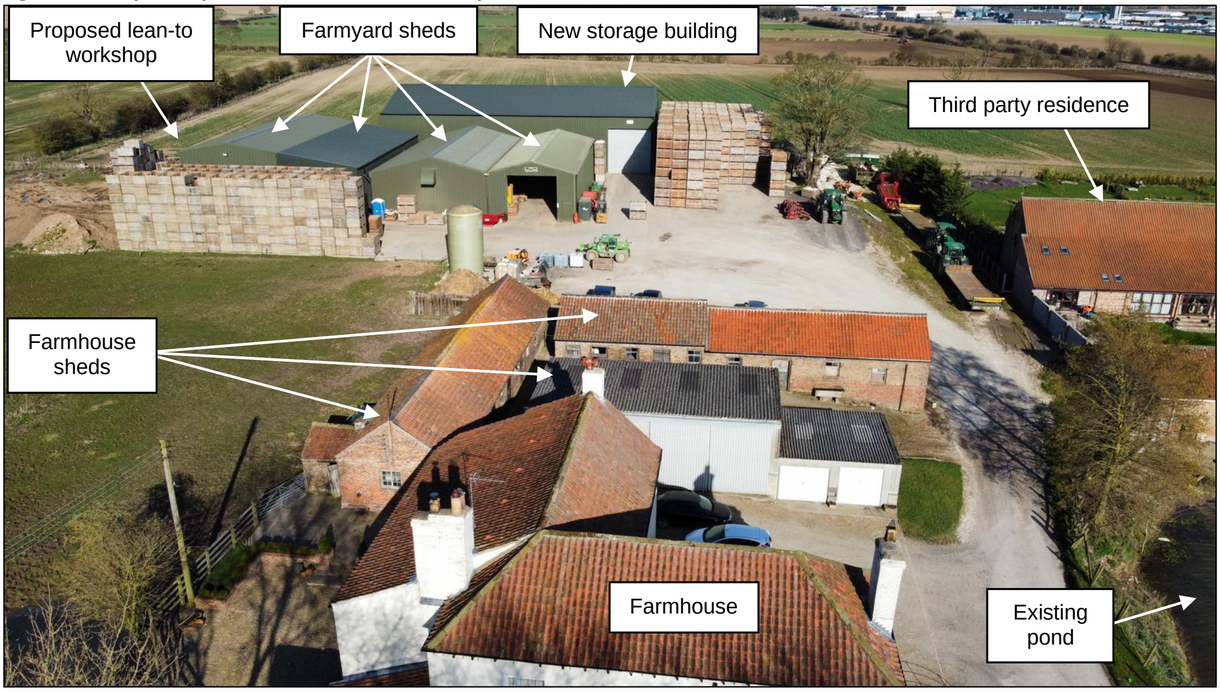
Figure 4 Block Plan of the proposed development, showing its relationship to bounding features



[1] https://newplanningaccess.eastriding.gov.uk/newplanningaccess/applicationDetails.do?keyVal=P7QYWRBJGF500&activeTab=summary

The drone shot in Figure 5 was taken during the summer of 2021 and gives a good overall view of Manor Farm. The features are labelled, using names that will be used throughout the text of this assessment.

Figure 5 Oblique air photo of the farm and farmyard



3 Climate Change

The Environment Agency and NPPF require a consideration of the impacts of climate change on the flood risk for any proposed development. In February 2016, the Environment Agency updated the climate change allowances required in Flood Risk Assessments and surface water management calculations. This advice updates previous climate change allowances to support the NPPF (DCLG, 2012). The Environment Agency (2016) state:

"Making an allowance for climate change in your flood risk assessment will help to minimise vulnerability and provide resilience to flooding and coastal change in the future. The climate change allowances are predictions of anticipated change for:

- peak river flow by river basin district;
- peak rainfall intensity;
- sea level rise;
- offshore wind speed and extreme wave height".

For rainfall, the Environment Agency[2] shows the anticipated changes in small catchments (Table 2), recommending a progressive increase, reaching 20% for the "central" and 40% for the 'upper end' allowance after 2070. These allowances would appear to be appropriate for this development, given the design life of 60 years.

Table 2 Peak rainfall intensity allowance in small and urban catchments

	Total potential change anticipated		
Applies across all of England	2015 to 2039	2040 to 2069	2070 to 2115
Upper end	10%	20%	40%
Central	5%	10%	20%

Source: Environment Agency (2016)

East Riding of Yorkshire Council, Level 1 Strategic Flood Risk Assessment (Capita, 2019)[3] confirms these allowances, stating (p.5) that:

> "*It is important that developers confirm the effect of climate change on their development as part of a site specific flood risk assessment, using the latest allowances appropriate for the type and lifetime of the planned development.*".

SuDS Combined Planning Note and Standing Advice - East Riding of Yorkshire Council (Sept 2016)[4] (p.14) further states:

> "*The drainage design should accommodate expected increases in rainfall volume due to climate change over the lifetime of the development. This should be demonstrated by increasing peak rainfall volume in hydraulic calculations by 30% or by increasing on-site storage by an additional 30%*".

[2] https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances#table-1

[3] https://www.eastriding.gov.uk/planning-permission-and-building-control/planning-policy-and-the-local-plan/strategic-flood-risk-assessment/

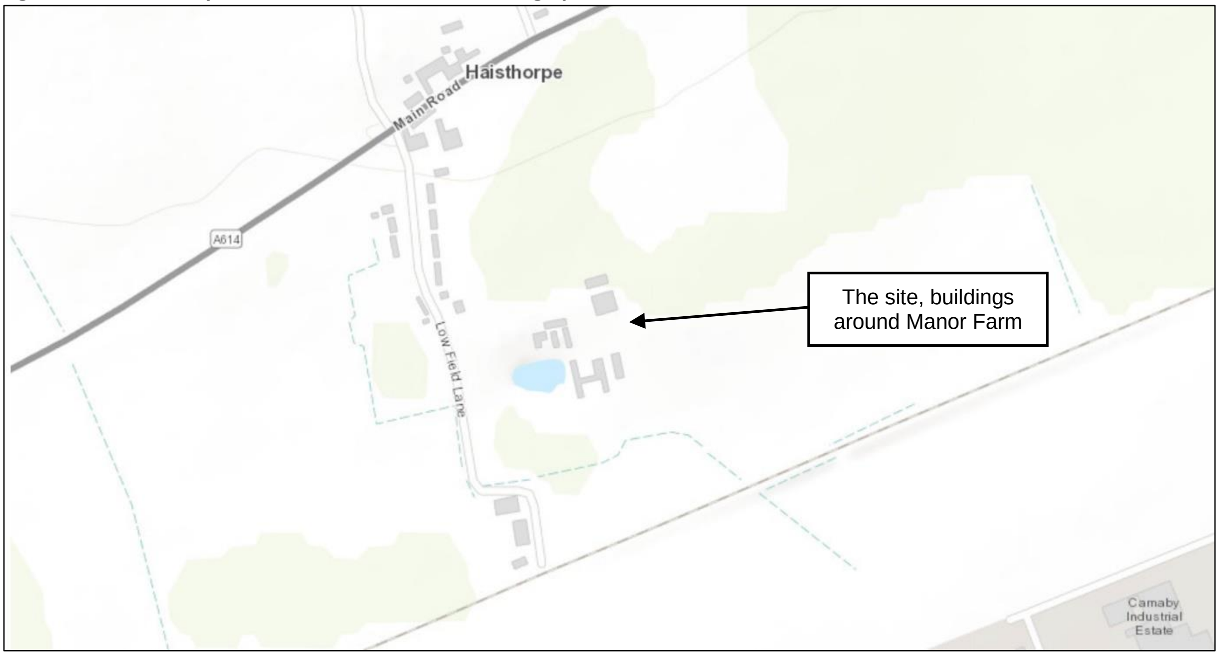
[4] https://www.eastriding.gov.uk/EasySiteWeb/GatewayLink.aspx?alId=604683

4 Drainage

The UK Rivers map (Figure 6)[5] shows no watercourses locally. Zooming into this mapping, smaller streams are shown with dotted lines (Figure 7), indication that flow is ephemeral and possibly seasonal. Many of these temporary drainage lines appear on Figure 7 to have been straightened, suggesting that they have been diverted along road, field boundaries or other features.

Figure 6 Map of rivers in this region, showing none in close vicinity to the site

Figure 7 Rivers locally marked as dotted lines, showing ephemeral flow

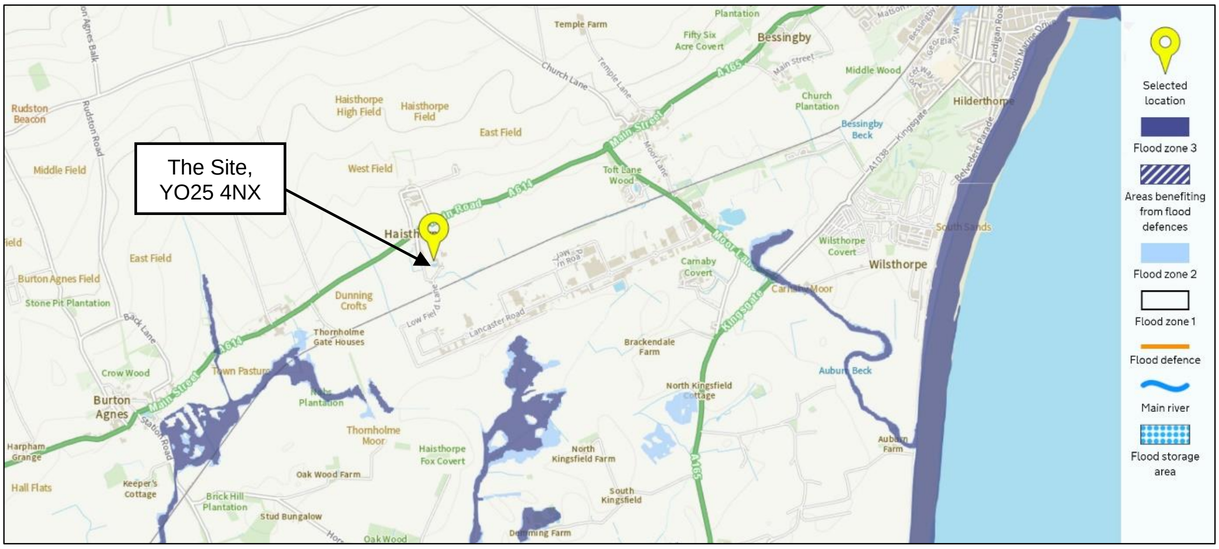


5 https://www.wwf.org.uk/uk-rivers-map

5 Flood Risk

The Flood Map for Planning (Figure 8) shows that the site is located in flood zone 1, beyond the limit of 1:1,000-year fluvial flooding. This is consistent with the Rivers Map (Figure 6). The map of surface water flood extent (Figure 9) picks out a few local streams and some basins in blue. The most severe surface water flooding locally is south east of the site, bounding the railway line and may be associated with an embanked stretch of track. Most of the area and all of the site is shown as having a “Very low” risk of surface water flooding, equivalent to less than 1:1,000-year or 0.1% annual exceedance probability (AEP).

Figure 8 Flood map for Planning shows fluvial flood risk in the region around the site



Source: https://flood-map-for-planning.service.gov.uk/confirm-location?easting=512896&northing=464340&placeOrPostcode=YO25%204NX

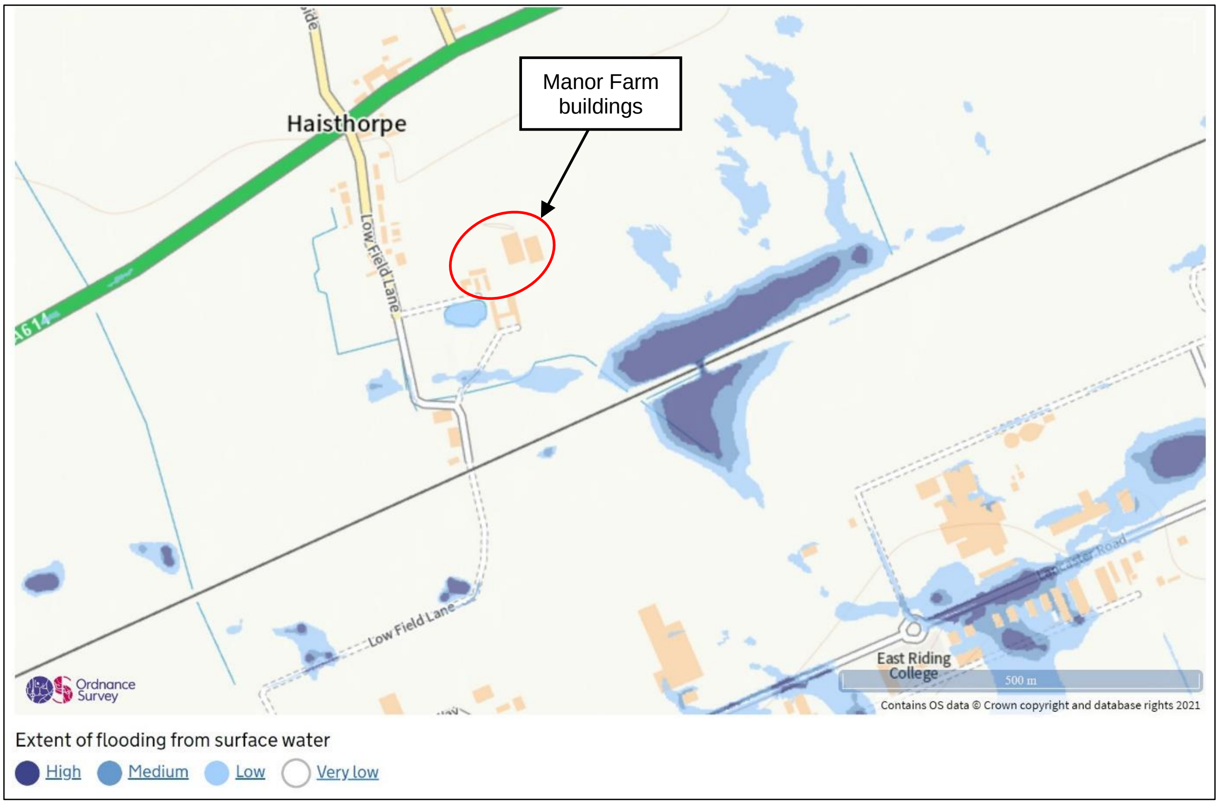
No records have been found of groundwater flooding, although this may be possible, given the permeable nature of the underlying geology. The SFRA (Capita, 2019, Section 5.4, p.50)[6] considers this possibility, stating as follows:

> “*On the upper Wolds, the chalk is overlain by thin soils which, when saturated by intense rainfall, can let water quickly soak through to recharge the groundwater and raise the water table. The soils overlying the chalk on the lower slopes of the Wolds are thicker and consist of clay which can seal water into the chalk.*
>
> *Where there are breaks in this thicker clay, or where the chalk is exposed in streams and river beds, the water pressure can push it to the surface as springs, known locally as kelds, and through river beds, known locally as gypseys*”.

The Environment Agency’s Areas Susceptible to Groundwater Flooding Map has been used within the SFRA to identify groundwater flood risk in the Area. The map is produced at a strategic scale, using a 1 km square grid to show the proportion of each square which may be susceptible to groundwater emergence. Part of this map is reproduced as Appendix E of the SFRA and part of that is included within Figure 10, which shows that over half the grid square that contains the site may be susceptible to groundwater flooding.

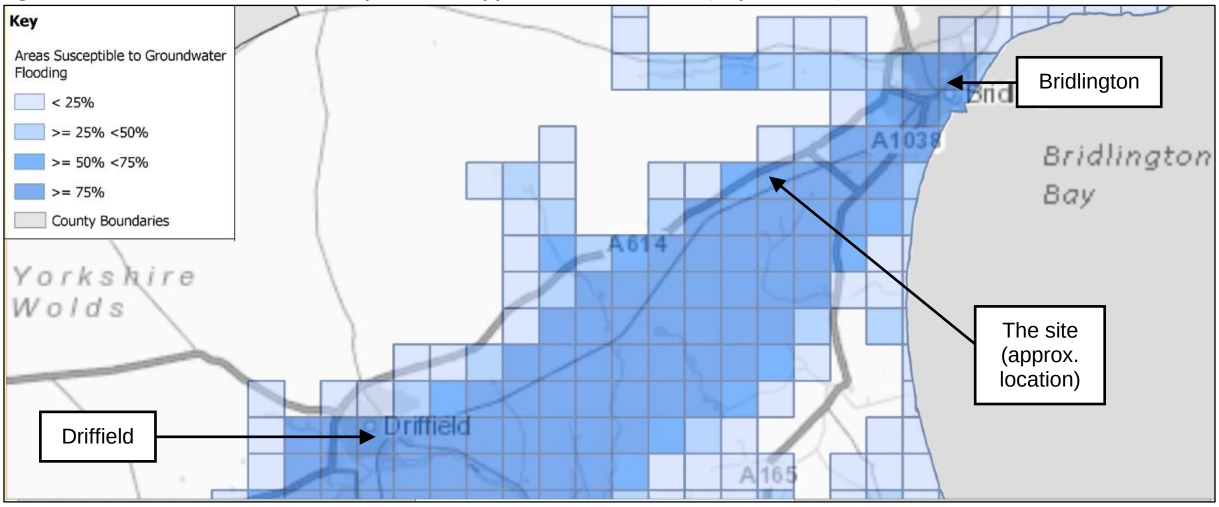
[6] https://www.eastriding.gov.uk/planning-permission-and-building-control/planning-policy-and-the-local-plan/strategic-flood-risk-assessment/

Figure 9 Map of surface water flood extent



Source: https://flood-warning-information.service.gov.uk/long-term-flood-risk/map

Figure 10 Groundwater flood risk, copied from Appendix E of the SFRA (Capita, 2019)

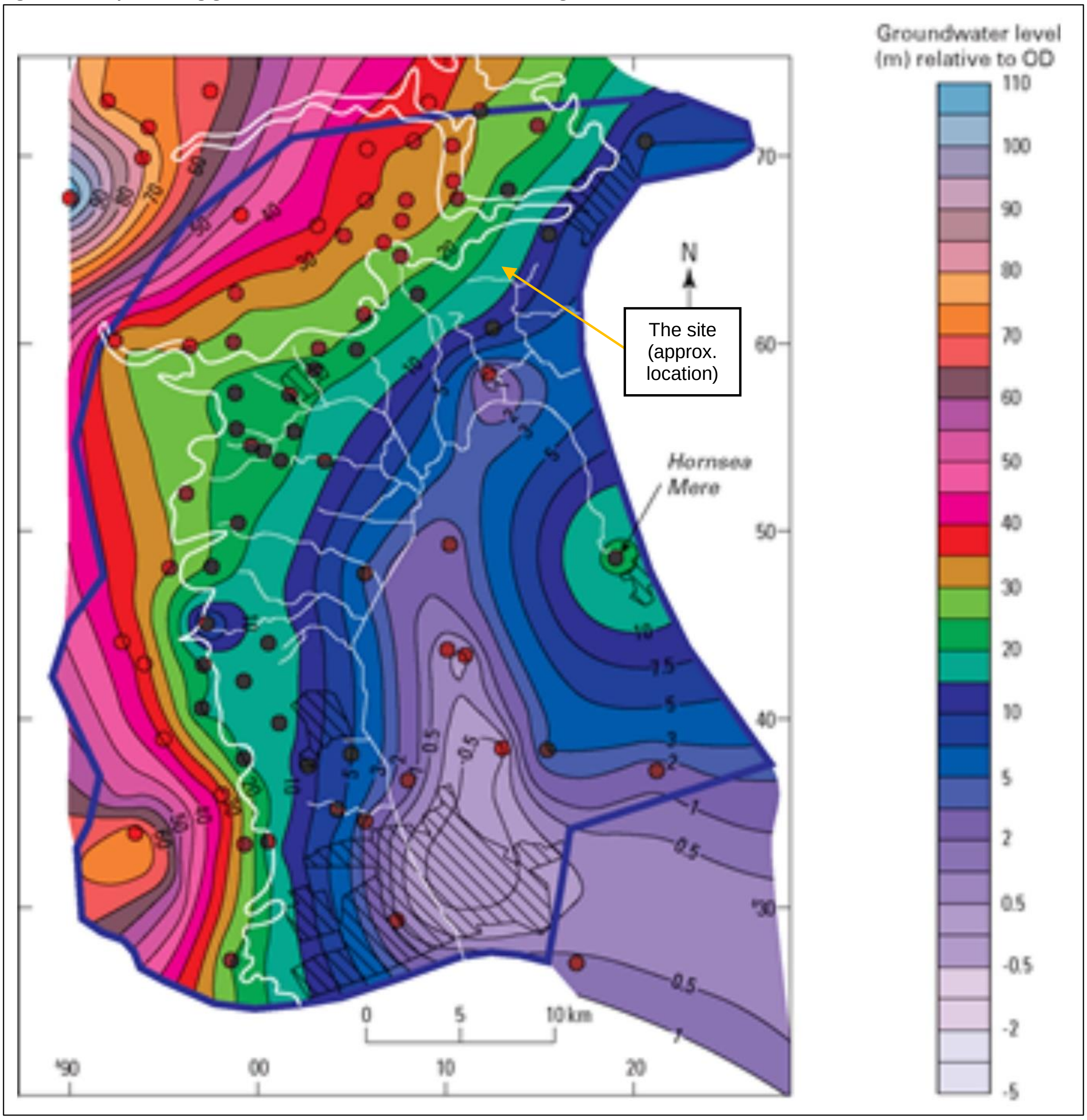


At about 15 mAOD (Figure 2), Manor Farm is located on the lower slopes of the Wolds, where it is underlain by a glacial diamicton (Figure 13). These are some of the clay soils described in the SFRA, which can seal water into the chalk. The Holderness 3D geological model describes groundwater locally. This was created using a package called 'Geological Surveying and Investigation in 3D'. Input data included 1,245 boreholes, geological mapping and a Digital Elevation Model (DEM) of the ground surface. The results are described in "How 3D geological models help flood risk management in E Yorkshire"[7].

[7] https://www.geolsoc.org.uk/Geoscientist/Archive/July-2016/Models-and-flooding

The white line on Figure 11 traces the margin of the chalk (Figure 13), with more recent and less permeable sediments to the east of that contact. Groundwater level at the site is shown to be near the surface, between about 15 mAOD and 20 mAOD. The site drops southward, through this range (Figure 2), and groundwater emergence would flow in that direction. It would probably take routes similar to those shown for surface water flooding (Figure 9).

Figure 11 Map showing groundwater levels on the eastern margin of the Yorkshire Wolds



Source: Figure 4 of How 3D geological models help flood risk management in E Yorkshire

In summary, the risk of flooding from rivers, the sea or surface water is regarded as very low. The risk of groundwater flooding is probably somewhat higher. Although no records have been found, if the site was to be affected by groundwater flooding, it would drain southward, along routes shown by surface water mapping (Figure 9), none of which affects the site.
A less vulnerable use such as this is regarded as being appropriate in locations with flood risk in this sort of range[8].

[8] https://www.gov.uk/guidance/flood-risk-and-coastal-change#Table-2-Flood-Risk-Vulnerability-Classification

6 Surface water management

6.1 Soil and Geology

Regional soil mapping (Figure 12)[9] shows the site to be on land described as “Slowly permeable” and “seasonally wet”, developed over glacial till (Figure 13)[10]. This is consistent with the hydro-geological situation described in the SFRA, shown in Figure 10 and Figure 11.

Figure 12 Soil map of the site and surrounding area

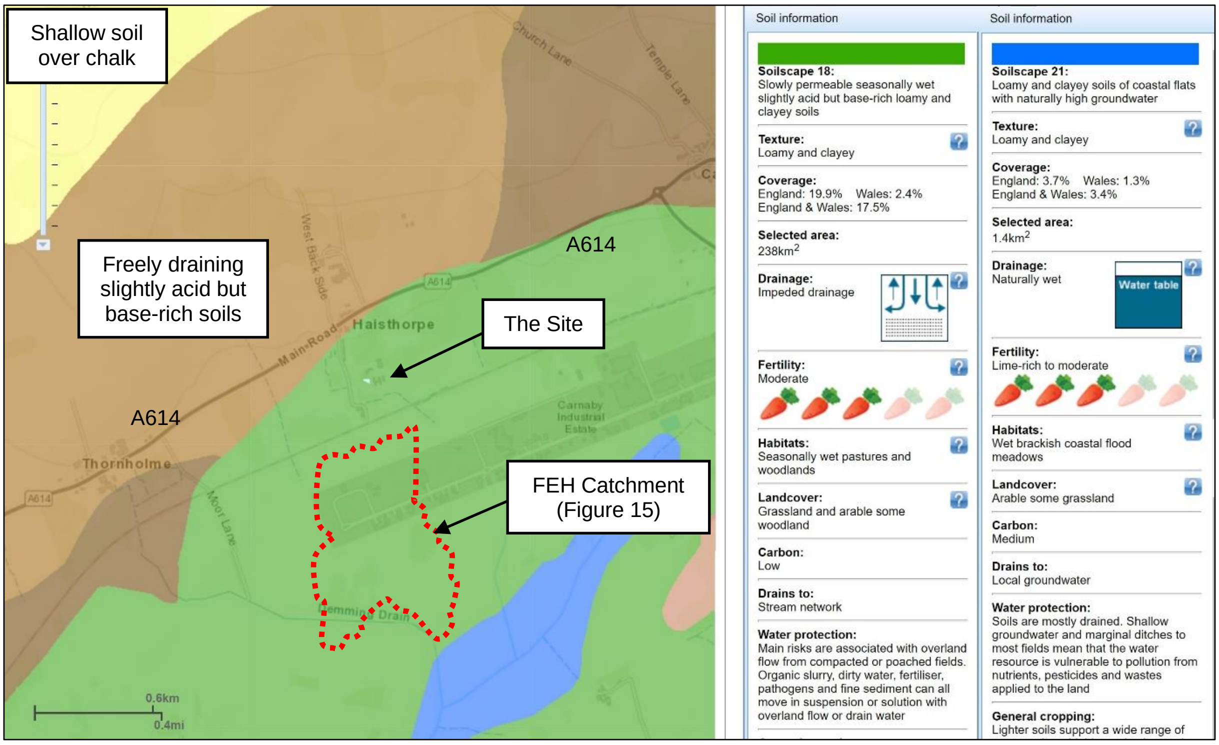
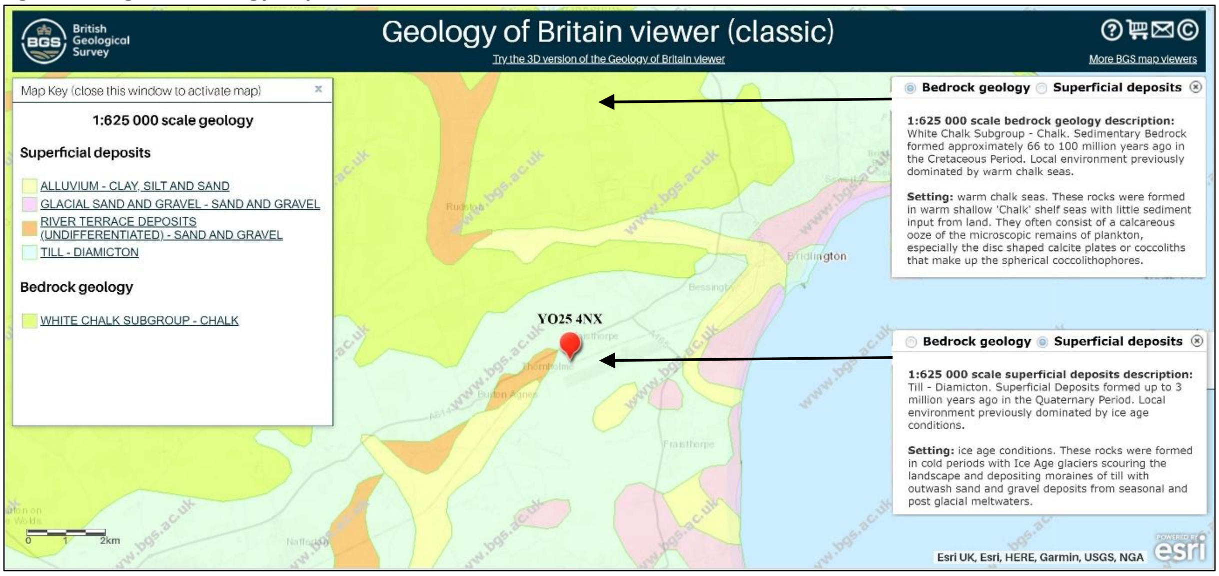


Figure 13 Regional Geology, superficial and bedrock



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[9] http://www.landis.org.uk/soilscapes/#

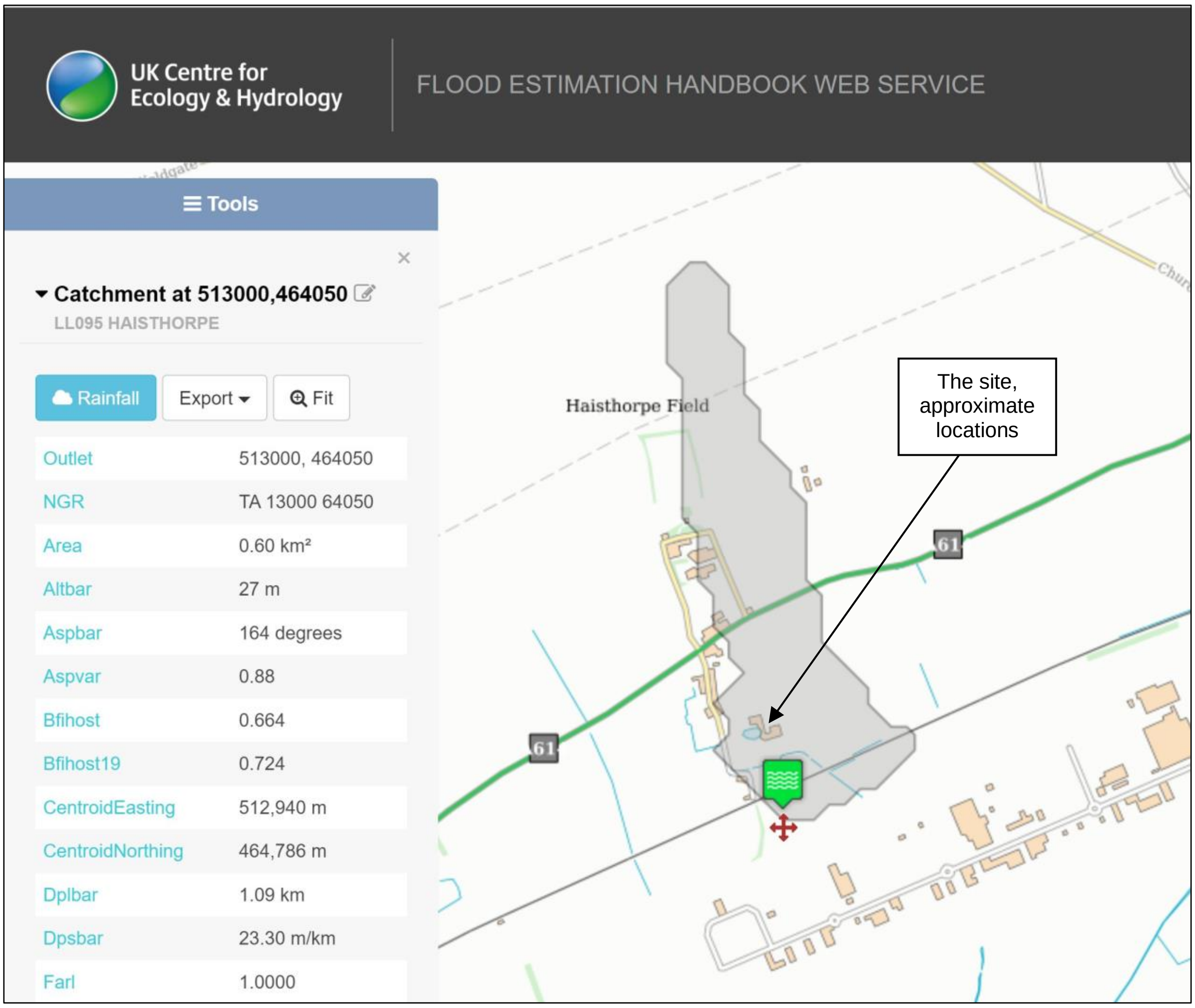
[10] http://mapapps.bgs.ac.uk/geologyofbritain/home.html

6.2 Soil Permeability at the site

A further check on the catchment characteristics is provided by Flood Estimation Handbook (FEH), which has mapped Britain in terms of catchment descriptors. The map in Figure 14 locates the FEH catchment of some 0.6 km^2, which includes the site. The best single indicator of surface permeability is provided by Standard Percentage Runoff, SPRHOST, which has been assessed at 25% in this catchment (Table 3).

This is low in a UK context, indicating high surface permeability, with relatively little rainfall going into runoff. The reason is clear from Figure 12, soils to the north of the A614, main road are permeable and the slowly permeable, seasonally wet soils shown in green on Figure 12 are shown only to the south of that road. Since the FEH catchment in Figure 14 covers both freely draining and slowly permeable soils, SPRHOST takes a value intermediate between the two types to represent the catchment as a whole.

Figure 14 FEH Catchment map, showing the area described in Table 3



Source: https://fehweb.ceh.ac.uk/GB/map

Table 3 Catchment Descriptors for the catchment mapped in Figure 14

CATCHMENT	TA 13000 64050	513000	464050
CENTROID	TA 12940 64786	512940	464786
Catchment Area	AREA	0.5975	
Mean Elevation in m	ALTBAR	27	
Mean Aspect (orientation) in Degrees	ASPBAR	164	
Aspect Variance in Degrees	ASPVAR	0.88	
Base Flow Index	BFIHOST	0.664	
Base Flow Index	BFIHOST19	0.724	
Mean Drainage Path Length	DPLBAR	1.09	
Mean Drainage Path Slope	DPSBAR	23.3	
Flood Attenuation by Reservoirs & Lakes	FARL	1	
Floodplain Extent	FPEXT	0.1967	
Mean Floodplain depth, 1:100-year event (m)	FPDBAR	1.544	
Location of Floodplains within Catchment	FPLOC	0.382	
Longest Drainage Path (km)	LDP	2.24	
Time Soil Moisture Deficit < 6mm	PROPWET	0.3	
annual max rainfall for duration of 1 hour	RMED-1H	10.1	
annual max rainfall for duration of 1 day	RMED-1D	31.7	
annual max rainfall for duration of 2 days	RMED-2D	39.3	
Average Annual Rainfall (1961-1990)	SAAR	663	
Average Annual Rainfall (1941-1970)	SAAR4170	701	
Standard Runoff Percentage	SPRHOST	25	
Extent of Urban Land Cover (2000)	URBEXT2000	0.0251	

Source: FEH Web Service

In view of regional soil mapping (Figure 12), describing the local soil as “Slowly permeable” and “seasonally wet” and the hydro-geological situation described in the previous section, the soil permeability was not tested. Although the underlying superficial geology of glacial till is described as a diamicton (meaning that it contains a range of particle sizes), it is clear from the description of “seasonally wet” that it is unlikely to be a reliable infiltration medium. Even if runoff could be infiltrated into the surface during dry periods, rising groundwaters during the subsequent wet season could enter any soakaway system, making it unusable. For these reasons, it is recommended that runoff from the new impermeable surfaces is attenuated.

Although the catchment shown in Figure 14 covers the site, it is not representative of site conditions, being heavily influenced by the more permeable soils to the north. For this reason, data was downloaded from the adjacent catchment (Figure 15) which is entirely underlain by glacial till (Figure 13) and entirely within the soil type shown at the site (Figure 12). Catchment Descriptors in Table 4 show a significantly higher value of SPRHOST, at 41%, which is far more representative of runoff over such a heavy and waterlogged soil (Figure 12). The catchment descriptors listed in Table 4 are the ones used to calculate values for Greenfield runoff in Appendix A and all the subsequent calculations that are used to design the surface water management system.

Figure 15 FEH Catchment map, showing the area described in Table 4

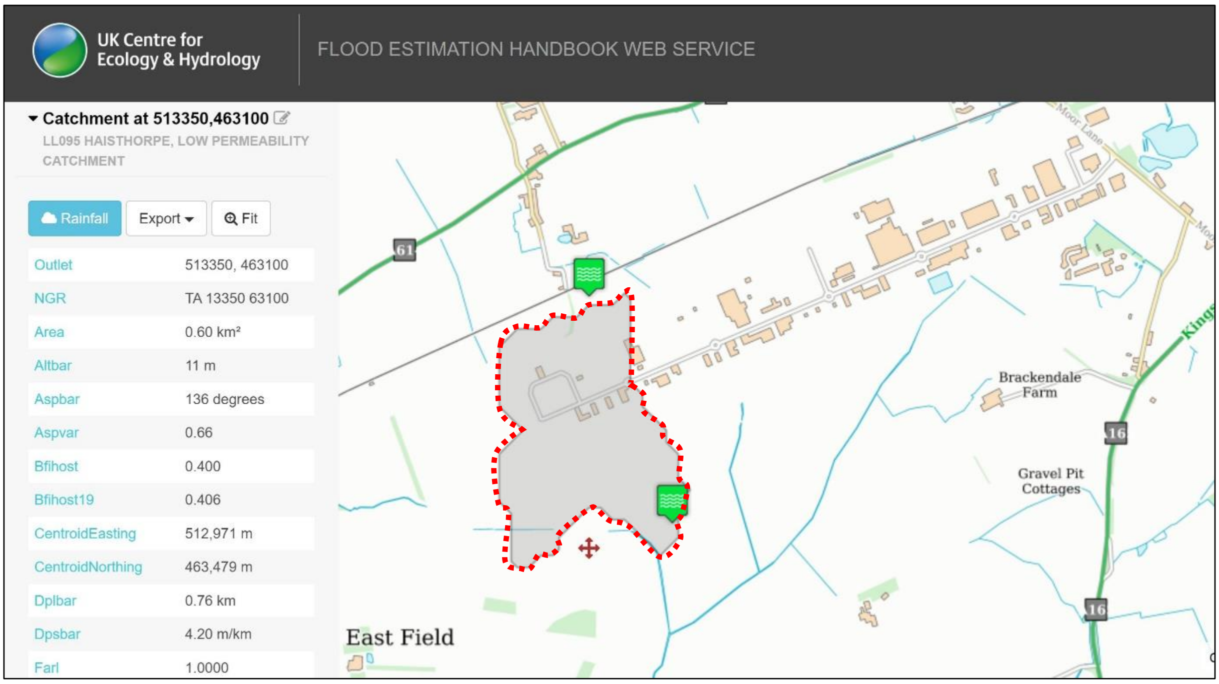


Table 4 Catchment Descriptors for the catchment mapped in Figure 15

CATCHMENT	TA 13350 63100	513350	463100
CENTROID	TA 12971 63479	512971	463479
Catchment Area	AREA	0.595	
Mean Elevation in m	ALTBAR	11	
Mean Aspect (orientation) in Degrees	ASPBAR	136	
Aspect Variance in Degrees	ASPVAR	0.66	
Base Flow Index	BFIHOST	0.4	
Base Flow Index	BFIHOST19	0.406	
Mean Drainage Path Length	DPLBAR	0.76	
Mean Drainage Path Slope	DPSBAR	4.2	
Flood Attenuation by Reservoirs & Lakes	FARL	1	
Floodplain Extent	FPEXT	0.4706	
Mean Floodplain depth, 1:100-year event (m)	FPDBAR	2.685	
Location of Floodplains within Catchment	FPLOC	0.684	
Longest Drainage Path (km)	LDP	1.29	
Time Soil Moisture Deficit < 6mm	PROPWET	0.3	
annual max rainfall for duration of 1 hour	RMED-1H	10.1	
annual max rainfall for duration of 1 day	RMED-1D	31.1	
annual max rainfall for duration of 2 days	RMED-2D	38.3	
Average Annual Rainfall (1961-1990)	SAAR	654	
Average Annual Rainfall (1941-1970)	SAAR4170	695	
Standard Runoff Percentage	SPRHOST	41.08	
Extent of Urban Land Cover (2000)	URBEXT2000	0	

Source: FEH Web Service

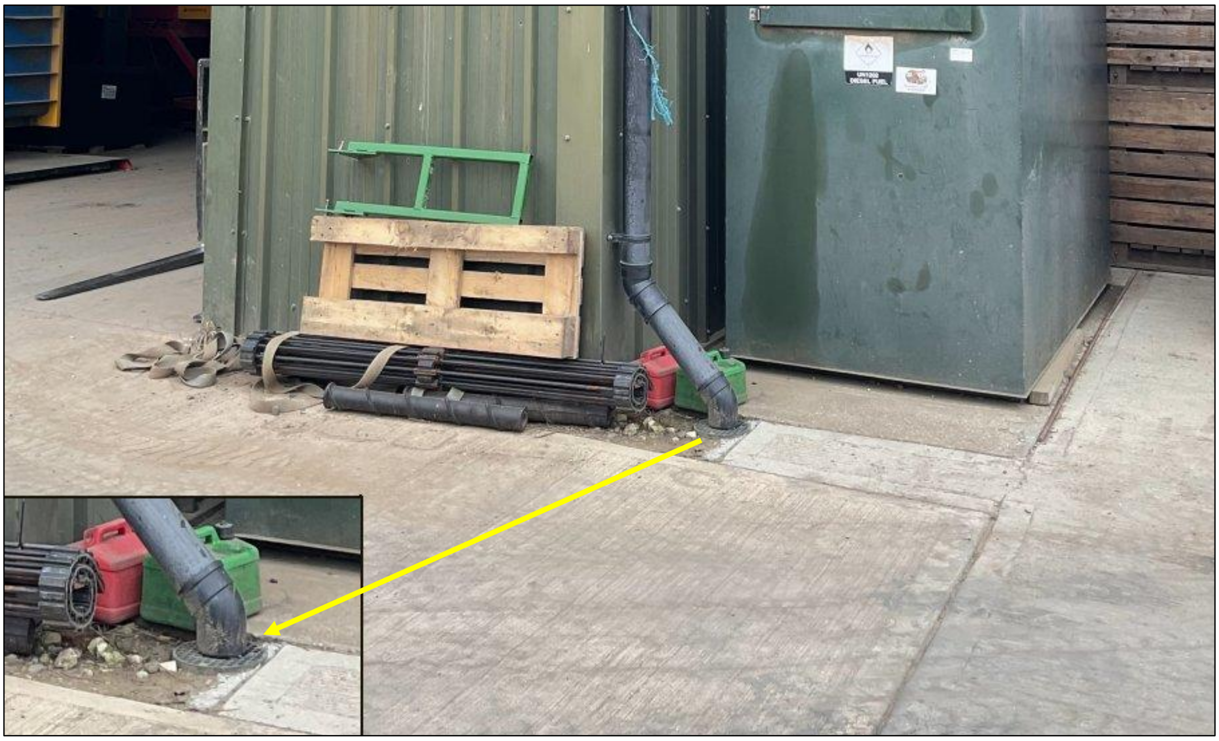
6.3 Site Drainage Arrangements

Existing surface water drainage arrangements at the site reflect the drainage associated with the existing buildings. These already drain underground from the farmhouse (Figure 16), the buildings around it (Figure 17) and from the new storage building (Figure 18).

Figure 16 Roof runoff at the farmhouse, adjacent to the access road

Figure 17 Roof drainage at one of the historic sheds to the immediate east of the farmhouse

Figure 18 Roof runoff from the new storage building is also plumbed into an underground system



6.4 Attenuation System

As shown above, runoff from impermeable surfaces on site is managed by conveying it underground, to the existing pond using closed plastic pipes, with the concrete work area bounding the sheds using filter drains. In the event of surcharge, caused by blockage or exceedance, runoff would reach the pond by flowing down the regional slope, towards the south. The Applicant describes the existing pond as overflowing through a pipe, with a 3-inch (~75 mm) diameter. This system will have provided some attenuation to outflow, but may not provide enough in terms of the flood risk provisions of the NPPF.

6.5 Orifice Plates and Perforated Riser

The outflow chamber, located immediately adjacent to the pond margin, should be set within a water-tight concrete pipe or box, inset into the surface and accessible from above. This arrangement is necessary for orifice plates, set within a perforated riser. The pond needs to connect directly with such an arrangement, which should be set within the lower part of the depth range of the pond itself. This is shown in Figure 23, a diagrammatic cross-section of the recommended attenuation pond, summarising some of the features and dimensions recommended within the drainage design.

One of the most common flow control devices in use on attenuation systems is the outflow orifice, commonly used as a restriction device to regulate flow downstream. Flow through an orifice is governed by the Orifice Equation, based on the Torricelli equation[11] and shown as Equation 1, below.

[11] Nicolas G. Adrien, 2003, Computational Hydraulics and Hydrology, An Illustrated Dictionary, CRC Press.

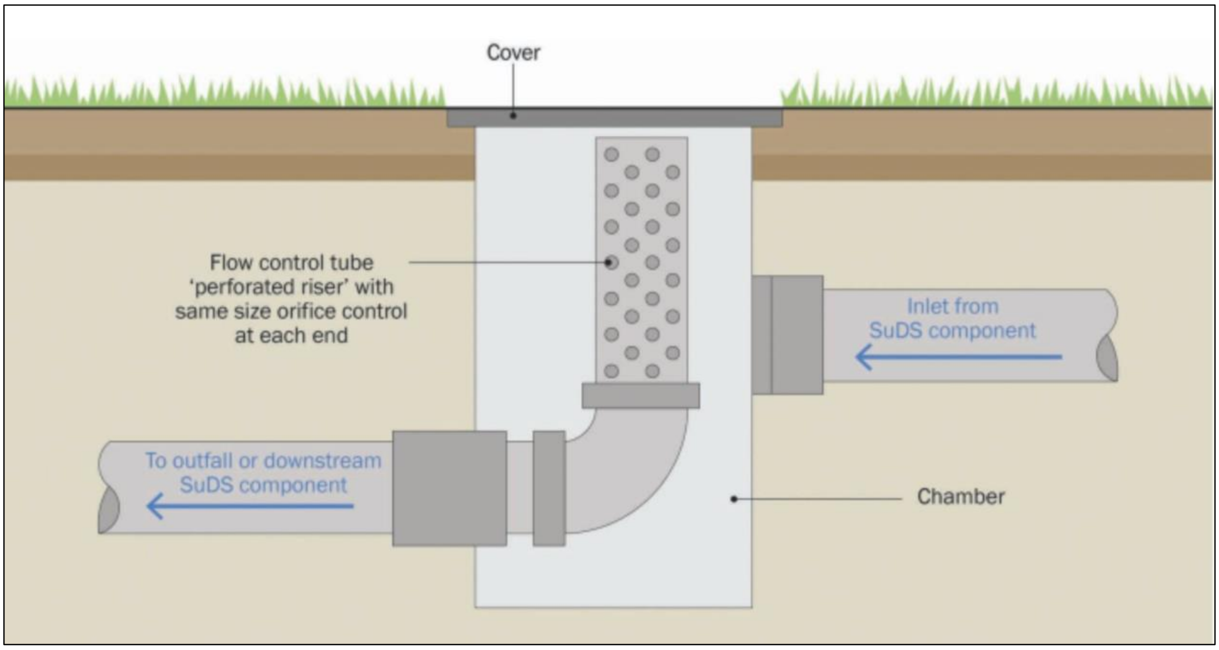
Equation 1

$$Q = C_d \, A_o \, \sqrt{2gh}$$

Where: Q = Orifice discharge rate (m^3/s)
C_d = Coefficient of discharge (m, 0.6 for an orifice plate)
A_o = Area of orifice (m^2)
h = Hydraulic head (m)
g = 9.81 m/s

The device can be mounted in a wall or baffle, in a perforated riser or in a T-piece section, used for regulating overflow above a given height. Since outflow from an attenuation pond cannot safely be interrupted by blockage, its use within a perforated riser is common in the context of attenuated discharge and is the combination discussed here. The example from the SuDS Manual is reproduced as Figure 19.

Figure 19 Example perforated riser, set within outflow chamber to facilitate maintenance



Source: CIRIA C753 (2015), Figure 28.19, p.620.

Outflow from the attenuation pond, to the right of Figure 19, enters the chamber containing the perforated riser, with an orifice control set at its base and another at its top. Water passes through the perforations in the riser tube, which are calibrated to ensure that they convey more water than the orifice outflow itself, so the riser does not control the rate of outflow. Within the tube, water passes through the orifice at its base before outflowing to the left of Figure 19, at an attenuated rate defined by the orifice's internal diameter.

Within the riser, perforations are designed to prevent particles reaching the orifice, which could contribute to blockage. Solids may drop to the base of the chamber or become ensconced within the perforations, forcing inflow to the top of the tube, where Figure 19 recommends a second orifice plate, of the same internal diameter. As water depth rises within the attenuation pond, it would also rise within the outflow chamber, eventually allowing outflow over the top of the perforated tube. Outflow would still be controlled by the lower orifice but the value of the perforated riser in filtering debris would be much reduced.

6.6 Maintenance

The proper maintenance of attenuation ponds is described by the SuDS Manual (CIRIA C753, 2015)[12]. An outline maintenance schedule is shown in Table 5. This generic guidance applies to a range of site conditions. It is recommended that a site-specific maintenance schedule be established along these lines, in order to define when maintenance tasks should be completed. Any regular maintenance required on the other structures, the sheds and road surfaces for instance should be added to produce a schedule for the whole site.

7 Occupants and Users of the Development

It was pointed out in Section 5, Flood Risk, that the site is located in flood zone 1, beyond the limit of 1:1,000-year fluvial flooding and that there is no risk from surface water or any other known source of flooding. The only possible exception to this is groundwater flooding. There is no record of this in the past and it is therefore understood that there is no significant flood risk to people working on the site or visiting it.

8 Sequential and Exception Tests

The Sequential test should be applied to ensure that a proposed development is located in an area which has the lowest possible flood risk. That is the case with this site, which is located entirely in flood zone 1. It is not necessary to apply the Exception Test to low vulnerability developments in flood zone 1.

9 Residual risk

Residual risks are confined to the surface water management system. They may involve exceedance of design rainfall or failure of elements of the system. Residual risks are considered towards the end of Appendix A, where an outline surface water management plan has been recommended.

[12] https://www.ciria.org/Resources/Free_publications/SuDS_manual_C753.aspx

Table 5 Operation and maintenance requirements for ponds and wetlands

Maintenance schedule	Required action	Typical frequency
Regular maintenance	Remove litter and debris	Monthly (or as required)
	Cut the grass – public areas	Monthly (during growing season)
	Cut the meadow grass	Half yearly (spring, before nesting season, and autumn)
	Inspect marginal and bankside vegetation and remove nuisance plants (for first 3 years)	Monthly (at start, then as required)
	Inspect inlets, outlets, banksides, structures, pipework etc for evidence of blockage and/or physical damage	Monthly
	Inspect water body for signs of poor water quality	Monthly (May – October)
	Inspect silt accumulation rates in any forebay and in main body of the pond and establish appropriate removal frequencies; undertake contamination testing once some build-up has occurred, to inform management and disposal options	Half yearly
	Check any mechanical devices, eg penstocks	Half yearly
	Hand cut submerged and emergent aquatic plants (at minimum of 0.1 m above pond base; include max 25% of pond surface)	Annually
	Remove 25% of bank vegetation from water's edge to a minimum of 1 m above water level	Annually
	Tidy all dead growth (scrub clearance) before start of growing season (Note: tree maintenance is usually part of overall landscape management contract)	Annually
	Remove sediment from any forebay.	Every 1–5 years, or as required
	Remove sediment and planting from one quadrant of the main body of ponds without sediment forebays.	Every 5 years, or as required
Occasional maintenance	Remove sediment from the main body of big ponds when pool volume is reduced by 20%	With effective pre-treatment, this will only be required rarely, eg every 25–50 years
Remedial actions	Repair erosion or other damage	As required
	Replant, where necessary	As required
	Aerate pond when signs of eutrophication are detected	As required
	Realign rip-rap or repair other damage	As required
	Repair / rehabilitate inlets, outlets and overflows.	As required

Source: The SuDS Manual, CIRIA C753 (2015), Table 23.1, p.502[13]

[13] https://ciria.sharefile.com/share/view/f0969d1215b248fe

10 Surface water management credentials

This surface water management plan was written by Chris Nugent of Lidar-Logic. Chris has worked since 1981 in areas of hydrology and fluvial geomorphology, specialising in flood risk assessment and surface water management in 2007. Since then, working for Hydro-Logic Services (HLS), he has written and/or managed well over 500 assessments of flood risk across the UK, most of which included a surface water management component. Chris left HLS to form Lidar-Logic in August 2018. The current work was prepared for submission to Planning in August and September 2021.

Appendix A - Drainage Design for Impermeable Areas

A.1 Greenfield Runoff

The "rural" rates and volumes of surface water runoff generated by the site are calculated as the Greenfield rates. This has previously been done using the Marshall and Bayliss (1994) methodology of IH 124[14]. Determination of Greenfield runoff rates has been improved by the introduction of Version 2 of the revitalised flood hydrograph model, known as ReFH2. This methodology has been shown to provide a more accurate assessment of Greenfield runoff than IH 124, at the plot scale, which is usually smaller than the catchment scale.

By using this facility, ReFH2 is able to obtain more accurate estimates of Greenfield Runoff from that part of the site which is proposed to be covered with an impermeable surface. Those parts which will not be developed in this way would be allowed to drain as at present and only runoff from impermeable areas would additional management be recommended. Greenfield runoff rate was estimated using the procedure described on the "refhdocs" website[15], summarised below:

1) Catchment descriptors derived from FEH (Table 4) were read into ReFH2. Equations for "plot scale" are different from those used for "catchment scale" calculations, so the former were selected.
2) The areal reduction factor was set to 1, to remove the effect of catchment area on design rainfall estimates.
3) The catchment area was set manually to 0.5 km^2 (50 ha), that value applied and the values for T_P and B_L were recorded, where T_P is the unit hydrograph time to peak in hours and B_L is the baseflow recession lag, also in hours.
4) At this point the catchment area was set to the proposed impermeable area on the site and the model updated, which automatically sets the values of T_P and B_L to those commensurate with the site area.
5) These values were then reset with the recorded values of T_P and B_L, that were generated for the 0.5 km^2 catchment. This sets the recommended duration to that for the 0.5 km^2 extent and effectively rescales results, as recommended by the SuDS guidance on model parameters.

Applying this procedure in ReFH2.2 produced Greenfield runoff values from the area which is proposed to become impermeable and the area of the attenuation structures which would receive rainfall directly. The calculated Greenfield runoff values are shown in Table 6 for a range of return periods: 1:2 years, 1:30 years and 1:100 years. The last column in Table 6 shows attenuated rates, derived from the MicroDrainage calculations described below. Attenuated runoff is at or below Greenfield rates at all these return periods.

Table 6 Greenfield and attenuated runoff from impermeable areas

0.6	Peak Flow		Attenuated
Return Period	**l/s/ha**	**l/s**	**l/s**
1:2 year	3.39	1.83	1.6
1:30 year	7.03	3.79	2.1
1:100 year	8.98	4.85	2.4

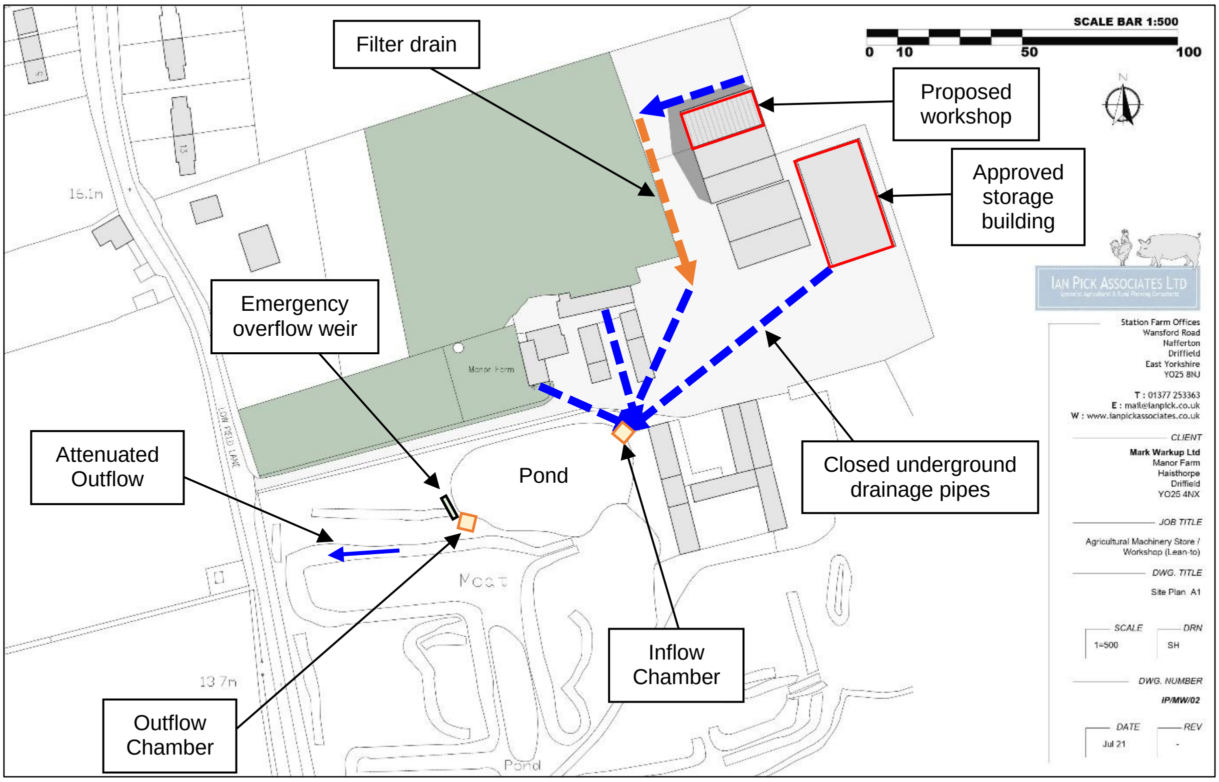
[14] http://nora.nerc.ac.uk/id/eprint/7367/1/IH_124.pdf

[15] https://refhdocs.hydrosolutions.co.uk/Drainage-Design-Applications/Greenfield-Runoff-Rates-and-Volumes/

A.2 Conveyance and Inflow

It is recommended that runoff from the proposed lean-to is directed to the pond in the same way as runoff from the existing sheds. This is shown in Figure 16, Figure 17 and Figure 18, where roof runoff goes into the closed underground system. Only along the margin of the existing concrete is a filter drain used, which drains into the closed system towards the pond Figure 20. Once runoff is within the closed, underground piping it has the advantage of not being subject to possible pollution from surface waters and not allowing groundwater in but the disadvantage that it may be difficult to locate and clear blockage. Since this is the system already employed at the site to convey roof runoff from the existing buildings, which are outside the scope of this Application, it is recommended that the same system is augmented to include the two new structures, the storage building and the proposed lean-to workshop.

Figure 20 Map of the site and immediate surrounds, showing impermeable surfaces and outline drainage system



Note: Routes taken by underground pipes are indicative

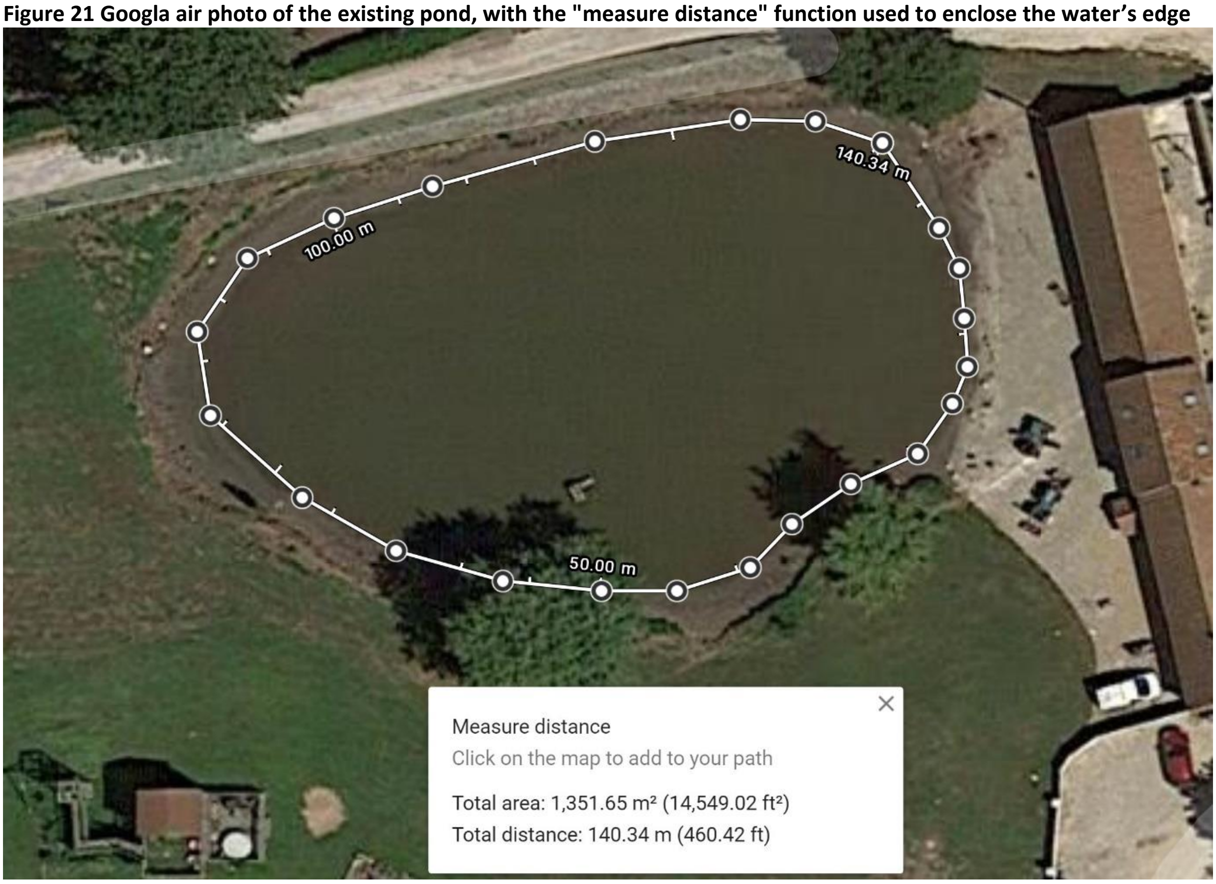
It can be seen from Figure 18 that drainage of the approved storage shed has already been implemented and it is assumed that a similar system would be used to drain the proposed workshop. An underground drainage pipe is shown on Figure 20, which would convey runoff to the northern end of a filter drain. Assuming that this filter drain has sufficient conveyance, it could be used to include the workshop runoff. Alternatively, the workshop runoff could be contained within a closed plastic pipe, buried within, beneath or beside the filter drain.

A.3 Attenuation Pond Design Constraints

The purpose of the attenuation pond is to receive the runoff from impermeable surfaces on the site and release it slowly, at a rate at or below Greenfield runoff rate. In that way, the development cannot increase flood risk elsewhere. The existing sheds already drain to the pond and, since it is proposed at a location adjacent to one of the sheds, the proposed lean-to would also be able to do so.

The current pond at this site covers an area of about 1,350 m^2 at water level (Figure 21). Since the pond is never expected to fall below that height, this can be regarded as the base of the attenuation layer, whose area therefore starts at the modern water level (Figure 21). The Applicant has reported that the pond currently discharges through a "three-inch diameter outflow pipe, set 18 inches below the rim" and it is assumed that the air photo in Figure 21 caught it at this resting level. The pond already provides some informal attenuation, as any significant rainstorm over the farmyard catchment into the pond would temporarily raise water level, with the three-inch diameter pipe attenuating subsequent outflow.

Figure 21 Googla air photo of the existing pond, with the "measure distance" function used to enclose the water's edge



The surface water management plan seeks to ensure that the outflow is attenuated down to rates equivalent to or less than rates of Greenfield runoff, at all return periods. At the same time, the pond needs to be safe and, as far as possible protected against blockage. In order to confirm this and determine the characteristics of the best flow control device, the pond was modelled in MicroDrainage, with the invert of the attenuation layer taken as 0 m.

Pond dimensions were measured from the air photo (Figure 21) and measurements taken by the Applicant. They are listed in Appendix C and summarised in Table 7. The pond margin, "cover level" in MicroDrainage was taken as 0.60 m. The lowest point on the pond rim was measured at 18 inches (about 450 mm) above the outflow.

A.4 Outflow and Overflow

Outflow from the existing pond uses the moat (Figure 22), on which the pond was originally built. It can be seen on Figure 22 that the rim of the pond to the right of the current overflow is about 450 mm above the resting lake level. It is recommended that the current overflow is converted into a formal outflow, as described in the next section and at least part of the rim of the pond is made into an emergency overflow weir, at a level a little below the current level.

Figure 22 Outflow and emergency overflow route from the attenuation pond

The outflow should be contained should be set within a water-tight concrete pipe or box, as described in Section 6.5. Attenuation is provided by the recommended flow control and the filtration of solid material, such as vegetation or plastic bags would be provided by a suitable system, a perforated riser is recommended. It is shown below that the recommended system, devised in MicroDrainage and described below would raise the pond surface by some 228 mm during the 1:100-year rainstorm, with the 30% allowance for climate change. This is the allowance recommended by the East Riding of Yorkshire Council in their Standing Advice on SuDS (see Section 3).

The Environment Agency's "upper end" estimate is that a 40% increment on peak rainfall should be applied. MicroDrainage modelling suggests that during the 1:100-year rainstorm, a 40% allowance for climate change would raise water level to 246 mm above the invert of the attenuation layer. By setting the emergency overflow weir at a level 300 mm above the outflow invert, both allowances for climate change would be managed by the pond, without any overflow.

As described in Section A.7, below, there are two residual risks which could affect the pond as designed. One is exceedance and it is possible that a rainstorm could significantly exceed the magnitude used in the pond design, the 1:100-year event with allowance for climate change. The second possibility is that the outflow could become blocked or partially blocked, causing water to rise to the level of the overflow weir, after which it could overtop the weir set in the pond rim and flow along the length of the moat, as shown in Figure 22. For this reason, it is recommended that the weir surface and the overflow route for some distance below it should be covered by a resilient material such as stone, concrete or Grasscrete. This would resist any downcutting, by the rapidly flow of water and help to channel the water safely away.

A.5 Attenuation Design

Several different flow control devices were tried at the outflow but discharge was kept below Greenfield rates, using a 50 mm diameter orifice at the invert of the attenuation layer (current resting water level). This ensures that outflow after rainstorms at the 1:2-year, 1:30-year and 1:100-year return periods, with allowance for climate change would be kept below Greenfield runoff rates. It is assumed that outflow from the pond will be below Greenfield rates at all return periods within this range.

The maximum water depth within an attenuation pond of the size specified below, during a 1:100-year rainstorm, with a 30% climate change allowance, was calculated as 0.228 m above the invert of the attenuation layer within the pond (summary in Table 8). The pond was tested in MicroDrainage using an “upper end” inflow, the 1:100-year rainstorm with a 40% increment and water depth in the attenuation layer rose to 0.246 m. This is 54 mm below the emergency overflow weir, showing that such an event would be contained by the attenuation pond.

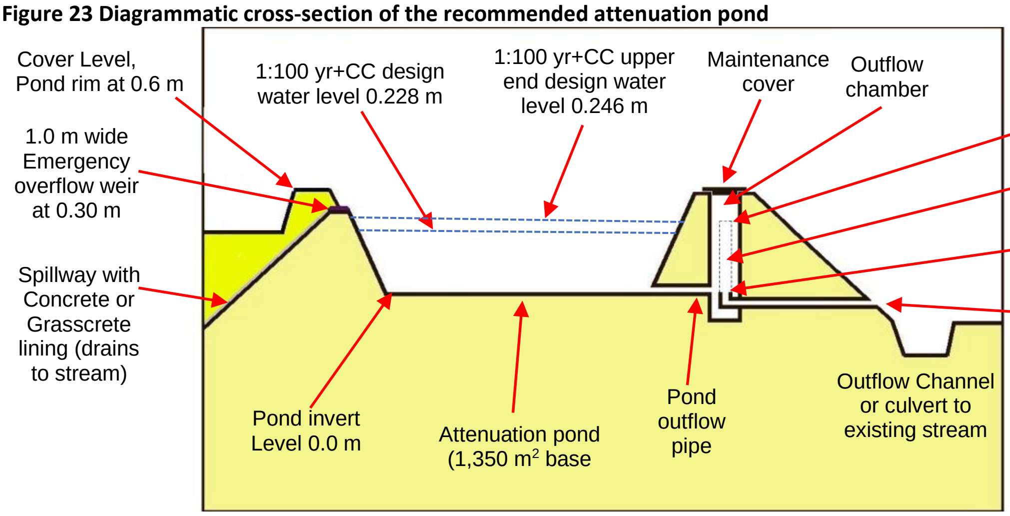
A summary of these and associated measures modelled in MicroDrainage are listed in Table 7. The MicroDrainage output is included as Appendix C and, for comparison with Greenfield rates, the peak outflow rate during each of these return periods is included as the last column of Table 6.

Table 7 MicroDrainage, summary of assumptions, settings and results

Summary - Manor Farm, Haisthorpe, Driffield		
Inflow	Rainfall	
Storage structure	Attenuation Pond	
Outflow	Orifice	
Overflow	Weir	
Design life (years)	60	
Details		
Rainfall model	FEH, 2013	
Catchment area (m^2)	5,400	
Area of storage at invert level (m^2)	1,350	
Area of storage at cover level (m^2)	1,725	
Orifice outflow diameter (mm)	50	
Level of overflow weir (m)	0.30	
Level of pond margin (cover level, m)	0.60	
Results, for 1:100 yr+CC rainstorm		
Scenario - Climate change allowance	30%	40%
Max. depth of storage (m)	0.228	0.246
Critical duration (winter, minutes)	960	960

The essential features of the recommended attenuation system listed in Table 7 are summarised diagrammatically in Figure 23, which represents the principal structures of the MicroDrainage design as a cross-section and mapped in Figure 20. These levels are listed in Table 8 for clarity. As described in text under residual risks (Section A.6, below) a rise in water level within the pond may be an indication of partial blockage of the perforated riser. As such, it serves as a potentially valuable indicator. This should be explained to staff at the site, so that should they ever observe such a rise in water level, they take the appropriate measure to inspect the perforated riser and clean out the filtration system, if necessary.

Figure 23 Diagrammatic cross-section of the recommended attenuation pond



The outflow from the pond, including the flow control orifice, would be set within the outflow chamber located in Figure 20, set within the bank to facilitate maintenance (Figure 23). The emergency overflow weir should be located nearby but not immediately above the chamber. It would be used only following exceedance of rainfall, above predicted levels or severe blockage of the outflow orifice. Perforated risers have been included, as these provide suitably rigorous filtration, as described in Section 6.5. The perforated section would have 50 mm orifice plates located at the top and bottom of the tube, providing a considerable level of reassurance over the avoidance of blockage.

Table 8 Proposed Attenuation Pond residual risk specifications summary

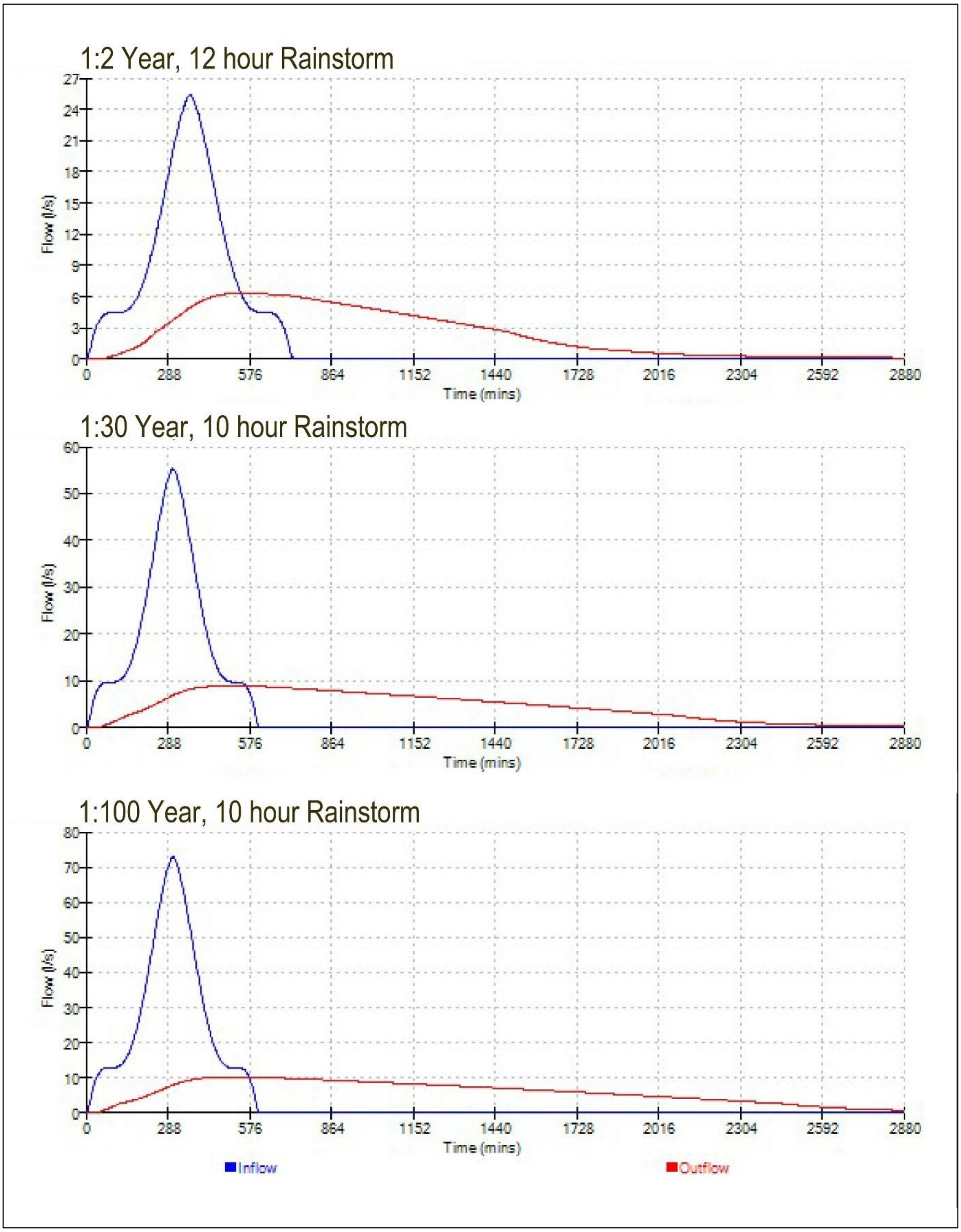
Structure	Ht. above pond base (m)
Embankment crest	0.60
Pond emergency weir level	0.30
Pond 1:100 yr+40%CC water level	0.246
Pond 1:100 yr+30%CC water level	0.228
Pond 1:30 yr+30%CC water level	0.185
Pond 1:2 yr+30%CC water level	0.113
Attenuation layer base invert level	0.000
Pond outflow orifice (invert level)	0.000

All levels in the table are above the invert of the outflow orifice, the current rest water level.

A.6 Attenuation Achieved

The graphs in Figure 24 were taken from the MicroDrainage output in Appendix C and illustrate the flow from the impermeable surfaces on the site, before and after passing through the recommended attenuation pond, following rainstorms of the critical duration. In each case, the outflow hydrograph is below the calculated "Greenfield" runoff, on the fully rural site.

Figure 24 Attenuation modifies the outflow hydrograph at the three return periods examined



A.7 Residual Risks

Residual risks include possibilities such as blockage of the outflow pipe or orifice and storms of magnitude greater than the 1:100-year+CC design storm. In order to mitigate against blockage, it is recommended that the outflow orifice should be set within a perforated riser with protected orifice plates, designed to filter out solid material such as vegetation, which could enter the pond. The enclosure, orifice and outflow pipe should be checked periodically, according to the maintenance schedule (Table 5) and any collected debris removed.

As pointed put in Section A1, a rise in water level within the pond could indicate partial blockage of the perforated riser. As such, it serves as a potentially valuable indicator. This should be explained to staff at the site, so that if they notice water levels within the pond rising to unusually high levels, they should inspect the perforated riser at the earliest opportunity, which can then be cleaned out as necessary.

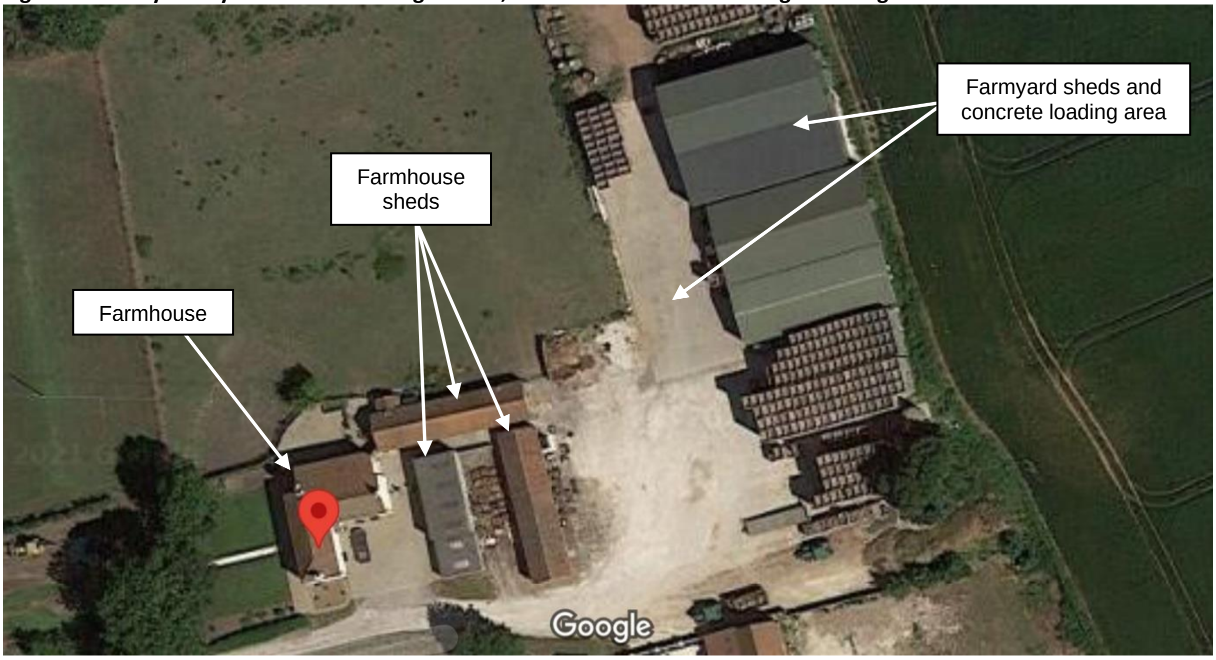
Appendix B Impermeable Areas

Since runoff from other buildings and impermeable areas is already directed into the pond, ignoring these surfaces could allow more runoff into the pond than it is designed to manage. Allowing outflow to surcharge over the emergency overflow weir would defeat the purpose of the flow control. For this reason, all the impermeable surfaces within the pond's local catchment are included. The Applicant provided details of where roof runoff is directed, summarised in Figure 25.

Figure 25 The buildings in blue drain into the large pond and yellow into the small pond to the north

Source: OS online mapping, https://osmaps.ordnancesurvey.co.uk/54.06272,-0.27657,18

Figure 26 Farmyard layout shown on Google Earth, note the most recent storage building and lean-to not shown



Source: https://www.google.com/maps/place/Haisthorpe,+Driffield+YO25+4NX/@54.0631222,-0.2759097,143m/data=!3m1!1e3!4m5!3m4!1s0x4878b33df7fbdbbd:0xca13374b600656e0!8m2!3d54.0626652!4d-0.2765846

The dimensions of five of the six areas coloured in blue in Figure 25 were estimated using the Google Earth website. The air photo in Figure 26 evidently predates the most recent shed and of course the proposed lean-to is shown on neither image. The area of the Farmyard sheds and the adjacent concrete loading area was measured as a single contiguous unit and the farmhouse and adjacent sheds were all measured separately.

Google Earth has a "Measure Distance" tool, which can be activated from the right-click menu. Points along a polygon are defined by left-clicking the mouse. Once a defined shape is closed, its area is calculated in square metres and displayed on the screen. Each of the five areas marked in blue on Figure 25 and available for measurement on Figure 26 is shown in the photo-montage of Figure 27 and the total impermeable area and associated catchment area are calculated in Table 9.

Figure 27 Photo-montage showing calculation of the five impermeable areas

Table 9 Impermeable and catchment areas draining into attenuation pond

Structure	Length (m)	Width (m)	Total Area (m^2)
Proposed Workshop lean-to	24.382	12.191	297.24
Approved Storage building	36.574	21.334	780.27
Concrete work area beside building	58	3.4	197.20
Farmhouse shed (a)			119.00
Farmhouse shed (b)			146.00
Farmhouse shed (c)			80.00
Farmhouse (d)			105.00
Farmyard sheds & concrete (e)			1,708.00
Total Impermeable			**3,433**
Attenuation pond			1,725
Filter drains			240
Total Catchment			**5,398**

Appendix C MicroDrainage output

The tables shown below were generated by MicroDrainage Source Control to calculate the optimum pond geometry and flow control arrangement for the recommended attenuation system at Manor Farm. They are arranged in three parts, showing the 1:2-year, 1:30-year and 1:100-year rainstorms. In each case, 30 percent has been added as an allowance for climate change. The 1:100-year event was also run with a 40% allowance for climate change and MicroDrainage modelling shows that this too would be contained within the pond.

Appendix C

Summary of Results for 2 year Return Period (+30%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
600 min Summer	0.094	0.094	1.4	0.0	1.4	130.7	O K
720 min Summer	0.096	0.096	1.4	0.0	1.4	133.5	O K
960 min Summer	0.099	0.099	1.4	0.0	1.4	137.8	O K
1440 min Summer	0.102	0.102	1.4	0.0	1.4	141.8	O K
2160 min Summer	0.103	0.103	1.5	0.0	1.5	142.8	O K
2880 min Summer	0.102	0.102	1.4	0.0	1.4	141.8	O K
600 min Winter	0.106	0.106	1.5	0.0	1.5	147.9	O K
720 min Winter	0.109	0.109	1.5	0.0	1.5	151.3	O K
960 min Winter	0.111	0.111	1.5	0.0	1.5	154.8	O K
1440 min Winter	0.113	0.113	1.6	0.0	1.6	158.0	O K
2160 min Winter	0.112	0.112	1.5	0.0	1.5	156.4	O K
2880 min Winter	0.109	0.109	1.5	0.0	1.5	152.4	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
600 min Summer	3.861	0.0	119.4	0.0	600
720 min Summer	3.392	0.0	125.6	0.0	662
960 min Summer	2.760	0.0	134.6	0.0	772
1440 min Summer	2.042	0.0	144.2	0.0	1028
2160 min Summer	1.500	0.0	195.5	0.0	1436
2880 min Summer	1.208	0.0	208.2	0.0	1848
600 min Winter	3.861	0.0	135.1	0.0	582
720 min Winter	3.392	0.0	141.8	0.0	688
960 min Winter	2.760	0.0	151.9	0.0	872
1440 min Winter	2.042	0.0	162.2	0.0	1096
2160 min Winter	1.500	0.0	220.5	0.0	1552
2880 min Winter	1.208	0.0	234.7	0.0	1992

Rainfall Details

Rainfall Model	FEH
Return Period (years)	2
FEH Rainfall Version	2013
Site Location	GB 513000 463000 TA 13000 63000
Data Type	
Summer Storms	Yes
Winter Storms	Yes
Cv (Summer)	0.750
Cv (Winter)	0.840
Shortest Storm (mins)	600
Longest Storm (mins)	2880
Climate Change %	+30

Time Area Diagram

Total Area (ha) 0.540

Time From:	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**
0	4	0.150	4	8	0.200	8	12	0.140	12	16	0.050

Model Details

Storage is Online Cover Level (m) 0.600

Tank or Pond Structure

Invert Level (m) 0.000

Depth (m)	**Area (m²)**	**Depth (m)**	**Area (m²)**	**Depth (m)**	**Area (m²)**	**Depth (m)**	**Area (m²)**
0.000	1350.0	0.700	1952.5	1.400	2665.8	2.100	3489.9
0.100	1429.3	0.800	2047.6	1.500	2776.7	2.200	3616.7
0.200	1510.8	0.900	2144.9	1.600	2889.9	2.300	3745.7
0.300	1594.6	1.000	2244.6	1.700	3005.4	2.400	3877.0
0.400	1680.7	1.100	2346.5	1.800	3123.1	2.500	4010.6
0.500	1769.0	1.200	2450.6	1.900	3243.1		
0.600	1859.6	1.300	2557.1	2.000	3365.4		

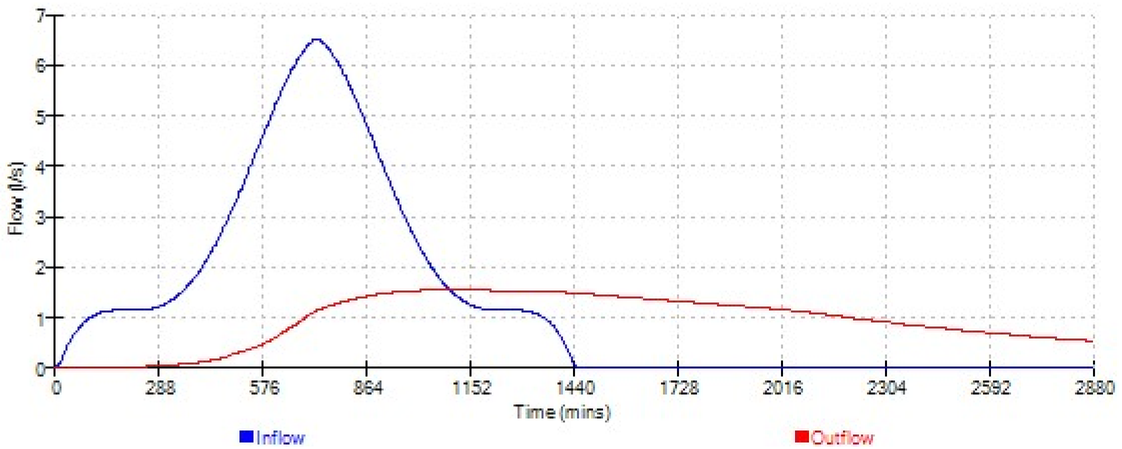
Orifice Outflow Control

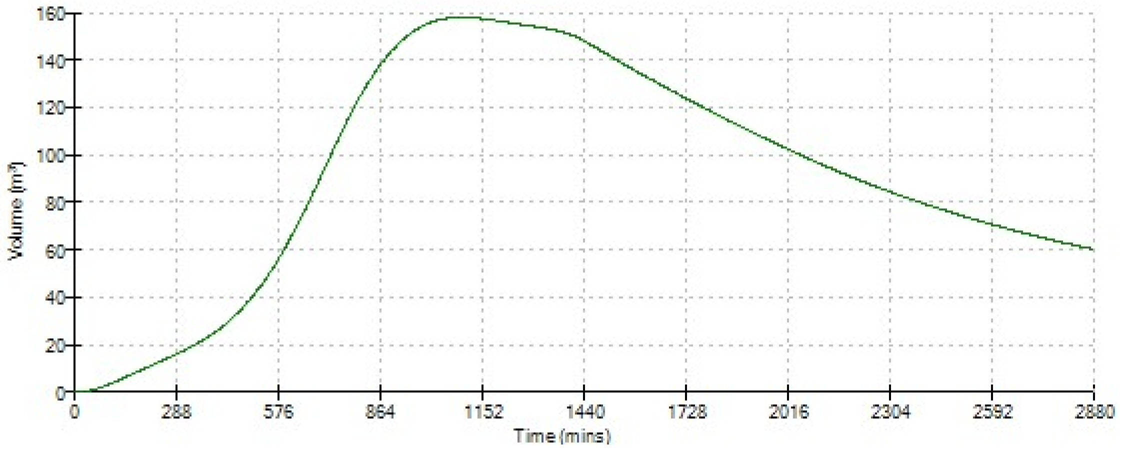
Diameter (m) 0.050 Discharge Coefficient 0.600 Invert Level (m) 0.000

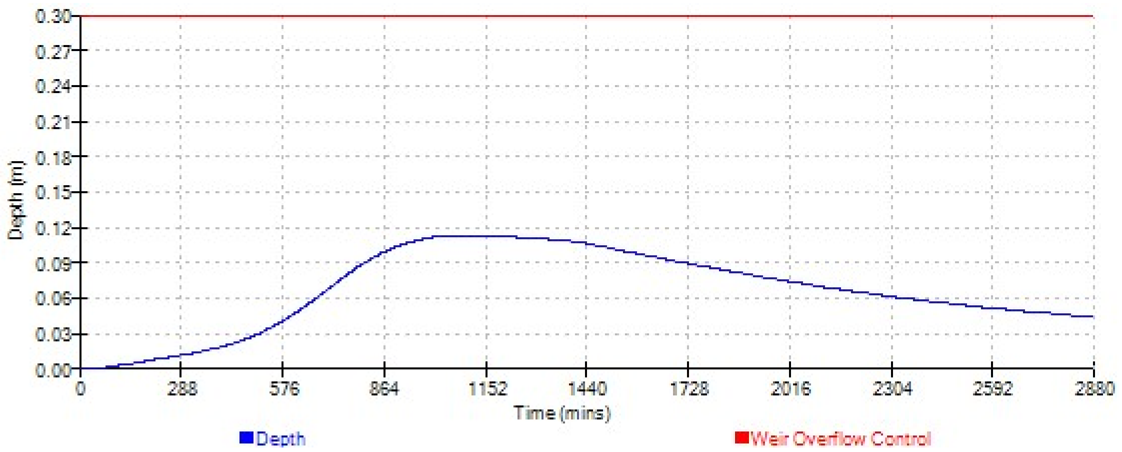
Weir Overflow Control

Discharge Coef 0.544 Width (m) 1.000 Invert Level (m) 0.300

Event: 1440 min Winter







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

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
600 min Summer	0.160	0.160	1.9	0.0	1.9	226.7	O K
720 min Summer	0.162	0.162	1.9	0.0	1.9	229.5	O K
960 min Summer	0.164	0.164	1.9	0.0	1.9	231.8	O K
1440 min Summer	0.165	0.165	2.0	0.0	2.0	233.9	O K
2160 min Summer	0.165	0.165	2.0	0.0	2.0	233.8	O K
2880 min Summer	0.164	0.164	1.9	0.0	1.9	231.9	O K
600 min Winter	0.180	0.180	2.1	0.0	2.1	256.2	O K
720 min Winter	0.183	0.183	2.1	0.0	2.1	259.9	O K
960 min Winter	0.185	0.185	2.1	0.0	2.1	263.0	O K
1440 min Winter	0.184	0.184	2.1	0.0	2.1	262.6	O K
2160 min Winter	0.182	0.182	2.1	0.0	2.1	259.6	O K
2880 min Winter	0.179	0.179	2.0	0.0	2.0	253.8	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
600 min Summer	6.539	0.0	206.8	0.0	602
720 min Summer	5.678	0.0	213.2	0.0	720
960 min Summer	4.537	0.0	221.6	0.0	848
1440 min Summer	3.303	0.0	226.2	0.0	1088
2160 min Summer	2.408	0.0	320.7	0.0	1484
2880 min Summer	1.934	0.0	339.4	0.0	1904
600 min Winter	6.539	0.0	230.5	0.0	588
720 min Winter	5.678	0.0	237.1	0.0	698
960 min Winter	4.537	0.0	245.0	0.0	914
1440 min Winter	3.303	0.0	247.3	0.0	1144
2160 min Winter	2.408	0.0	360.1	0.0	1604
2880 min Winter	1.934	0.0	380.4	0.0	2052

Rainfall Details

Rainfall Model	FEH
Return Period (years)	30
FEH Rainfall Version	2013
Site Location	GB 513000 463000 TA 13000 63000
Data Type	
Summer Storms	Yes
Winter Storms	Yes
Cv (Summer)	0.750
Cv (Winter)	0.840
Shortest Storm (mins)	600
Longest Storm (mins)	2880
Climate Change %	+30

Time Area Diagram

Total Area (ha) 0.540

Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)
0	4	0.150	4	8	0.200	8	12	0.140	12	16	0.050

Model Details

Storage is Online Cover Level (m) 0.600

Tank or Pond Structure

Invert Level (m) 0.000

Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)
0.000	1350.0	0.700	1952.5	1.400	2665.8	2.100	3489.9
0.100	1429.3	0.800	2047.6	1.500	2776.7	2.200	3616.7
0.200	1510.8	0.900	2144.9	1.600	2889.9	2.300	3745.7
0.300	1594.6	1.000	2244.6	1.700	3005.4	2.400	3877.0
0.400	1680.7	1.100	2346.5	1.800	3123.1	2.500	4010.6
0.500	1769.0	1.200	2450.6	1.900	3243.1		
0.600	1859.6	1.300	2557.1	2.000	3365.4		

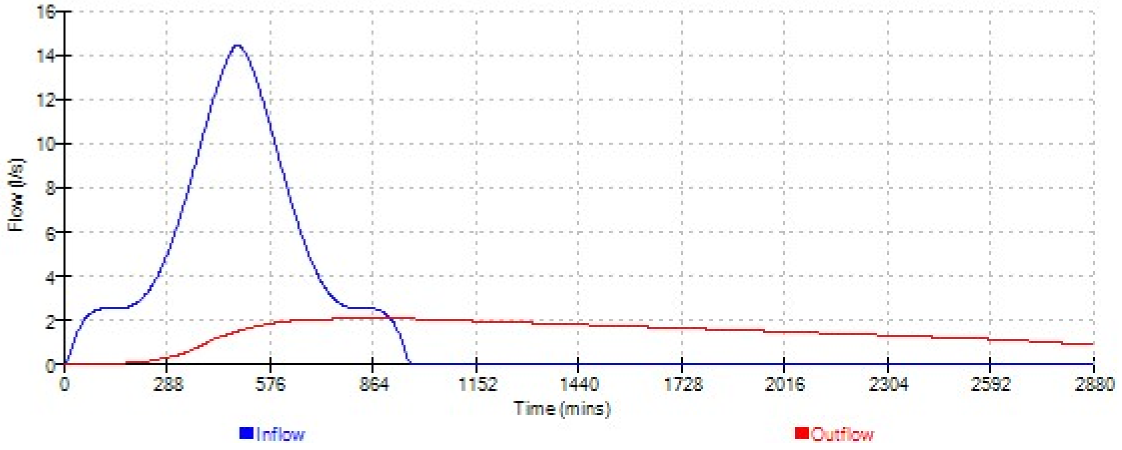
Orifice Outflow Control

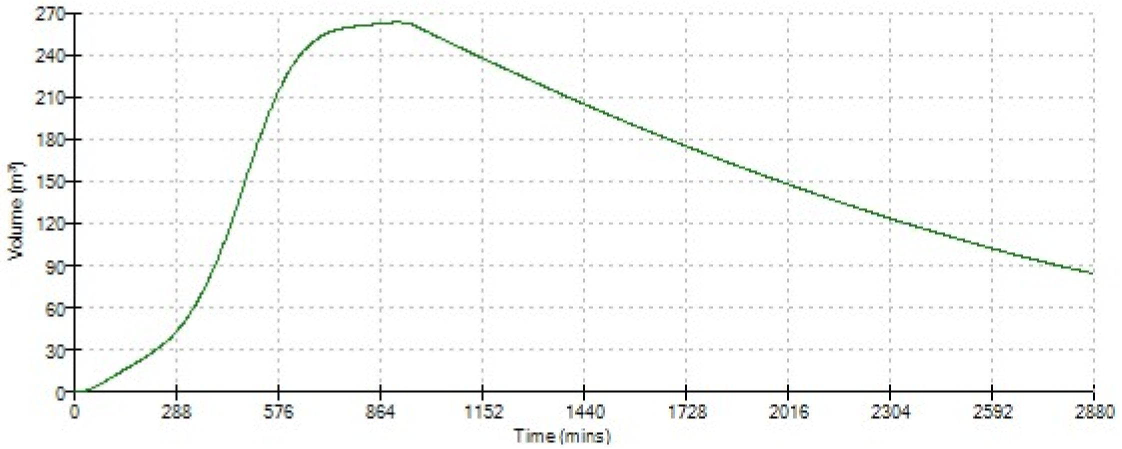
Diameter (m) 0.050 Discharge Coefficient 0.600 Invert Level (m) 0.000

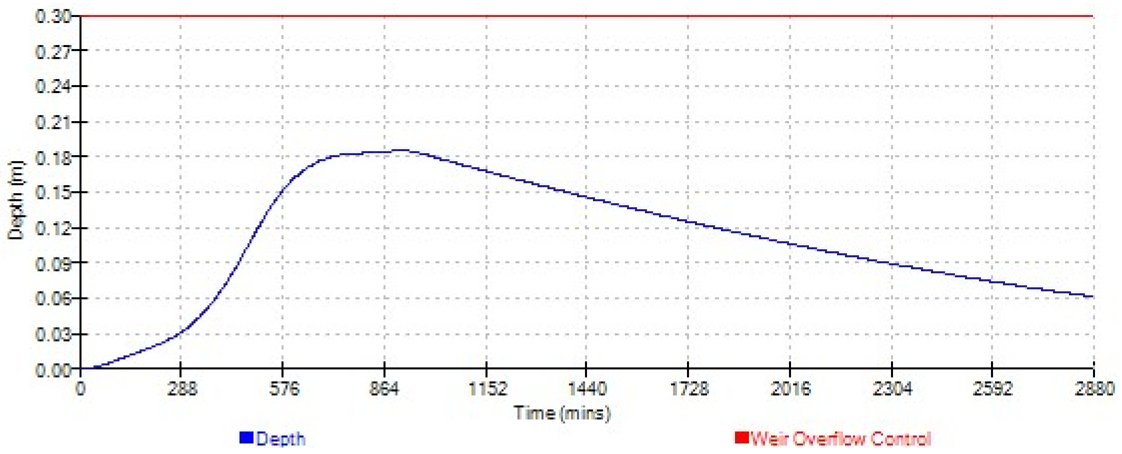
Weir Overflow Control

Discharge Coef 0.544 Width (m) 1.000 Invert Level (m) 0.300

Event: 960 min Winter







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

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
600 min Summer	0.198	0.198	2.2	0.0	2.2	283.6	O K
720 min Summer	0.201	0.201	2.2	0.0	2.2	287.1	O K
960 min Summer	0.203	0.203	2.2	0.0	2.2	289.8	O K
1440 min Summer	0.204	0.204	2.2	0.0	2.2	292.4	O K
2160 min Summer	0.205	0.205	2.2	0.0	2.2	293.7	O K
2880 min Summer	0.205	0.205	2.2	0.0	2.2	292.8	O K
600 min Winter	0.223	0.223	2.3	0.0	2.3	320.3	O K
720 min Winter	0.226	0.226	2.3	0.0	2.3	324.9	O K
960 min Winter	0.228	0.228	2.4	0.0	2.4	329.3	O K
1440 min Winter	0.228	0.228	2.4	0.0	2.4	329.2	O K
2160 min Winter	0.228	0.228	2.3	0.0	2.3	327.9	O K
2880 min Winter	0.225	0.225	2.3	0.0	2.3	323.3	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
600 min Summer	8.090	0.0	252.1	0.0	604
720 min Summer	7.009	0.0	257.9	0.0	722
960 min Summer	5.592	0.0	264.2	0.0	912
1440 min Summer	4.073	0.0	264.9	0.0	1134
2160 min Summer	2.982	0.0	398.2	0.0	1520
2880 min Summer	2.402	0.0	420.9	0.0	1936
600 min Winter	8.090	0.0	277.7	0.0	590
720 min Winter	7.009	0.0	282.8	0.0	702
960 min Winter	5.592	0.0	288.2	0.0	920
1440 min Winter	4.073	0.0	288.1	0.0	1184
2160 min Winter	2.982	0.0	445.7	0.0	1628
2880 min Winter	2.402	0.0	470.1	0.0	2084

Rainfall Details

Rainfall Model	FEH
Return Period (years)	100
FEH Rainfall Version	2013
Site Location	GB 513000 463000 TA 13000 63000
Data Type	
Summer Storms	Yes
Winter Storms	Yes
Cv (Summer)	0.750
Cv (Winter)	0.840
Shortest Storm (mins)	600
Longest Storm (mins)	2880
Climate Change %	+30

Time Area Diagram

Total Area (ha) 0.540

Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)
0	4	0.150	4	8	0.200	8	12	0.140	12	16	0.050

Model Details

Storage is Online Cover Level (m) 0.600

Tank or Pond Structure

Invert Level (m) 0.000

Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)
0.000	1350.0	0.700	1952.5	1.400	2665.8	2.100	3489.9
0.100	1429.3	0.800	2047.6	1.500	2776.7	2.200	3616.7
0.200	1510.8	0.900	2144.9	1.600	2889.9	2.300	3745.7
0.300	1594.6	1.000	2244.6	1.700	3005.4	2.400	3877.0
0.400	1680.7	1.100	2346.5	1.800	3123.1	2.500	4010.6
0.500	1769.0	1.200	2450.6	1.900	3243.1		
0.600	1859.6	1.300	2557.1	2.000	3365.4		

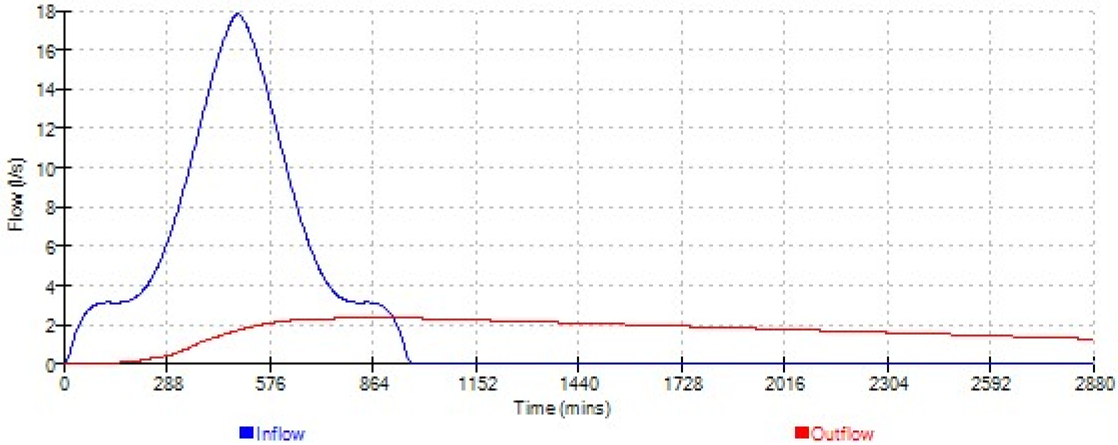
Orifice Outflow Control

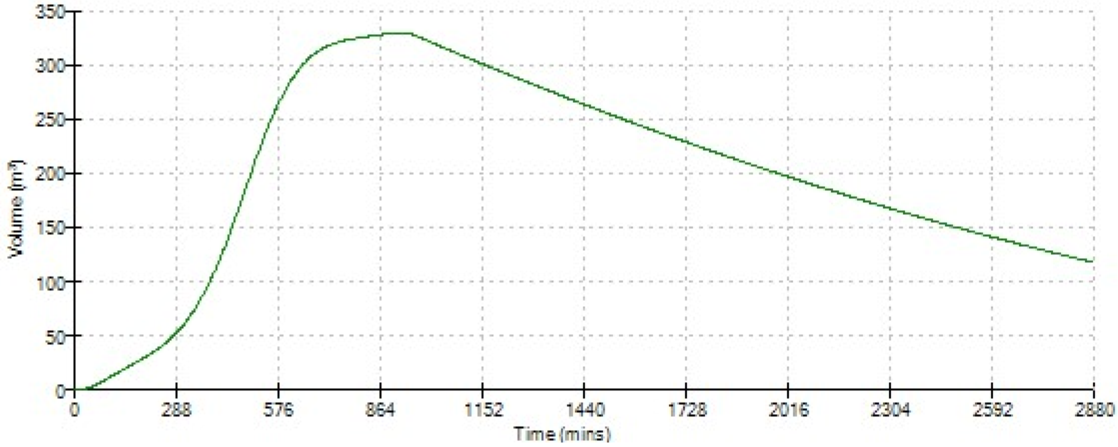
Diameter (m) 0.050 Discharge Coefficient 0.600 Invert Level (m) 0.000

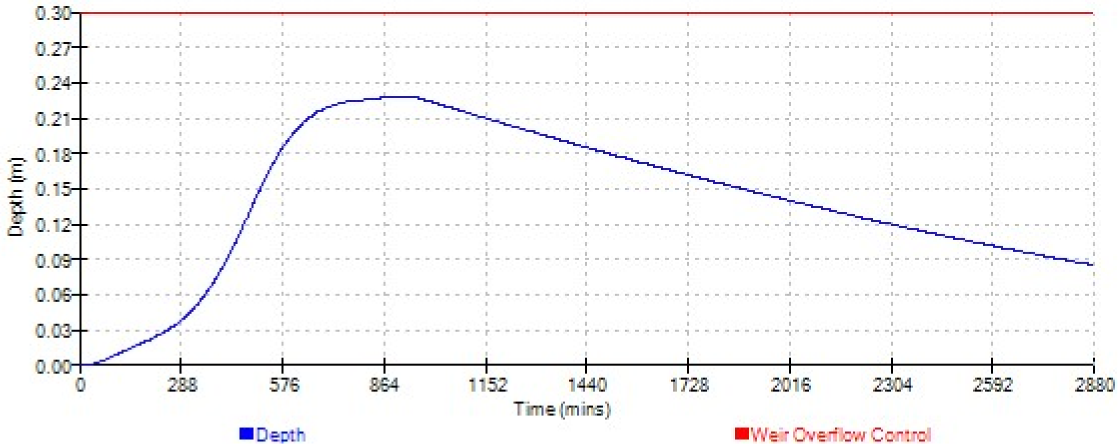
Weir Overflow Control

Discharge Coef 0.544 Width (m) 1.000 Invert Level (m) 0.300

Event: 960 min Winter







Summary of Results for 100 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
600 min Summer	0.214	0.214	2.3	0.0	2.3	306.6	O K
720 min Summer	0.216	0.216	2.3	0.0	2.3	310.6	O K
960 min Summer	0.218	0.218	2.3	0.0	2.3	313.8	O K
1440 min Summer	0.220	0.220	2.3	0.0	2.3	316.5	O K
2160 min Summer	0.221	0.221	2.3	0.0	2.3	318.0	O K
2880 min Summer	0.221	0.221	2.3	0.0	2.3	317.3	O K
600 min Winter	0.239	0.239	2.4	0.0	2.4	346.2	O K
720 min Winter	0.243	0.243	2.4	0.0	2.4	351.4	O K
960 min Winter	0.246	0.246	2.5	0.0	2.5	356.7	O K
1440 min Winter	0.246	0.246	2.5	0.0	2.5	356.7	O K
2160 min Winter	0.246	0.246	2.5	0.0	2.5	355.8	O K
2880 min Winter	0.243	0.243	2.4	0.0	2.4	351.3	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
600 min Summer	8.712	0.0	268.7	0.0	604
720 min Summer	7.548	0.0	274.0	0.0	722
960 min Summer	6.022	0.0	279.5	0.0	934
1440 min Summer	4.387	0.0	279.4	0.0	1146
2160 min Summer	3.211	0.0	428.6	0.0	1532
2880 min Summer	2.587	0.0	452.3	0.0	1940
600 min Winter	8.712	0.0	294.2	0.0	590
720 min Winter	7.548	0.0	299.0	0.0	704
960 min Winter	6.022	0.0	304.1	0.0	924
1440 min Winter	4.387	0.0	303.4	0.0	1292
2160 min Winter	3.211	0.0	479.1	0.0	1636
2880 min Winter	2.587	0.0	504.4	0.0	2104

Rainfall Details

Rainfall Model	FEH
Return Period (years)	100
FEH Rainfall Version	2013
Site Location	GB 513000 463000 TA 13000 63000
Data Type	
Summer Storms	Yes
Winter Storms	Yes
Cv (Summer)	0.750
Cv (Winter)	0.840
Shortest Storm (mins)	600
Longest Storm (mins)	2880
Climate Change %	+40

Time Area Diagram

Total Area (ha) 0.540

Time From:	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**
0	4	0.150	4	8	0.200	8	12	0.140	12	16	0.050

Model Details

Storage is Online Cover Level (m) 0.600

Tank or Pond Structure

Invert Level (m) 0.000

Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)
0.000	1350.0	0.700	1952.5	1.400	2665.8	2.100	3489.9
0.100	1429.3	0.800	2047.6	1.500	2776.7	2.200	3616.7
0.200	1510.8	0.900	2144.9	1.600	2889.9	2.300	3745.7
0.300	1594.6	1.000	2244.6	1.700	3005.4	2.400	3877.0
0.400	1680.7	1.100	2346.5	1.800	3123.1	2.500	4010.6
0.500	1769.0	1.200	2450.6	1.900	3243.1		
0.600	1859.6	1.300	2557.1	2.000	3365.4		

Orifice Outflow Control

Diameter (m) 0.050 Discharge Coefficient 0.600 Invert Level (m) 0.000

Weir Overflow Control

Discharge Coef 0.544 Width (m) 1.000 Invert Level (m) 0.300

Event: 960 min Winter