PROPOSED DEVELOPMENT OF SOLAR PHOTOVOLTAIC PANELS AND ASSOCIATED WORKS AT MANOR FARM, NOKE, CHERWELL, OXFORDSHIRE

FLOOD RISK ASSESSMENT

J-14174

Nijhuis Saur Industries | UK & Eire

PROPOSED DEVELOPMENT OF SOLAR PHOTOVOLTAIC PANELS AND ASSOCIATED WORKS AT MANOR FARM, NOKE, CHERWELL, OXFORDSHIRE

FLOOD RISK ASSESSMENT

Report No.	Issue Detail	Originator	Date	Checked By	Date
06	Green Nation	GS	10/05/2023	HG	10/05/2023

For: Green Nation

Job No: J-14174
Date: May 2023
Edition: 06

CONTENTS

APPENDICES

1.0 INTRODUCTION

Green Nation are currently investigating the possibility of the development of a solar PV farm site on land at Manor Farm, Noke, Cherwell, Oxfordshire, OX3 9TU.

As the site is over 1ha in size it is necessary to produce a Flood Risk Assessment for the site, in accordance with the National Planning Policy Framework (NPPF) and Planning Practice Guidance (PPG) to accompany the planning application.

In addition to this, there are areas of the site that appear to be at risk of fluvial flooding and therefore any planning application should include a Flood Risk Assessment to assess the risks to the site.

In order to address these requirements, Nijhuis Industries have been commissioned to prepare a Flood Risk Assessment for the development, generally in accordance with PPG. The FRA will address the risks of flooding and provide proposals for minimising risks to acceptable levels if practicable.

2.0 SITE LOCATION AND DESCRIPTION

2.1 Site Location

The proposed solar park development is to take place on land at Manor Farm, Noke, Cherwell, Oxfordshire, OX3 9TU. The Ordnance Survey Grid Reference for the centre of the site is SP 54132 13950. The site location plan is included in **Appendix A** and in Figure 2.1 below.

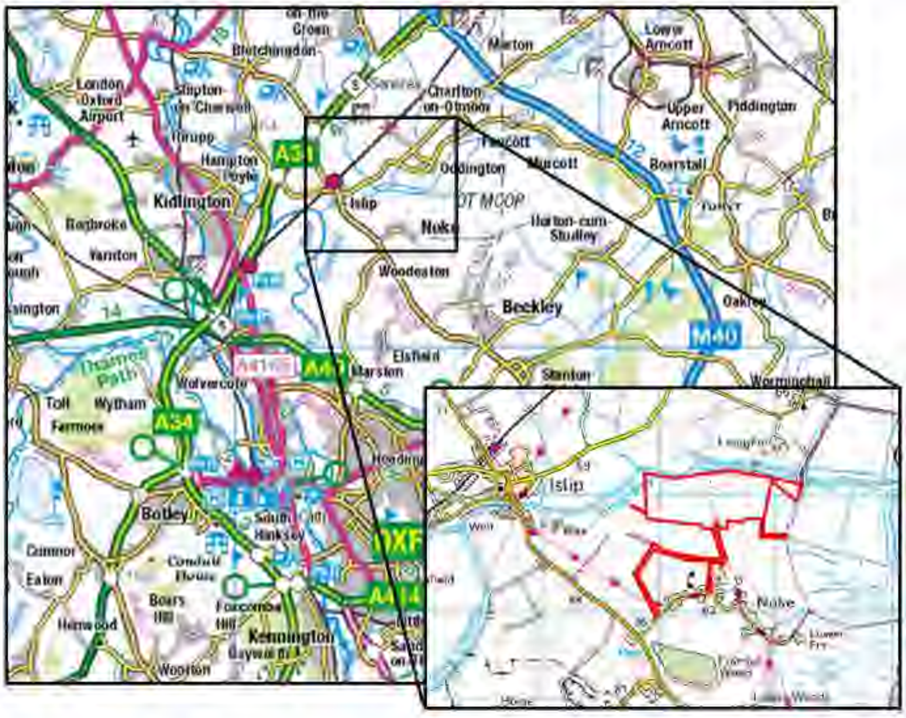


Figure 2.1 Site Location Plan

With respect to topography, the site has elevations between 64.85m AOD and 58.56m AOD. All elevations are based on site-specific topographic survey data.

2.2 Existing Usage

The existing site consists of a grassed area, currently used as agricultural land adjacent to the village of Islip.

2.3 Proposed Usage

It is proposed to install a solar PV farm and associated infrastructure over an area of approximately 31.4ha with a red line boundary area of approximately 43.76 ha. The site is to consist of solar modules supported by a table/racking system, each with support posts. Further landscaping works will be put forward within the design proposal, such as hedging, fencing and planting arrangements.

2.4 Existing Hydrology

The development site is located in an area of relatively flat countryside. The surrounding area comprises mainly of agricultural land and small townships. There is a watercourse at the northern boundary of the site called River Ray. The River Ray flows from the northeast towards the village of Islip. After passing through the village, its confluences with the River Cherwell and then flows into the River Thames south of the city of Oxford.

3.0 FLOODING MECHANISMS

A number of possible flooding mechanisms have been considered at the site and are discussed below.

3.1 Groundwater Flooding

There are limited sources of information available to assess groundwater flood risk as groundwater risk mapping is still in its infancy. Groundwater levels can be affected by periods of sustained heavy rainfall which can cause levels to rise, potentially resulting in periods of sustained flooding. This mechanism of flooding can be related to the presence of aquifers.

The Cherwell District Councils Strategic Flood Risk Assessment (SFRA) states; "There is a risk of groundwater flooding within the district". The proposed site location has been identified as having a 25-50% chance of experiencing groundwater flooding.

MAGIC mapping data online have produced maps that show the groundwater vulnerability of areas across the UK. This mapping system shows that the site straddles several risk categories and as such a conservative approach would be to assume a Medium to High vulnerability of groundwater flooding at the site as seen in **Figure 3.1** below.

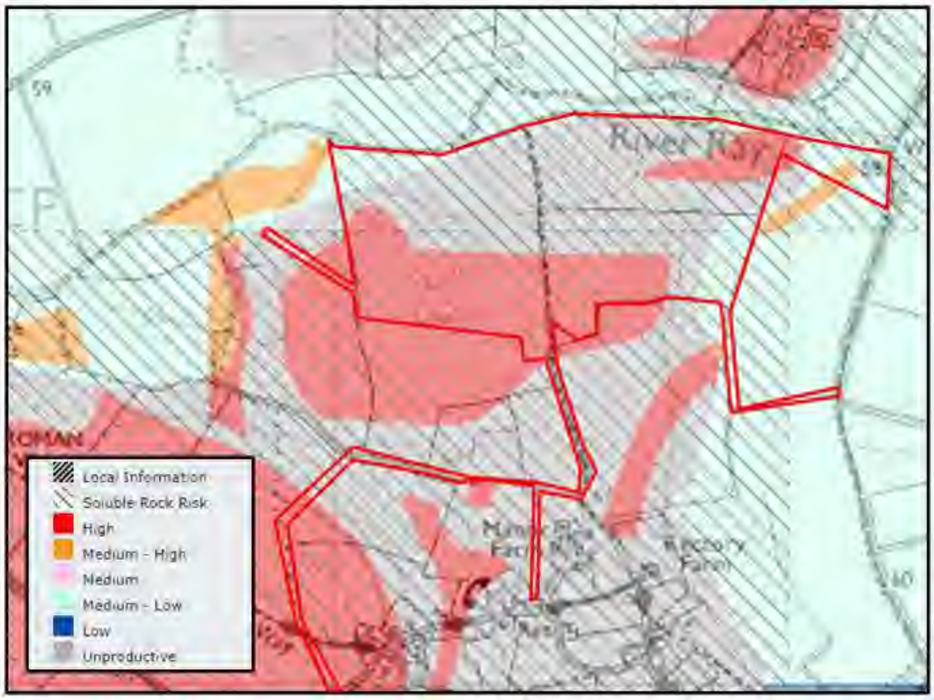


Figure 3.1 MAGIC Map groundwater vulnerability Map

The Cranfield Soil and Agrifood Institute (CSAI) Soilscapes map displays the type of soil within the site location.

As shown below in **Figure 3.2** the subject site is composed of several soil types, including "Loamy and clayey floodplain soils with naturally high groundwater", "Loamy soil with naturally high groundwater" and "Shallow lime-rich soils over chalk or limestone.

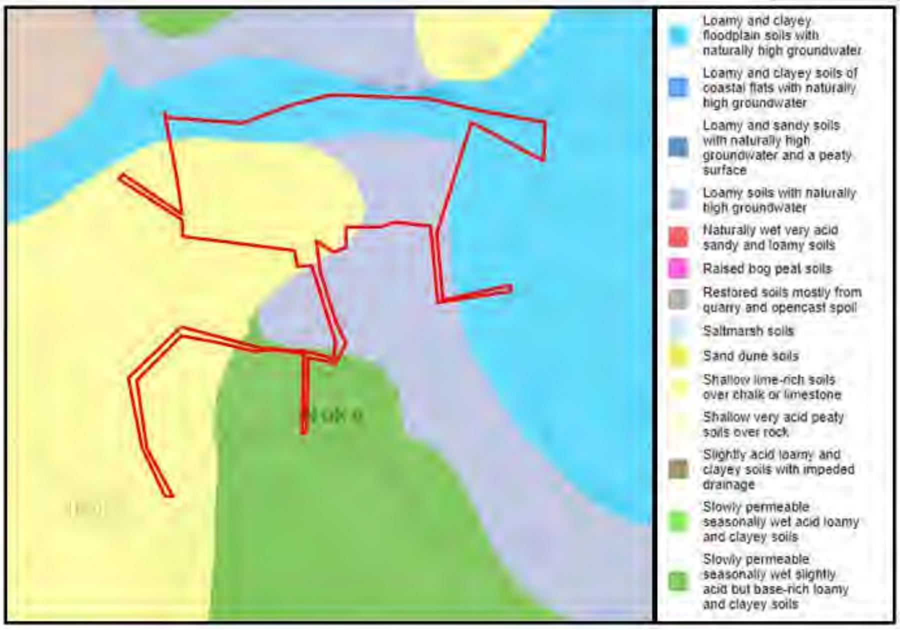


Figure 3.2 CSAI Soilscapes Map extract

Given the nature of the development, with vulnerable infrastructure raised above the ground level, it is considered that groundwater flooding does not pose a significant risk to most of the development site. Therefore, groundwater flooding will not be considered further within this report.

3.2 Overland Sheet Flow

The catchment area upstream of the development site consists mainly of greenfield. As such the potential for overland flow that can directly affect the site is considered to be small. The site is covered with permeable ground which provides varying degrees of infiltration depending on the subsoil; these factors will serve to reduce the potential for overland flows to develop.

The Environment Agency Risk of Flooding from Surface Water map, as shown below in **Figure 3.3**, indicates that the site largely has a 'low risk' of surface water flooding. There are some localised areas at higher risk of surface water flooding but there are likely to be linked to ditches or localised low spots on the site.

Figure 3.3 Extract from EA risk of surface water flooding map

Given the assessed overall low risk of flooding on the site, and the nature of the development infrastructure, it is considered that surface water flooding will not cause issues relating to the operation of the site and will not be considered further within this report.

3.3 Fluvial (River) Flooding

The site is shown to be partially located within Flood Zone 3 (high risk). Therefore, fluvial flooding will be considered further within this report.

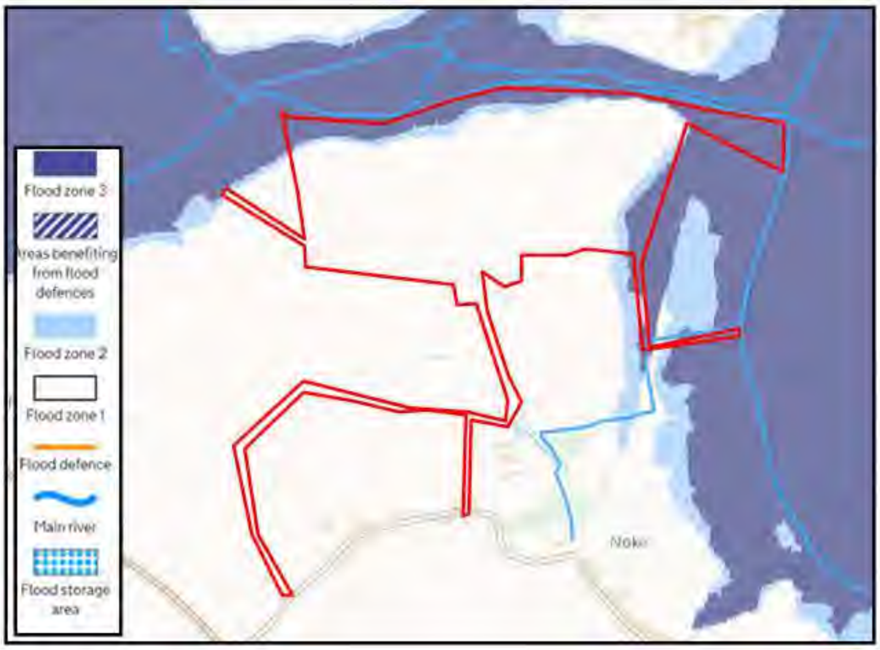


Figure 3.4 Extract from EA Flood Map for Planning

3.4 Tidal Flooding

The site is shown to be located approximately 70 miles from the sea. Therefore, tidal flooding will not be considered further within this report.

3.5 Flooding as a Result of Development

The proposed development has the potential to introduce an impermeable area around the site where the land was previously permeable. This could have the potential to increase the runoff rates across the site which could increase the flood risk to adjacent sites.

The drainage system need only contend with the volume of runoff from this area to ensure flood risk is not increased, however, additional storage should be provided to allow for inconsistencies and provide betterment. The potential for a sustainable drainage system to be installed within the development can be outlined in a future report.

3.6 Land Usage Effects on Flood Risk

Changing the site's primary function to solar power generation will have benefits regarding runoff rates if there is an inclusion of drainage features.

The potential drainage features would provide betterment to the existing situation in terms of runoff rates and flood risk.

4.0 FLUVIAL FLOODING

The Environment Agency Indicative Flood Map shown in **Figure 3.4** illustrates that the site is partially located within Flood Zone 3.

The EA have provided flood information for fluvial flooding. The mechanism of flooding is investigated further below.

With regards to the site levels, the elevations of the site range from **64.85m AOD** at the centre and south down to **58.56m AOD** towards the west.

4.1 Fluvial Flooding

The EA information provided was in the form of shapefiles indicating flood depths from the national JFlow study for the reach of the river Ray upstream of its confluence with the River Cherwell. The 100yr and 1000-year events both with an allowance for climate change were provided. **Figure 4.1** shows the flood extents for the 1 in a 100-year event with a climate change allowance while **Figure 4.2** shows the flood extents for the 1 in the 1000-year event with an allowance for climate change. This information is also included in **Appendix C.**

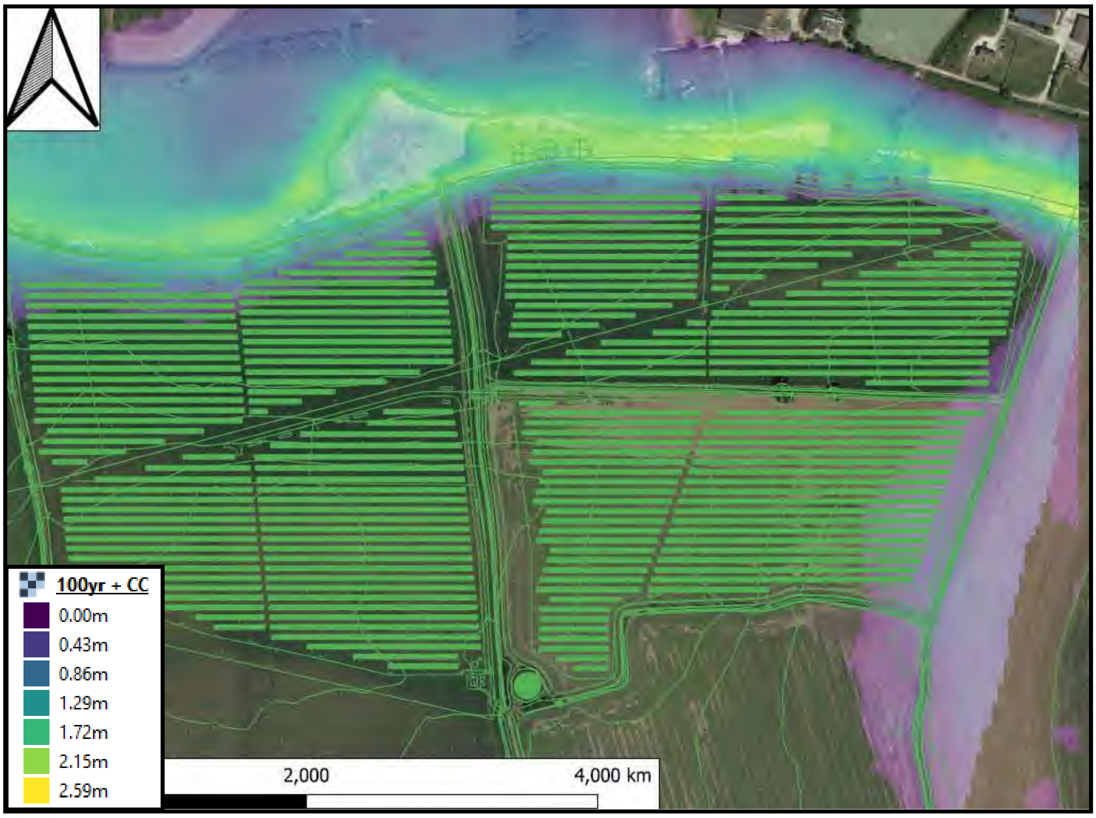


Figure 4.1 Fluvial Flood Extent 100yr + CC Event

Both **Figures 4.1** and **4.2** show areas of the site are susceptible to flooding. The maximum flood depth in the areas where the panels are located is 0.5m. The lowest height of the modules is 0.9m and consequently, the maximum flood depth means that the infrastructure can accommodate the standard design. It is shown that while the 1000yr event is, as expected, significantly larger there is also flooding shown to critical depth during the 100yr event.

It is noted that while the data provided by the Environment Agency has included an allowance for climate change, there is no indication as to what this allowance is. Therefore, in combination with the fact that the JFlow modelling has significant issues regarding accuracy, the 1 in 1000yr event shall be used to ensure that the fluvial flood design level for the site is not underestimated.

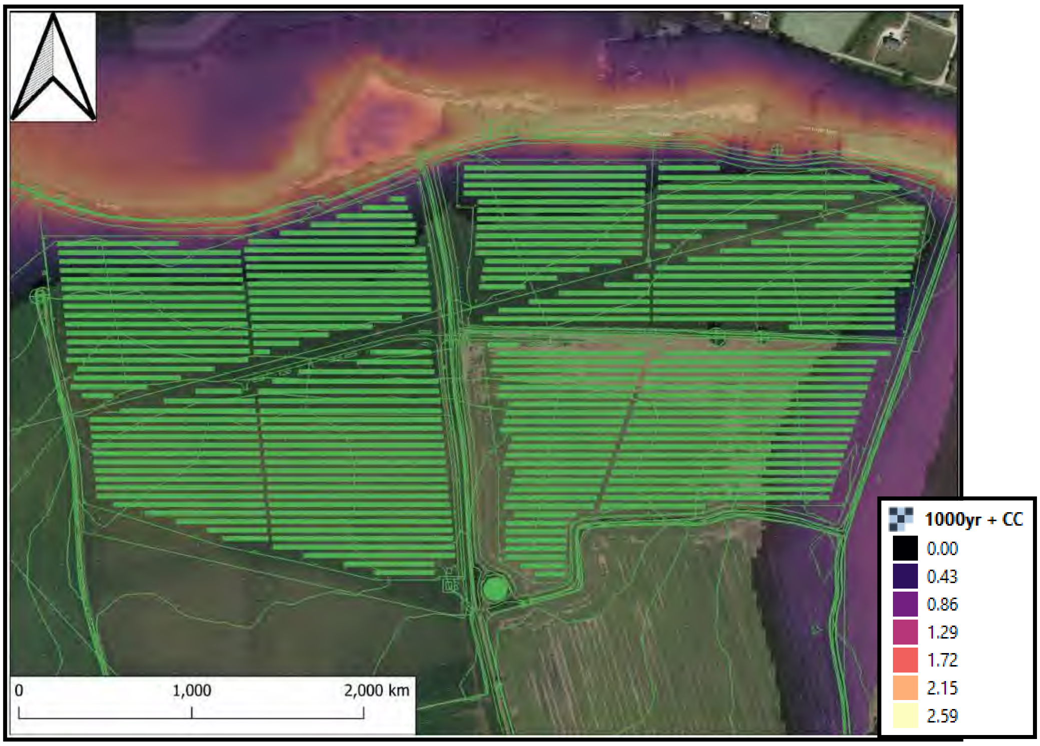


Figure 4.2 Fluvial Flood Extent 1000yr + CC event

Based on the site levels it is deemed that the site is at risk from fluvial flooding when considering an allowance for climate change for both the 100yr and 1000yr events. Using the 1 in 1000yr event as a precautionary approach, it is deemed that the site area could be at risk of flooding with a maximum depth of up to **0.86m**.

All tables are set at a minimum elevation of 0.90m above the ground level and as such, it is determined that all ground-level infrastructure will be raised above the worst-case maximum of 1 in the 1000-year flood event.

Although there are portions to the north and east at risk of flooding, this risk is generally at a depth between 0.43m and 0.86m.

All associated critical infrastructure is to be restricted to Flood Zone 1 and therefore is shown to be safe from flooding through this assessment.

4.2 Flood Risk Summary

When considering an allowance for climate change the site is considered to be at risk of fluvial flooding from the nearby River Ray. The Environment Agency provided flood depth shapefiles for this watercourse. These maps show a maximum inundation depth of 0.86m AGL for the 1 in 1000yr + CC event.

It is noted that while the site is inundated during the 1000yr event, only a small portion of the working site is affected. All PV tables are set at a minimum height of 0.90m and are therefore deemed free from flooding. All other infrastructures and access routes are unaffected by flooding.

4.3 Flood Mitigation Measures

The following mitigation measures are proposed to minimise the impacts of potential flooding on the solar park infrastructure in the case of an extreme flood event.

- All Services (cabling etc) should be designed and installed to be flood-resilientent / water compatible. This should be achieved in accordance with appropriate design standards and best practice guidance.

- The panels will be supported by piles which are adequately spaced to allow for the free flow of water between them. Structural assessment should be undertaken to ensure the panel supports can resist additional dynamic loadings induced by a flood event.

- The security fencing mesh sizing should be made as large as reasonably practical to ensure the free flow of flood water through the fence and reduce the possibility of debris buildup affecting flow routes.

- A SuDS scheme to manage surface water runoff is outlined in **Section 7** of this report.

- If flood water is present on the site, construction and maintenance operations should be avoided. A suitable risk assessment should be undertaken to assess whether it is safe to access the site, during a flood event. Given the infrequent nature of the maintenance requirements for a PV site, it is highly unlikely that maintenance would occur at the same instance as a flood event. Maintenance can be rescheduled if a flood warning is in place.

- During the construction phase of the project materials, equipment and site services should be located in Flood Zone 1 (Low-Risk Areas) when practicable.

The site has the potential to be a contamination risk as spoil present during construction could enter the watercourse during a flood event. There are a number of measures that should be undertaken to prevent this from occurring including (but not limited to).

- Preventing soil from being washed off-site through surface water run-off or fluvial influences;

- Loose spoil stored off-site in Flood Zone 1 if possible;

- Excavated material for swales to be permanently removed to provide compensatory storage.

Further questions have been raised regarding the siting of the perimeter fence in Flood Zone 3b. It is determined that the fencing will be designed as to not restrict the flow of any potential flood water and to reduce the blockage risk. The security fencing around the site could affect flow routing if debris collects along the fence during a flood event. It is recommended that wide-spaced mesh fencing will be used. This should have minimal impact on flood flows (especially compared to finer mesh security fences often used around PV sites). Given the length of the fence it is considered that blockages would be small relative to the fence area. Flows affected by debris would pass through the fence a short distance downstream from any blockage. This would allow the fields to flood in a similar manner to the existing condition during an extreme event.

4.4 Loss of Flood Plain Storage

The Environment Agency have requested that an assessment of loss of flood plain storage is determined when considering the additional impermeable area within areas shown as Flood Zone 3.

It is determined that there are roughly 63 tables with approximately 8 legs and 28 tables with around 4 legs, equating to around 0.5m^2 of impermeable area. When considering the maximum flood depth of 0.86m this equates to a loss of 0.43m^3

This loss of flood storage will need to be included to ensure that no potential flooding is caused downstream. It is anticipated that 0.43m^3 of storage can be include within the site boundary bolted onto Flood Zone 3. Perhaps an area of 1m x 1.5m lowered by 0.3m.

4.5 Affect On Adjacent Sites

The extent of the impermeable areas introduced across the site by the proposed development is relatively small. Therefore, any additional runoff from the impermeable areas will be small and more than adequately could be managed by an appropriate SuDS. As such there will be no impact on the nearby watercourses and neighbouring sites as a result of the proposed development.

In addition, the pragmatic approach to the design of the SuDS will provide an improved storage and interception capacity. This capacity will reduce any potential flood risks to adjacent sites that are created by surface water runoff when compared to the pre-development situation.

5.0 SUSTAINABLE DRAINAGE SCHEME (SUDS)

5.1 Overview

SuDS is a concept that incorporates long-term environmental and social factors to design surface water drainage systems, in accordance with the ideals of sustainable development. SuDS takes into account the quantity and quality of surface water runoff and the value of surface water to the urban and rural environments. Many existing urban drainage systems can cause problems of flooding, pollution or damage to the environment, so the SuDS aim to avoid this in the future.

Most proposed urbanisation creates impermeable surfaces which will need drainage solutions to remove surface water runoff. Traditionally, it is only the quantity of flow that has been accounted for in drainage solutions, preventing floods locally by conveying the water away from the site swiftly in underground pipes. These traditional methods frequently alter natural flow patterns which can lead to problems elsewhere in the catchment area. More recently, water quality issues must be accounted for, in order to avoid pollutants from urban areas being transported into rivers or groundwater.

Other aspects, such as water resources, community facilities, landscaping and provision of wildlife habitats have been largely ignored; a well-designed and well-managed SuDS can offer the following benefits:

- management of runoff flow rates, reducing the environmental impact of urbanisation
- maintenance or enhancement of water quality
- consideration of the requirements of the local community
- enhancement of biodiversity in urban watercourses
- maintain the natural groundwater level

5.2 Design Standards

The design of the site drainage infrastructure and Sustainable Urban Drainage System (SuDS) is to be carried out in line with best practices and industry-standard design procedures. A number of publications, including design guidance and best practice guidance will be applied to different components of the final infrastructure. The sections below provide an overview of the design standards to be used on this project for various aspects of the infrastructure design.

5.3 The CIRIA SuDS Manual

This document is a comprehensive publication covering the design, construction, operation and maintenance of SuDS. The advice and best practice outlined in this document have been utilised in the design of the site SuDS features, which have been detailed in this report.

5.4 Building Regulations Part H

Building Regulations Part H ‘Drainage and Waste Disposal’ covers the design and installation of surface water and foul water systems. All private drainage including pipes, manholes, down pipes, and other drainage infrastructure on the site should be designed and installed in accordance with this document.

5.5 The Wallingford Procedure

Developed by HR Wallingford, this publication covers the design of urban drainage systems. In addition, the document includes regional rainfall data for use in the design for varying return period events.

Basic sizing calculations for the swales and the estimation of the runoff volumes have been made using this method.

5.6 National Planning Policy Framework

The National Planning Policy Framework (NPPF) contains the policy relating to the appropriate assessment of flood risk within the UK. The associated technical guidance provides further details on the definitions, classifications and constraints used to apply national policy to new developments.

It contains details on flood zone definition, site-specific FRA's, vulnerability classifications, appropriate development, climate change allowances, residual risk management, flood resilience, the sequential test and the exception test.

5.7 Percolation Testing

In view of the relatively small areas of the impermeable surface being introduced across the site, there will be a minimal impact on the runoff rates, resulting from the development. The assessment of the likely ground conditions in **Section 3.1** shows that infiltration is likely to fail on this site due to the potential for high groundwater. The subsoil percolation rate will have no impact on the difference between pre-and post-development runoff rates as the ground's surface will remain the same with the exception of the infrastructure and foundations of the modules, which will be compensated in the SuDS design. Therefore, percolation testing is not planned to be undertaken as part of this project.

During the design of the conceptual SuDS layout, it is considered that the primary function of the SuDS will be the interception and storage of water until it evaporates or permeates back to groundwater.

In order to follow the drainage hierarchy set out by the EA subject to percolation tests, an infiltration-based system of swales will infiltrate into the ground, and based on a conservative rate. Should percolation testing be conducted and fail to drain, we would then look at the swales being a form of conveyance swale with a flow control device connecting to the adjacent watercourses/ditches.

5.8 Environmental Considerations

The nature of the development means that runoff could originate from the solar panel arrays, solar panel pile systems and inverters. The runoff from the panels poses a low environmental risk. It has been assumed that any additional foul/industrial waste from the maintenance and operation of the park will be disposed of elsewhere.

The use of heavy plants on wet scrubland may cause the topsoil to be disrupted which in turn can pose a pollution risk to the local River Ray. Although the swales may provide some benefits, it is advised that silt fences are installed during the construction phase of the project to intercept silt-laden runoff, if construction traffic or adverse weather is likely to cause damage to the topsoil.

6.0 INFILTRATION SUDS DESIGN

Since the solar panels are located on a sloped frame between approximately 0.9 on the lowest edge and 2.38m and the higher edge above ground level, it is anticipated that rain falling on each solar panel table will run off the panels and flow/infiltrate in the sheltered rain shadow area underneath the down-slope modules. A minimum of 10mm gap surrounding the panels will allow water to drain off each module.

The SuDS design will not consider the runoff from the access and maintenance roads as these will be constructed of grass tracks/unbound crushed stones/gravel or similar permeable materials, which will allow infiltration of water into these areas. The access roads will, therefore, not increase surface water runoff rates from the site.

The enclosed layout indicates the solar PV tables will typically support 56 modules each, with 8 support posts respectively elevating the panels above the ground.

The drawing shows two sized panels full-sized and half-sized with 8 legs and 4 legs respectively. Which totals an increase of impermeable of **4.7m^2**.

The switch rooms, inverters and the welfare building have a combined area of 356.12m^2. The total introduced impermeable area is calculated to be around **362.03m^2**.

The volume of additional runoff from the site has been calculated, firstly using FEH to determine the catchment parameters and then applying the ReFH2 maximum hourly peak rainfall volume over a 6-hour duration event for the 1 in 100yr event including an additional 40% to take climate change into account. These calculations give a deliberately overestimated total additional rainfall volume of **20.7m^3** for the additional impermeable surfaces introduced to the site.

In order to adopt a pragmatic approach and promote infiltration across the site, a system of swales is proposed to manage the surface water runoff. The details showing surface water management features are outlined in **Drawing 3001** in **Appendix C**.

In order to ensure interception of flows and a maintainable system, an oversized system has been implemented which will serve to reduce the runoff rate to less than the predeveloped rates; thus, reducing the potential flood risk created by the site.

It is proposed to install swales of 0.2m base width and 0.15m depth with side slopes of 1 in 4. The layout of these swales is shown in more detail in **Drawing 3001** in **Appendix B**. The system should provide around **1632m** of swales which will provide up to 0.12m^3/m of storage located adjacent to any access roads and downslope boundaries. This totals around **195.84m^3** of storage which is in excess of the calculated minimum required storage.

For more detail on calculations of runoff refer to **Appendix D**.

6.1 Attenuation SuDS Design

If infiltration rates are found to be poor, then surface water runoff from the development will need to be attenuated on site and discharged to a suitable receptor at an appropriate rate.

In line with best practice, the runoff rate from the development should not exceed pre-development Greenfield runoff rates for Qbar and should allow for climate change. This is the case for all drainage on site should the percolation tests show poor rates of infiltration.

It is deemed that the most suitable method of disposal, to ensure that all surface water is captured and disposed of effectively at a controlled rate would be to split the site into 2 areas, with an attenuation swale sized specifically for the impermeable area in that location.

The site was split into 2 areas to size the attenuation swales and provide a suitable outfall.

Area 1 and Area 3

The surface water flows from areas 1 and 3 are to be conveyed through swales to a dedicated attenuation swale with a flow control device. Based on an impermeable area of 250m^2 for areas 1 and 3 the swale has a depth of 0.4m, a base width of 0.4m and side slopes of 1 in 4. The swale has to be 15m long. The Qbar for the impermeable areas of 1 and 3 is 0.1l/s. This creates a blockage risk in that the orifice size would be too small, therefore a Hydrobrake Optimum has been specified as it can control flows to a minimum of 0.7l/s. As such the runoff is attenuated to 0.7 l/s for this area.

The brochure for the Hydrobrake Optimum Vortex Flow Control is included in **Appendix F**.

Area 2 and Area 4

The surface water flows from areas 2 and 4 are to be conveyed through swales to a dedicated attenuation swale with a flow control device**.** Based on an impermeable area of areas 2 and 4 being 120m^2 the Qbar value for this is 0.0l/s. Therefore as per areas 1 and 3 a Hydrobrake Optimum has been specified to limit the 0.7l/s as this is the lowest flow that can be easily restricted. The attenuation swale will have a base width of 0.4m, a depth of 0.4m and 1 in 4 side slopes. The swale will need to be 5m in length.

As noted, there is the River Ray at the north of the site which would offer a suitable connection point for the outfall of the swales as recommended by the client as a section is owned by the landowner.

The calculations for the attenuation option and subsequent conceptual drawing are attached with this report in **Appendix E**.

6.2 Maintenance Requirements

Maintenance of the drainage network is essential to ensure the optimal performance of the drainage elements. As such, maintenance requirements for the drainage system will include but not be limited to:

- Inspection and cleaning of the swales to ensure that the capacity and infiltration rates are maintained throughout the lifetime of the site. The maintenance of the swales can be timed to coincide with routine maintenance. The swales should be inspected every 6-12 months and cleaned if found to be necessary further maintenance is included in figure 7.1.

TABLE 17.1 Operation and maintenance requirements for swales

Maintenance schedule	Required action	Typical frequency
Regular maintenance	Remove litter and debris	Monthly, or as required
	Cut grass – to retain grass height within specified design range	Monthly (during growing season), or as required
	Manage other vegetation and remove nuisance plants	Monthly at start, then as required
	Inspect inlets, outlets and overflows for blockages, and clear if required	Monthly
	Inspect infiltration surfaces for ponding, compaction, silt accumulation, record areas where water is ponding for > 48 hours	Monthly, or when required
	Inspect vegetation coverage	Monthly for 6 months, quarterly for 2 years, then half yearly
	Inspect inlets and facility surface for silt accumulation, establish appropriate silt removal frequencies	Half yearly
Occasional maintenance	Reseed areas of poor vegetation growth, alter plant types to better suit conditions, if required	As required or if bare soil is exposed over 10% or more of the swale treatment area
Remedial actions	Repair erosion or other damage by re-turfing or reseeding	As required
	Relevel uneven surfaces and reinstate design levels	As required
	Scarify and spike topsoil layer to improve infiltration performance, break up silt deposits and prevent compaction of the soil surface	As required
	Remove build-up of sediment on upstream gravel trench, flow spreader or at top of filter strip	As required
	Remove and dispose of oils or petrol residues using safe standard practices	As required

Figure 6.1. Extract from CIRIA SuDS Manual

- Maintenance of the orifices and outfalls will include periodic inspections to monitor any potential blockages. Any flood events will also require inspection and cleaning to be able to maintain their ability to protect the site.

The drainage system will remain in private ownership; the site operator would, therefore, be responsible for the maintenance of the drainage features within the site. The developer of the site should make this responsibility clear to the site operator by providing a maintenance plan for the development.

6.3 Summary

Percolation testing has not been conducted at the proposed development site, due to the small area of impermeable surface introduced by the development. It is anticipated that there will be only a slight increase in runoff from the development which can be adequately managed by the proposed swales system.

The extent of the impermeable areas introduced across the site by the proposed development is extremely small. Therefore, any additional runoff from the impermeable areas will be small and more than adequately managed by the proposed SuDS design. As such there will be no impact on the nearby watercourses and neighbouring sites as a result of the proposed development.

7.0 POLICY SUMMARY

The development has been shown to be located within Flood Zone 3. In accordance with Planning Practice Guidance (PPG) Table 3, a development of this type *"of Essential utility infrastructure"* is deemed to be subject to the Sequential and Exception Test (see Figure 7.1 below).

It is also noted that; *''In Flood Zone 3a essential infrastructure should be designed and constructed to remain operational and safe in times of flood.''*

This has been addressed within the surface water drainage and mitigation measures illustrated above within this report.

Flood Zones	Flood Risk Vulnerability Classification				
	Essential infrastructure	Highly vulnerable	More vulnerable	Less vulnerable	Water compatible
Zone 1	✓	✓	✓	✓	✓
Zone 2	✓	Exception Test required	✓	✓	✓
Zone 3a †	Exception Test required †	✗	Exception Test required	✓	✓
Zone 3b *	Exception Test required *	✗	✗	✗	✓ *

Key:

✓ Development is appropriate

✗ Development should not be permitted.

Figure 7.1 PPG Table 3

With respect to the NPPF & PPG, it would appear that the site could be developed, although it would be necessary to demonstrate that no reasonably developable sites are available in lower-risk flood zones in order to pass the sequential test. However, it should be noted that the strict requirements for the placement of a solar PV site (i.e., distance from the sub-station, visual impact etc.), finding an alternative site would likely prove difficult. Paragraph 3 of PPG states:

"The Sequential Test ensures that a sequential approach is followed to steer new development to areas with the lowest probability of flooding. The flood zones as refined in the Strategic Flood Risk Assessment for the area provide the basis for applying the Test. The aim is to steer new development to Flood Zone 1 (areas with a low probability of river or sea flooding).

Although now superseded by the NPPF, the previous PPS 25 provided planning guidance about flood risk, and it is considered that certain sections are still relevant. Paragraph 4.39 of PPS 25 states the following specifically regarding renewable energy projects which are not covered in the NPPF:

"Specific national planning policy in Planning Policy Statement 22 Renewable Energy advises how, given the particular factors that relate to renewable energy projects, LPAs should not use a sequential approach in the consideration of such proposals."

As such this suggests that a renewable energy proposal such as this one should not be subject to the Sequential Test.

As the site is classified as ‘essential infrastructure’, the development is therefore also subject to the Exception Test.

NPPF Paragraph 102 states *“If following the application of the Sequential Test, it is not possible, consistent with wider sustainability objectives, for the development to be located in zones with a lower probability of flooding, the Exception Test can be applied if appropriate. For the exception test to be passed:*

- *It must be demonstrated that the development provides wider sustainability benefits to the community that outweighs flood risk.*
- *The FRA must demonstrate that the development will be safe over its lifetime given the vulnerability of its users.*

It would appear that this development would meet the requirements of the Exception Test provided the mitigation measures recommended in this report are adopted.

8.0 CONCLUSIONS AND RECOMMENDATIONS

The proposed development is shown to be partially located within Flood Zone 3 according to EA flood mapping, although the majority of the site is situated in Flood Zone 1 and all essential infrastructure is either in Flood Zone 1 or raised above the predicted 1 in 100-year flood level.

The site level has a maximum elevation of 64.85m AOD dropping to 58.56m AOD.

Utilizing EA information obtained for the site, the 1 in the 1000-year flood level including an allowance for climate change gives a maximum flood depth of **0.86m AGL** in some isolated portions of the development site.

It is determined that all essential infrastructure is to be situated within Flood Zone 1 and all solar panels are set at a minimum height of 0.90m AGL. Therefore, the panels are deemed to be free from flooding. In addition, the majority of the site is within Flood Zone 1 and all essential infrastructure is within Flood Zone 1 and outside of the flood to one extent.

The study has identified a number of mitigation proposals to reduce the risk of flooding to the areas in the flood zone to an acceptable level. These include:

- Sufficient spacing between the piles supporting the panels to minimise flow disruption during a flood event.

- The security fencing mesh sizing should be made as large as reasonably practical to reduce the chance of blockage and obstruction of flow routes.

This study has investigated the impact that the development will have on runoff rates from the site. The additional runoff from the impermeable areas is minimal, however, calculations have been made to determine a suitably sized swale system to capture the additional runoff anticipated. These swales have been designed to capture and store surface water runoff with the possibility of infiltration occurring at a slow rate due to the soil types identified at the site location. Swales are shown on the drawing in **Appendix C** of this report.

An attenuation option utilising HydroBrake Optimum Flow Control Devices has also been provided should percolation testing prove infiltration rates to be poor. This will attenuate the runoff from the site to pre-development greenfield runoff rates for Qbar.

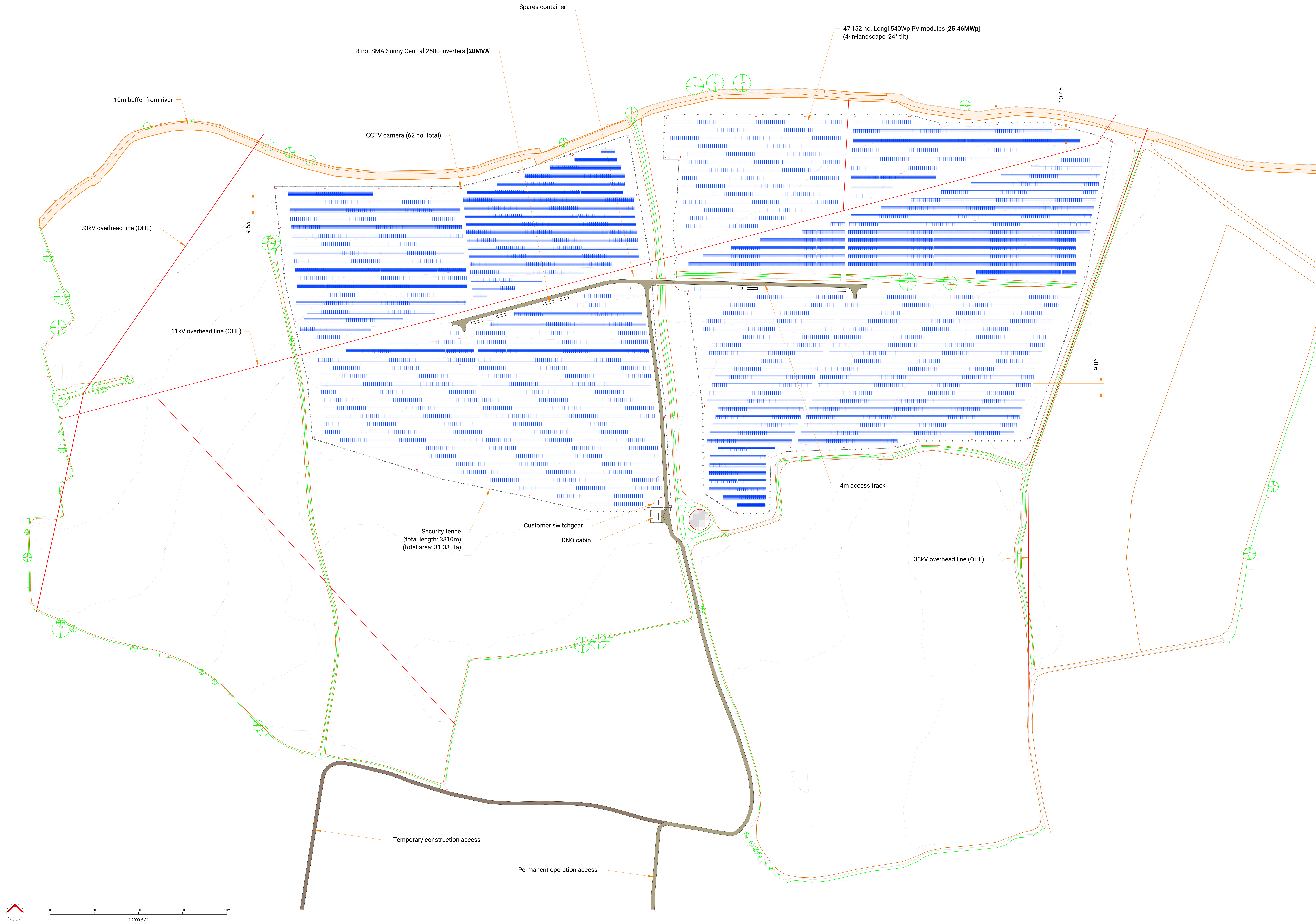
A proposed development either entirely or partially within Flood Zones 2 or 3 would be required to pass the Sequential Test; demonstrating that there are no other reasonably developable sites at a lower risk of flooding. However, where NPPF does not cover areas within the superseded PPS25, then PPS25 is still considered relevant. Paragraph 3.49 of PPS25 states that renewable energy projects such as this do not require the application of the Sequential Test. Further to this, the location of the Solar PV site has been chosen for its ability to connect to the grid and cannot be located elsewhere.

The proposed development is classified as ‘essential infrastructure, in which the development would be required to pass the Exception Test before being deemed appropriate. It is anticipated that the site would pass the Exception Test as it provides wider sustainability benefits and can be developed safely with regard to flood risk (as set out in **Sections 5-7**).

The site is deemed to be partly at risk of flooding from fluvial sources, however, all infrastructure within the site is deemed to be above the worst case 1 the n 1000 year flood event plus climate change, or in Flood Zone 1.

Subject to the implementation of mitigation measures set out within this report, the development can be kept appropriately safe throughout its lifetime and the development will not increase the risk to third parties downstream, or the neighbouring land.

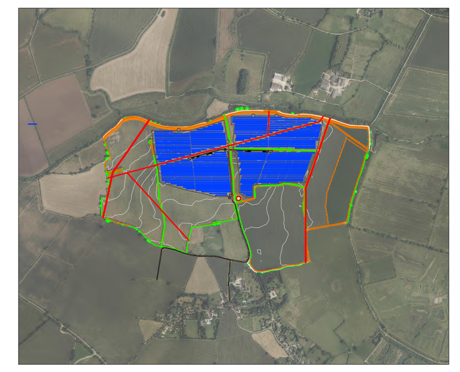
APPENDIX A SITE LOCATION



Notes:

1. All details are indicative only.
2. Dimensions are in metres unless stated otherwise.
3. Based on drawing "ASC.21.002 - Manor Farm Noke - January 2021.dwg".
4. Refer to HSE document "Avoiding danger from overhead power lines - Guidance Note GS6" to ensure safe operation of machinery in proximity to overhead power lines.

KEY PLAN



REVISIONS

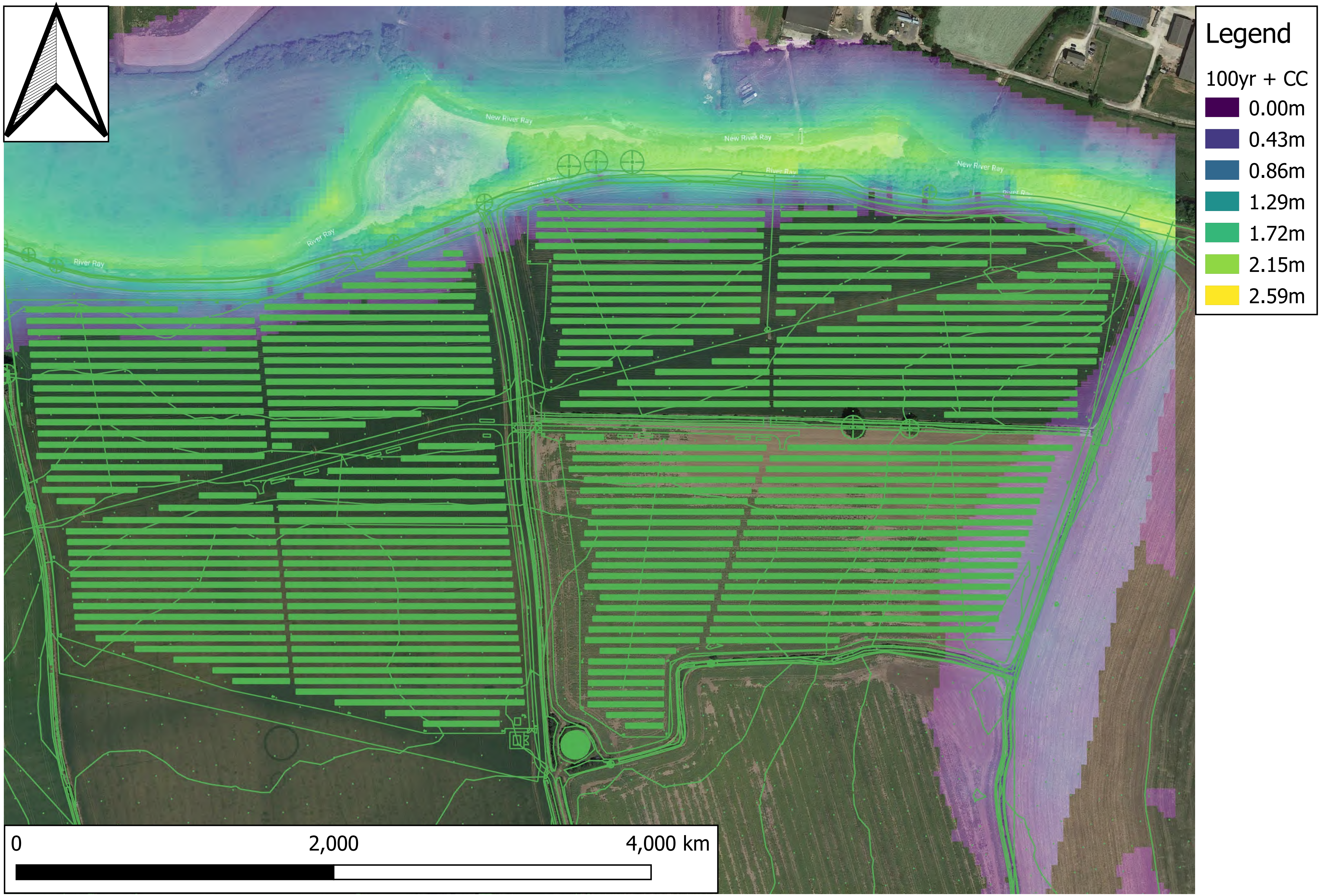
REV	DATE	COMMENTS	BY	CHKD
K	09.11.21	Removal of 3x tables in Noke field	SS	LH
J	10.08.21	Additional containers & tables to south	SS	LH
I	20.07.21	Variable row spacing	SS	LH
H	08.06.21	Fence adjustment in Far Loggs field	SS	LH
G	01.06.21	Removal of panels in Far Loggs field	SS	LH
F	31.03.21	CCTV amendments	SS	LH
E	31.03.21	Half tables/DNO adjustments	SS	LH

CLIENT	Green Nation
PROJECT	Noke Solar Farm
LOCATION	Land off B4027, Noke, Woodeaton, Oxford, OX3 9TU
TITLE	Proposed PV Layout
DWG NO	GN-NOKE-GA-01
REV	K

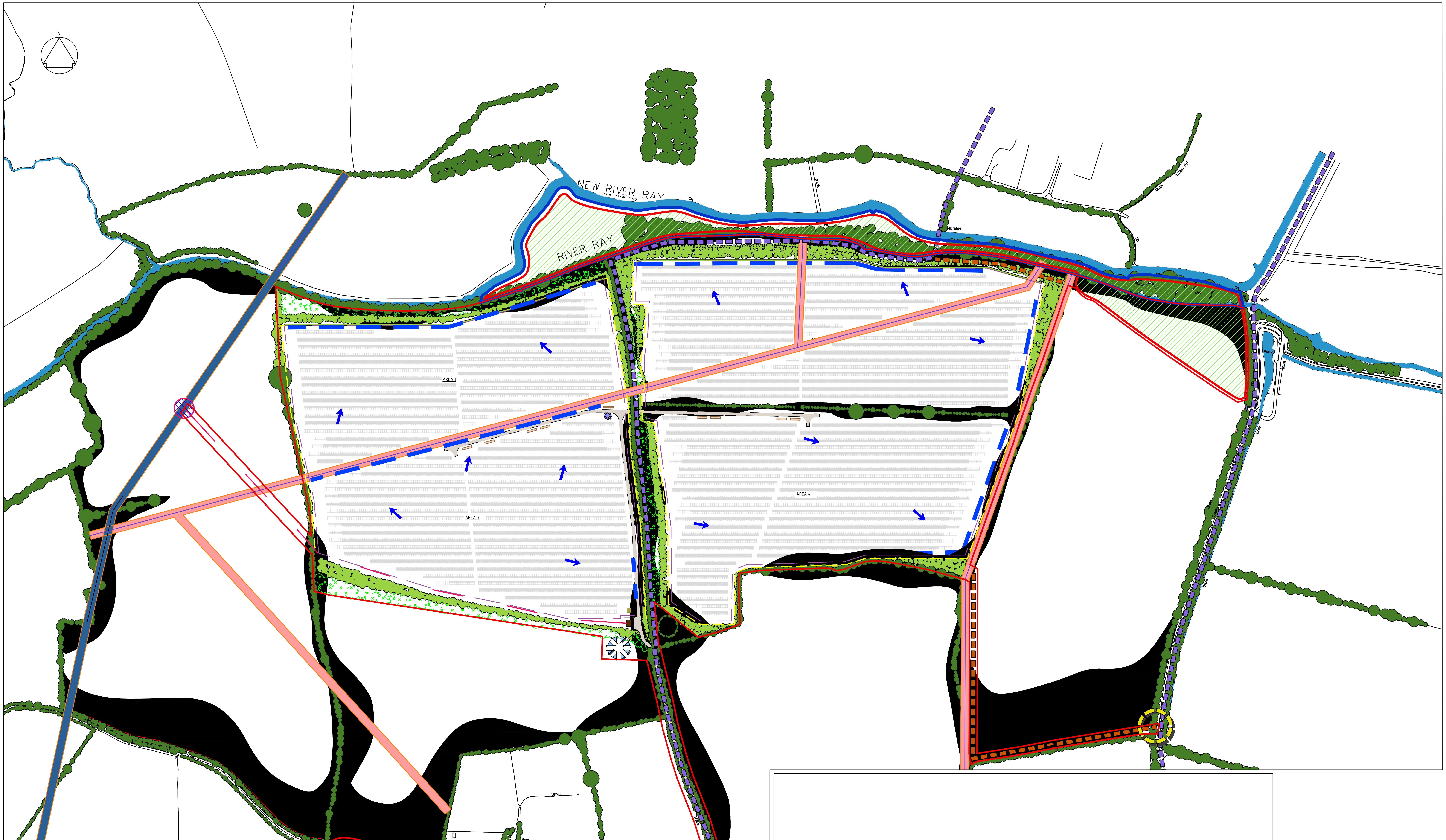
HELIOWORKS

APPENDIX B FLOOD EXTENTS

Legend
1000yr + CC
0.00m
0.43m
0.86m
1.29m
1.72m
2.15m
2.59m
New River Ray
River Ray
0
1,000
2,000 km


Legend
100yr + CC
0.00m
0.43m
0.86m
1.29m
1.72m
2.15m
2.59m
0
2,000
4,000 km
New River Ray
River Ray

APPENDIX C SUDS DESIGN

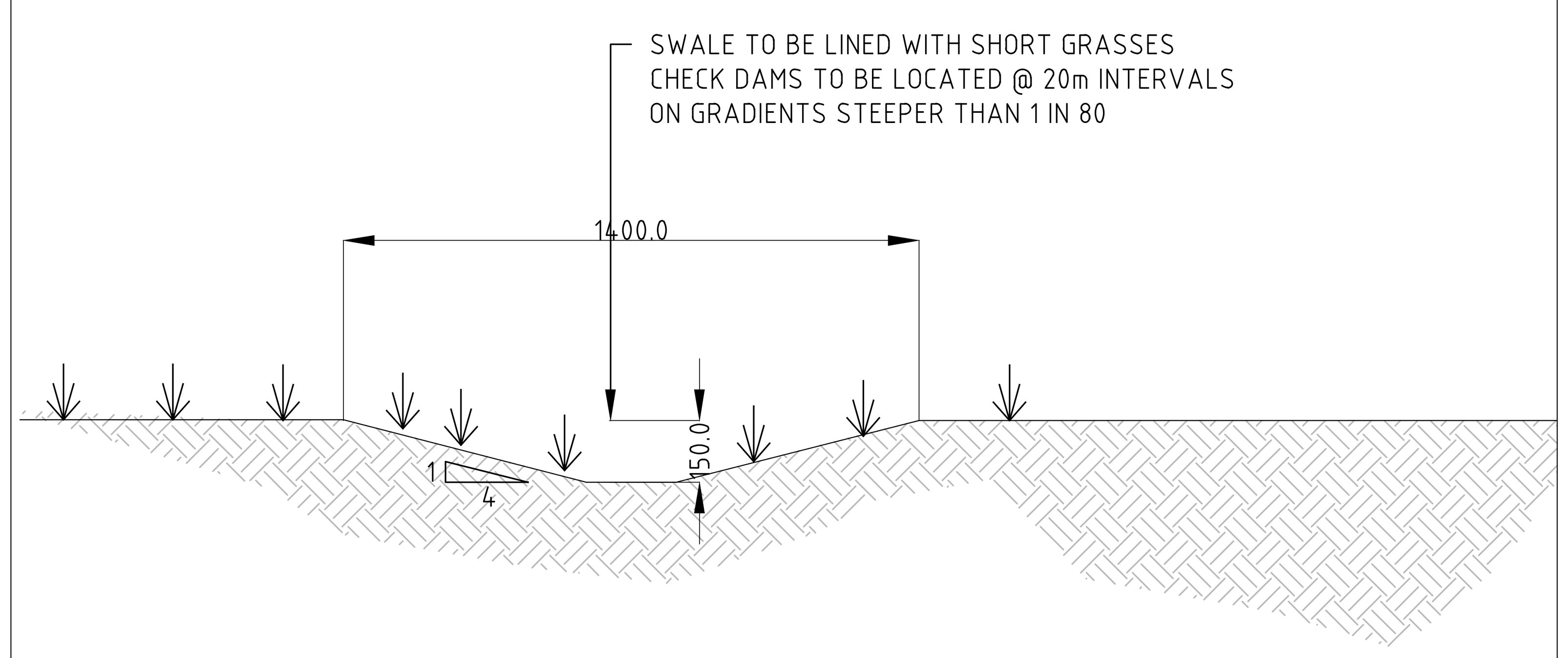


NOTES

1. THIS DRAWING AND ANY ANCILLARY DRAWINGS OR DATA ARE COPYRIGHT OF NIJHUIS H2OK Ltd AND MAY NOT BE USED, COPIED OR AMENDED FOR ANY PURPOSE WHATSOEVER WITHOUT WRITTEN APPROVAL.
2. THIS DRAWING IS ONLY TO BE USED FOR THE PURPOSES DESCRIBED IN THE STATUS BOX BELOW. WORK TO FIGURED DIMENSIONS ONLY, DO NOT SCALE.
3. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ALL OTHER DRAWINGS, DETAILS AND SPECIFICATIONS PERTAINING TO THE WORK DESCRIBED.
4. MATERIALS AND WORKMANSHIP SHALL COMPLY TO THE APPROPRIATE BRITISH STANDARDS AND CODES OF PRACTICE UNLESS OTHERWISE STATED.
5. THE ACTIVITIES REQUIRED TO CONSTRUCT THE WORK, SHOWN ON DRAWINGS CLEARLY MARKED FOR CONSTRUCTION, MAY BE SUBJECT TO THE PROVISIONS OF THE CONSTRUCTION (DESIGN AND MANAGEMENT) REGULATIONS 2015 THE CONTRACTOR AND CLIENT MUST ENSURE THAT THEY ARE ADEQUATELY CONVERSANT WITH THESE REGULATIONS AND THAT THE APPROPRIATE PROCEDURES REQUIRED UNDER THE REGULATIONS ARE OBSERVED AT ALL TIMES.

KEY

PROPOSED SITE BOUNDARY
PROPOSED SWALE
OVERLAND FLOW ARROW



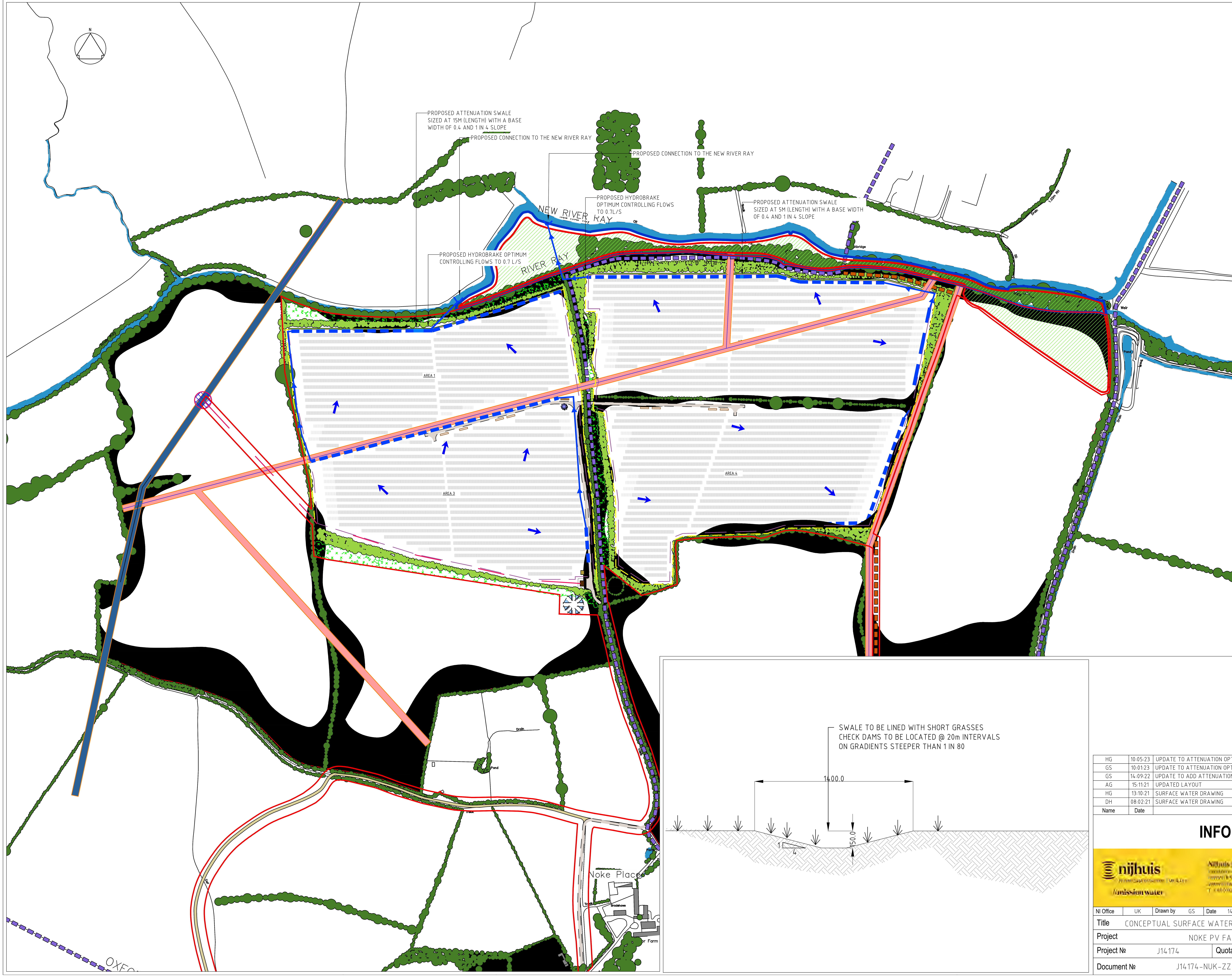
Name	Date	Remarks	Revision
HG	10:05:23	UPDATE TO ATTENUATION OPTION ANNOTATION	P06
GS	10:01:23	UPDATE TO ATTENUATION OPTION	P05
GS	14:09:22	UPDATE TO ADD ATTENUATION OPTION	P04
AG	15:11:21	UPDATED LAYOUT	P03
HG	13:10:21	SURFACE WATER DRAWING	P02
DH	08:02:21	SURFACE WATER DRAWING	P01

INFORMATION

nijhuis

NI Office: UK	Drawn by: GS	Date: 14:09:22	Status: S2
Title	CONCEPUTAL SURFACE WATER DRAINAGE SCHEME		
Project	NOKE PV FARM		
Project №	J14174	Quotation №	
Document №	J14174-NUK-ZZ-ZZ-DR-D-3001		

Version	V01
Revision	P06
Released by	HG
Release Date	14:09:22
Size	A1
Sheet	1 OF 2
Scale	1:2500
Unit	M



NOTES

1. THIS DRAWING AND ANY ANCILLARY DRAWINGS OR DATA ARE COPYRIGHT OF NIJHUIS H2OK Ltd AND MAY NOT BE USED, COPIED OR AMENDED FOR ANY PURPOSE WHATSOEVER WITHOUT WRITTEN APPROVAL.
2. THIS DRAWING IS ONLY TO BE USED FOR THE PURPOSES DESCRIBED IN THE STATUS BOX BELOW. WORK TO FIGURED DIMENSIONS ONLY, DO NOT SCALE.
3. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ALL OTHER DRAWINGS, DETAILS AND SPECIFICATIONS PERTAINING TO THE WORK DESCRIBED.
4. MATERIALS AND WORKMANSHIP SHALL COMPLY TO THE APPROPRIATE BRITISH STANDARDS AND CODES OF PRACTICE UNLESS OTHERWISE STATED.
5. THE ACTIVITIES REQUIRED TO CONSTRUCT THE WORK, SHOWN ON DRAWINGS CLEARLY MARKED FOR CONSTRUCTION, MAY BE SUBJECT TO THE PROVISIONS OF THE CONSTRUCTION (DESIGN AND MANAGEMENT) REGULATIONS 2015 THE CONTRACTOR AND CLIENT MUST ENSURE THAT THEY ARE ADEQUATELY CONVERSANT WITH THESE REGULATIONS AND THAT THE APPROPRIATE PROCEDURES REQUIRED UNDER THE REGULATIONS ARE OBSERVED AT ALL TIMES.

KEY

- PROPOSED SITE BOUNDARY
- PROPOSED SWALE
- PROPOSED CONVEYANCE SWALES
- OVERLAND FLOW ARROW

Name	Date	Remarks	Revision
HG	10:05:23	UPDATE TO ATTENUATION OPTION ANNOTATION	P06
GS	10:01:23	UPDATE TO ATTENUATION OPTION	P05
GS	14:09:22	UPDATE TO ADD ATTENUATION OPTION	P04
AG	15:11:21	UPDATED LAYOUT	P03
HG	13:10:21	SURFACE WATER DRAWING	P02
DH	08:02:21	SURFACE WATER DRAWING	P01

INFORMATION

NI Office	UK	Drawn by	GS	Date	14:09:22	Status	S2	Version	V01
Title	CONCEPTUAL SURFACE WATER DRAINAGE SCHEME							Revision	P06
								Released by	HG
Project	NOKE PV FARM							Release Date	14:09:22
								Size	A1
Project №	J14174			Quotation №				Sheet	1 OF 2
								Scale	1:2500
Document №	J14174-NUK-ZZ-ZZ-DR-D-3002							Unit	M

APPENDIX D CALCULATIONS FOR INFILTRATION

UK Design Flood Estimation

Generated on Tuesday, February 9, 2021 5:23:06 PM by dhigginson
Printed from the ReFH2 Flood Modelling software package, version 3.0.7275.28566

Summary of estimate using the Flood Estimation Handbook revitalised flood hydrograph method (ReFH2)

Site details Checksum: 4A6C-4E01

Site name: FEH_Catchment_Descriptors_454000_214200

Easting: 454000

Northing: 214200

Country: England, Wales or Northern Ireland

Catchment Area (km^2): 251.89

Using plot scale calculations: No

Model: ReFH2.3

Site description: None

Model run: 100 year 1.4 CC

Summary of results

Rainfall - FEH 2013 model (mm):	96.74	Total runoff (ML):	5613.20
Total Rainfall (mm):	57.14	Total flow (ML):	14429.48
Peak Rainfall (mm):	36.36	Peak flow (m^3/s):	86.58

Parameters

Where the user has overriden a system-generated value, this original value is shown in square brackets after the value used.
** Indicates that the user locked the duration/timestep*

Rainfall parameters (Rainfall - FEH 2013 model)

Name	Value	User-defined?
Duration (hh:mm:ss)	06:00:00 [22:00:00]	Yes
Timestep (hh:mm:ss)	02:00:00	No
SCF (Seasonal correction factor)	0.68	No
ARF (Areal reduction factor)	0.87	No
Seasonality	Winter	No
Climate change factor	1.40	Yes

Loss model parameters

Name	Value	User-defined?
Cini (mm)	107.51	No
Cmax (mm)	354.01	No
Use alpha correction factor	No	No
Alpha correction factor	n/a	No

Routing model parameters

Name	Value	User-defined?
Tp (hr)	14.06	No
Up	0.65	No
Uk	0.8	No

Baseflow model parameters

Name	Value	User-defined?
BF0 (m^3/s)	6.63	No
BL (hr)	58.79	No
BR	1.6	No

Urbanisation parameters

Name	Value	User-defined?
Urban area (km^2)	8.17	No
Urbext 2000	0.02	No
Impervious runoff factor	0.7	No
Imperviousness factor	0.4	No
Tp scaling factor	0.75	No
Depression storage depth (mm)	0.5	No
Exporting drained area (km^2)	0.00	Yes
Sewer capacity (m^3/s)	0.00	Yes

Time series data

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m³/s)	Baseflow (m³/s)	Total Flow (m³/s)
00:00:00	10.394	0.000	3.373	0.000	6.543	6.543
02:00:00	36.356	0.000	14.178	0.806	6.345	7.151
04:00:00	10.394	0.000	4.734	5.798	6.299	12.097
06:00:00	0.000	0.000	0.000	15.294	6.622	21.915
08:00:00	0.000	0.000	0.000	25.915	7.441	33.355
10:00:00	0.000	0.000	0.000	36.536	8.769	45.305
12:00:00	0.000	0.000	0.000	47.098	10.589	57.687
14:00:00	0.000	0.000	0.000	57.280	12.885	70.165
16:00:00	0.000	0.000	0.000	65.693	15.610	81.303
18:00:00	0.000	0.000	0.000	68.020	18.558	86.578
20:00:00	0.000	0.000	0.000	63.561	21.375	84.935
22:00:00	0.000	0.000	0.000	57.352	23.831	81.183
24:00:00	0.000	0.000	0.000	51.193	25.892	77.085
26:00:00	0.000	0.000	0.000	45.178	27.570	72.747
28:00:00	0.000	0.000	0.000	39.229	28.878	68.106
30:00:00	0.000	0.000	0.000	33.499	29.834	63.333
32:00:00	0.000	0.000	0.000	28.928	30.487	59.416
34:00:00	0.000	0.000	0.000	25.785	30.920	56.705
36:00:00	0.000	0.000	0.000	23.024	31.188	54.212
38:00:00	0.000	0.000	0.000	20.263	31.308	51.571
40:00:00	0.000	0.000	0.000	17.523	31.284	48.807
42:00:00	0.000	0.000	0.000	14.874	31.122	45.996
44:00:00	0.000	0.000	0.000	12.313	30.826	43.139
46:00:00	0.000	0.000	0.000	9.772	30.400	40.172
48:00:00	0.000	0.000	0.000	7.231	29.849	37.080
50:00:00	0.000	0.000	0.000	4.690	29.177	33.867
52:00:00	0.000	0.000	0.000	2.247	28.391	30.639
54:00:00	0.000	0.000	0.000	0.489	27.517	28.005
56:00:00	0.000	0.000	0.000	0.022	26.610	26.632
58:00:00	0.000	0.000	0.000	0.000	25.721	25.721
60:00:00	0.000	0.000	0.000	0.000	24.860	24.860
62:00:00	0.000	0.000	0.000	0.000	24.029	24.029
64:00:00	0.000	0.000	0.000	0.000	23.225	23.225
66:00:00	0.000	0.000	0.000	0.000	22.448	22.448
68:00:00	0.000	0.000	0.000	0.000	21.697	21.697

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m^3/s)	Baseflow (m^3/s)	Total Flow (m^3/s)
70:00:00	0.000	0.000	0.000	0.000	20.972	20.972
72:00:00	0.000	0.000	0.000	0.000	20.270	20.270
74:00:00	0.000	0.000	0.000	0.000	19.592	19.592
76:00:00	0.000	0.000	0.000	0.000	18.937	18.937
78:00:00	0.000	0.000	0.000	0.000	18.304	18.304
80:00:00	0.000	0.000	0.000	0.000	17.691	17.691
82:00:00	0.000	0.000	0.000	0.000	17.100	17.100
84:00:00	0.000	0.000	0.000	0.000	16.528	16.528
86:00:00	0.000	0.000	0.000	0.000	15.975	15.975
88:00:00	0.000	0.000	0.000	0.000	15.440	15.440
90:00:00	0.000	0.000	0.000	0.000	14.924	14.924
92:00:00	0.000	0.000	0.000	0.000	14.425	14.425
94:00:00	0.000	0.000	0.000	0.000	13.942	13.942
96:00:00	0.000	0.000	0.000	0.000	13.476	13.476
98:00:00	0.000	0.000	0.000	0.000	13.025	13.025
100:00:00	0.000	0.000	0.000	0.000	12.590	12.590
102:00:00	0.000	0.000	0.000	0.000	12.169	12.169
104:00:00	0.000	0.000	0.000	0.000	11.761	11.761
106:00:00	0.000	0.000	0.000	0.000	11.368	11.368
108:00:00	0.000	0.000	0.000	0.000	10.988	10.988
110:00:00	0.000	0.000	0.000	0.000	10.620	10.620
112:00:00	0.000	0.000	0.000	0.000	10.265	10.265
114:00:00	0.000	0.000	0.000	0.000	9.922	9.922
116:00:00	0.000	0.000	0.000	0.000	9.590	9.590
118:00:00	0.000	0.000	0.000	0.000	9.269	9.269
120:00:00	0.000	0.000	0.000	0.000	8.959	8.959
122:00:00	0.000	0.000	0.000	0.000	8.659	8.659
124:00:00	0.000	0.000	0.000	0.000	8.370	8.370
126:00:00	0.000	0.000	0.000	0.000	8.090	8.090
128:00:00	0.000	0.000	0.000	0.000	7.819	7.819
130:00:00	0.000	0.000	0.000	0.000	7.558	7.558
132:00:00	0.000	0.000	0.000	0.000	7.305	7.305
134:00:00	0.000	0.000	0.000	0.000	7.061	7.061
136:00:00	0.000	0.000	0.000	0.000	6.824	6.824
138:00:00	0.000	0.000	0.000	0.000	6.596	6.596

Appendix

Catchment descriptors

Name	Value	User-defined value used?
Area (km^2)	251.89	No
ALTBAR	79	No
ASPBAR	186	No
ASPVAR	0.14	No
BFIHOST	0.46	No
BFIHOST19	0.44	No
DPLBAR (km)	16.9	No
DPSBAR (mkm^{-1})	18.3	No
FARL	0.99	No
LDP	31.92	No
PROPWET (mm)	0.32	No
RMED1H	9.9	No
RMED1D	31.3	No
RMED2D	38.8	No
SAAR (mm)	628	No
SAAR4170 (mm)	653	No
SPRHOST	39.14	No
Urbext2000	0.02	No
Urbext1990	0.01	No
URBCONC	0.8	No
URBLOC	0.86	No
DDF parameter C	-0.02	No
DDF parameter D1	0.33	No
DDF parameter D2	0.32	No
DDF parameter D3	0.25	No
DDF parameter E	0.29	No
DDF parameter F	2.47	No
DDF parameter C (1km grid value)	-0.02	No
DDF parameter D1 (1km grid value)	0.33	No
DDF parameter D2 (1km grid value)	0.33	No
DDF parameter D3 (1km grid value)	0.22	No
DDF parameter E (1km grid value)	0.29	No
DDF parameter F (1km grid value)	2.46	No

APPENDIX E CALCULATIONS FOR ATTENUATION

ICP SUDS Mean Annual Flood

Input

Return Period (years)	100	Soil	0.400
Area (ha)	0.025	Urban	0.000
SAAR (mm)	659	Region Number	Region 6

Results	**l/s**
QBAR Rural	0.1
QBAR Urban	0.1
Q100 years	0.3
Q1 year	0.1
Q30 years	0.2
Q100 years	0.3

ICP SUDS Mean Annual Flood

Input

Return Period (years)	100	Soil	0.400
Area (ha)	0.012	Urban	0.000
SAAR (mm)	659	Region Number	Region 6

Results	**l/s**
QBAR Rural	0.0
QBAR Urban	0.0
Q100 years	0.1
Q1 year	0.0
Q30 years	0.1
Q100 years	0.1

Summary of Results for 100 year Return Period (+50%)

Half Drain Time : 149 minutes.

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
15 min Summer	99.878	0.278	0.0	0.7	0.7	5.7	Flood Risk
30 min Summer	99.922	0.322	0.0	0.7	0.7	7.5	Flood Risk
60 min Summer	99.952	0.352	0.0	0.7	0.7	8.9	Flood Risk
120 min Summer	99.961	0.361	0.0	0.7	0.7	9.3	Flood Risk
180 min Summer	99.954	0.354	0.0	0.7	0.7	8.9	Flood Risk
240 min Summer	99.945	0.345	0.0	0.7	0.7	8.5	Flood Risk
360 min Summer	99.929	0.329	0.0	0.7	0.7	7.8	Flood Risk
480 min Summer	99.912	0.312	0.0	0.7	0.7	7.1	Flood Risk
600 min Summer	99.895	0.295	0.0	0.7	0.7	6.4	Flood Risk
720 min Summer	99.877	0.277	0.0	0.7	0.7	5.7	Flood Risk
960 min Summer	99.836	0.236	0.0	0.7	0.7	4.3	Flood Risk
1440 min Summer	99.762	0.162	0.0	0.7	0.7	2.2	Flood Risk
2160 min Summer	99.685	0.085	0.0	0.7	0.7	0.7	O K
2880 min Summer	99.659	0.059	0.0	0.6	0.6	0.4	O K
4320 min Summer	99.643	0.043	0.0	0.4	0.4	0.2	O K
5760 min Summer	99.636	0.036	0.0	0.3	0.3	0.2	O K
7200 min Summer	99.632	0.032	0.0	0.3	0.3	0.1	O K
8640 min Summer	99.629	0.029	0.0	0.2	0.2	0.1	O K
10080 min Summer	99.627	0.027	0.0	0.2	0.2	0.1	O K
15 min Winter	99.899	0.299	0.0	0.7	0.7	6.6	Flood Risk

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
15 min Summer	148.021	0.0	6.9	35
30 min Summer	97.184	0.0	9.1	47
60 min Summer	60.764	0.0	11.4	72
120 min Summer	36.692	0.0	13.8	122
180 min Summer	26.945	0.0	15.2	156
240 min Summer	21.513	0.0	16.1	188
360 min Summer	15.627	0.0	17.6	256
480 min Summer	12.453	0.0	18.7	324
600 min Summer	10.434	0.0	19.6	392
720 min Summer	9.026	0.0	20.3	460
960 min Summer	7.175	0.0	21.5	582
1440 min Summer	5.185	0.0	23.3	808
2160 min Summer	3.740	0.0	25.2	1128
2880 min Summer	2.963	0.0	26.7	1472
4320 min Summer	2.131	0.0	28.8	2192
5760 min Summer	1.686	0.0	30.3	2936
7200 min Summer	1.404	0.0	31.6	3624
8640 min Summer	1.209	0.0	32.6	4336
10080 min Summer	1.065	0.0	33.6	5104
15 min Winter	148.021	0.0	7.8	35

Summary of Results for 100 year Return Period (+50%)

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
30 min Winter	99.946	0.346	0.0	0.7	0.7	8.6	Flood Risk
60 min Winter	99.980	0.380	0.0	0.7	0.7	10.2	Flood Risk
120 min Winter	99.993	0.393	0.0	0.7	0.7	10.9	Flood Risk
180 min Winter	99.986	0.386	0.0	0.7	0.7	10.5	Flood Risk
240 min Winter	99.976	0.376	0.0	0.7	0.7	10.0	Flood Risk
360 min Winter	99.954	0.354	0.0	0.7	0.7	8.9	Flood Risk
480 min Winter	99.930	0.330	0.0	0.7	0.7	7.9	Flood Risk
600 min Winter	99.906	0.306	0.0	0.7	0.7	6.8	Flood Risk
720 min Winter	99.878	0.278	0.0	0.7	0.7	5.7	Flood Risk
960 min Winter	99.811	0.211	0.0	0.7	0.7	3.5	Flood Risk
1440 min Winter	99.698	0.098	0.0	0.7	0.7	0.9	O K
2160 min Winter	99.654	0.054	0.0	0.5	0.5	0.3	O K
2880 min Winter	99.643	0.043	0.0	0.4	0.4	0.2	O K
4320 min Winter	99.633	0.033	0.0	0.3	0.3	0.1	O K
5760 min Winter	99.629	0.029	0.0	0.2	0.2	0.1	O K
7200 min Winter	99.626	0.026	0.0	0.2	0.2	0.1	O K
8640 min Winter	99.624	0.024	0.0	0.2	0.2	0.1	O K
10080 min Winter	99.622	0.022	0.0	0.2	0.2	0.1	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
30 min Winter	97.184	0.0	10.2	48
60 min Winter	60.764	0.0	12.8	72
120 min Winter	36.692	0.0	15.4	122
180 min Winter	26.945	0.0	17.0	170
240 min Winter	21.513	0.0	18.1	200
360 min Winter	15.627	0.0	19.7	276
480 min Winter	12.453	0.0	20.9	350
600 min Winter	10.434	0.0	21.9	424
720 min Winter	9.026	0.0	22.7	496
960 min Winter	7.175	0.0	24.1	610
1440 min Winter	5.185	0.0	26.1	800
2160 min Winter	3.740	0.0	28.3	1112
2880 min Winter	2.963	0.0	29.9	1444
4320 min Winter	2.131	0.0	32.2	2204
5760 min Winter	1.686	0.0	34.0	2864
7200 min Winter	1.404	0.0	35.4	3584
8640 min Winter	1.209	0.0	36.6	4352
10080 min Winter	1.065	0.0	37.6	4984

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)	20.000	Shortest Storm (mins)	15
Ratio R	0.400	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+50

Time Area Diagram

Total Area (ha) 0.025

Time From:	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**
0	4	0.004	8	12	0.004	16	20	0.004
4	8	0.004	12	16	0.004	20	24	0.005

Model Details

Storage is Online Cover Level (m) 100.000

Swale Structure

Infiltration Coefficient Base (m/hr)	0.00000	Length (m)	15.0
Infiltration Coefficient Side (m/hr)	0.00000	Side Slope (1:X)	4.0
Safety Factor	2.0	Slope (1:X)	500.0
Porosity	1.00	Cap Volume Depth (m)	0.000
Invert Level (m)	99.600	Cap Infiltration Depth (m)	0.000
Base Width (m)	0.4		

Hydro-Brake® Optimum Outflow Control

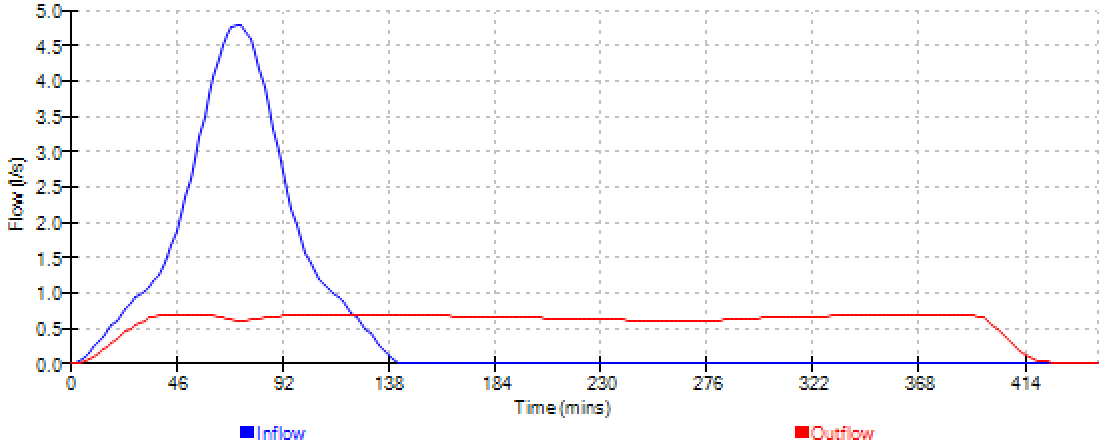
Unit Reference	MD-SHE-0046-7000-0400-7000
Design Head (m)	0.400
Design Flow (l/s)	0.7
Flush-Flo™	Calculated
Objective	Minimise upstream storage
Application	Surface
Sump Available	Yes
Diameter (mm)	46
Invert Level (m)	99.600
Minimum Outlet Pipe Diameter (mm)	75
Suggested Manhole Diameter (mm)	1200

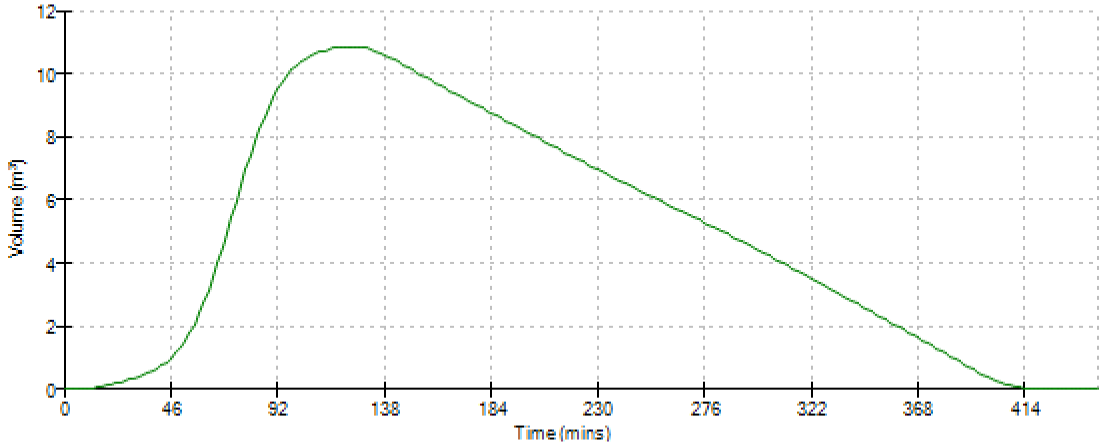
Control Points	**Head (m)**	**Flow (l/s)**	**Control Points**	**Head (m)**	**Flow (l/s)**
Design Point (Calculated)	0.400	0.7	Kick-Flo®	0.270	0.6
Flush-Flo™	0.119	0.7	Mean Flow over Head Range	-	0.6

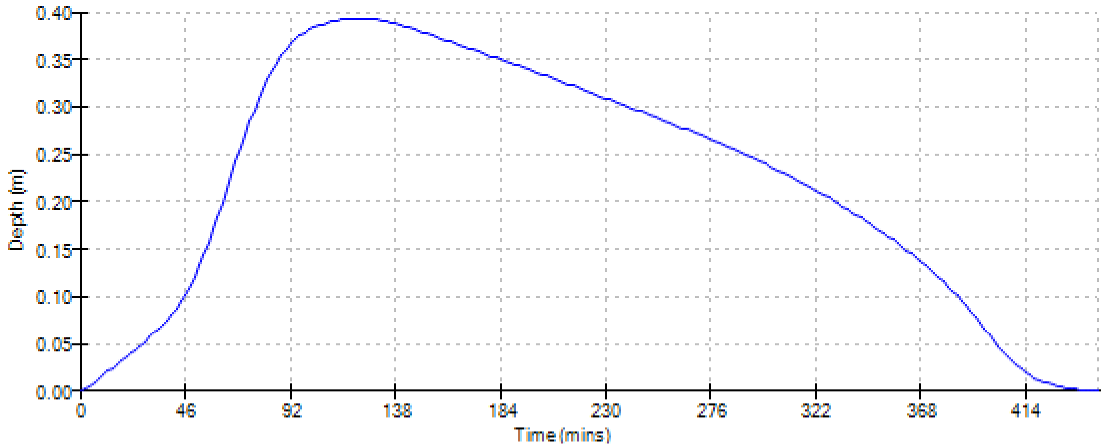
The hydrological calculations have been based on the Head/Discharge relationship for the Hydro-Brake® Optimum as specified. Should another type of control device other than a Hydro-Brake Optimum® be utilised then these storage routing calculations will be invalidated

Depth (m)	**Flow (l/s)**	**Depth (m)**	**Flow (l/s)**	**Depth (m)**	**Flow (l/s)**	**Depth (m)**	**Flow (l/s)**
0.100	0.7	1.200	1.1	3.000	1.7	7.000	2.6
0.200	0.7	1.400	1.2	3.500	1.8	7.500	2.7
0.300	0.6	1.600	1.3	4.000	2.0	8.000	2.8
0.400	0.7	1.800	1.4	4.500	2.1	8.500	2.9
0.500	0.8	2.000	1.4	5.000	2.2	9.000	2.9
0.600	0.8	2.200	1.5	5.500	2.3	9.500	3.0
0.800	0.9	2.400	1.6	6.000	2.4		
1.000	1.0	2.600	1.6	6.500	2.5		

Event: 120 min Winter







Summary of Results for 100 year Return Period (+50%)

Half Drain Time : 54 minutes.

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
15 min Summer	99.892	0.292	0.0	0.7	0.7	2.2	Flood Risk
30 min Summer	99.942	0.342	0.0	0.7	0.7	2.9	Flood Risk
60 min Summer	99.963	0.363	0.0	0.7	0.7	3.3	Flood Risk
120 min Summer	99.950	0.350	0.0	0.7	0.7	3.1	Flood Risk
180 min Summer	99.931	0.331	0.0	0.7	0.7	2.8	Flood Risk
240 min Summer	99.909	0.309	0.0	0.7	0.7	2.5	Flood Risk
360 min Summer	99.859	0.259	0.0	0.7	0.7	1.8	Flood Risk
480 min Summer	99.806	0.206	0.0	0.7	0.7	1.2	Flood Risk
600 min Summer	99.758	0.158	0.0	0.7	0.7	0.8	Flood Risk
720 min Summer	99.718	0.118	0.0	0.7	0.7	0.5	Flood Risk
960 min Summer	99.670	0.070	0.0	0.7	0.7	0.2	O K
1440 min Summer	99.649	0.049	0.0	0.5	0.5	0.1	O K
2160 min Summer	99.637	0.037	0.0	0.4	0.4	0.1	O K
2880 min Summer	99.632	0.032	0.0	0.3	0.3	0.1	O K
4320 min Summer	99.626	0.026	0.0	0.2	0.2	0.1	O K
5760 min Summer	99.623	0.023	0.0	0.2	0.2	0.0	O K
7200 min Summer	99.621	0.021	0.0	0.1	0.1	0.0	O K
8640 min Summer	99.619	0.019	0.0	0.1	0.1	0.0	O K
10080 min Summer	99.618	0.018	0.0	0.1	0.1	0.0	O K
15 min Winter	99.919	0.319	0.0	0.7	0.7	2.6	Flood Risk

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
15 min Summer	148.021	0.0	3.3	33
30 min Summer	97.184	0.0	4.4	42
60 min Summer	60.764	0.0	5.5	62
120 min Summer	36.692	0.0	6.6	98
180 min Summer	26.945	0.0	7.3	132
240 min Summer	21.513	0.0	7.7	164
360 min Summer	15.627	0.0	8.4	230
480 min Summer	12.453	0.0	9.0	286
600 min Summer	10.434	0.0	9.4	342
720 min Summer	9.026	0.0	9.7	396
960 min Summer	7.175	0.0	10.3	502
1440 min Summer	5.185	0.0	11.2	736
2160 min Summer	3.740	0.0	12.1	1100
2880 min Summer	2.963	0.0	12.8	1468
4320 min Summer	2.131	0.0	13.8	2160
5760 min Summer	1.686	0.0	14.6	2872
7200 min Summer	1.404	0.0	15.2	3568
8640 min Summer	1.209	0.0	15.7	4344
10080 min Summer	1.065	0.0	16.1	5128
15 min Winter	148.021	0.0	3.7	33

Summary of Results for 100 year Return Period (+50%)

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
30 min Winter	99.970	0.370	0.0	0.7	0.7	3.4	Flood Risk
60 min Winter	99.995	0.395	0.0	0.7	0.7	3.8	Flood Risk
120 min Winter	99.980	0.380	0.0	0.7	0.7	3.6	Flood Risk
180 min Winter	99.952	0.352	0.0	0.7	0.7	3.1	Flood Risk
240 min Winter	99.920	0.320	0.0	0.7	0.7	2.6	Flood Risk
360 min Winter	99.838	0.238	0.0	0.7	0.7	1.6	Flood Risk
480 min Winter	99.753	0.153	0.0	0.7	0.7	0.7	Flood Risk
600 min Winter	99.688	0.088	0.0	0.7	0.7	0.3	O K
720 min Winter	99.664	0.064	0.0	0.6	0.6	0.2	O K
960 min Winter	99.649	0.049	0.0	0.5	0.5	0.1	O K
1440 min Winter	99.637	0.037	0.0	0.4	0.4	0.1	O K
2160 min Winter	99.630	0.030	0.0	0.3	0.3	0.1	O K
2880 min Winter	99.626	0.026	0.0	0.2	0.2	0.1	O K
4320 min Winter	99.622	0.022	0.0	0.2	0.2	0.0	O K
5760 min Winter	99.619	0.019	0.0	0.1	0.1	0.0	O K
7200 min Winter	99.617	0.017	0.0	0.1	0.1	0.0	O K
8640 min Winter	99.616	0.016	0.0	0.1	0.1	0.0	O K
10080 min Winter	99.615	0.015	0.0	0.1	0.1	0.0	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
30 min Winter	97.184	0.0	4.9	43
60 min Winter	60.764	0.0	6.1	64
120 min Winter	36.692	0.0	7.4	104
180 min Winter	26.945	0.0	8.1	140
240 min Winter	21.513	0.0	8.7	176
360 min Winter	15.627	0.0	9.5	240
480 min Winter	12.453	0.0	10.0	292
600 min Winter	10.434	0.0	10.5	336
720 min Winter	9.026	0.0	10.9	378
960 min Winter	7.175	0.0	11.6	498
1440 min Winter	5.185	0.0	12.5	734
2160 min Winter	3.740	0.0	13.6	1108
2880 min Winter	2.963	0.0	14.3	1440
4320 min Winter	2.131	0.0	15.5	2144
5760 min Winter	1.686	0.0	16.3	2856
7200 min Winter	1.404	0.0	17.0	3744
8640 min Winter	1.209	0.0	17.6	4304
10080 min Winter	1.065	0.0	18.0	5040

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)	20.000	Shortest Storm (mins)	15
Ratio R	0.400	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+50

Time Area Diagram

Total Area (ha) 0.012

Time From:	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**
0	4	0.002	8	12	0.002	16	20	0.002
4	8	0.002	12	16	0.002	20	24	0.002

Model Details

Storage is Online Cover Level (m) 100.000

Swale Structure

Infiltration Coefficient Base (m/hr)	0.00000	Length (m)	5.0
Infiltration Coefficient Side (m/hr)	0.00000	Side Slope (1:X)	4.0
Safety Factor	2.0	Slope (1:X)	500.0
Porosity	1.00	Cap Volume Depth (m)	0.000
Invert Level (m)	99.600	Cap Infiltration Depth (m)	0.000
Base Width (m)	0.4		

Hydro-Brake® Optimum Outflow Control

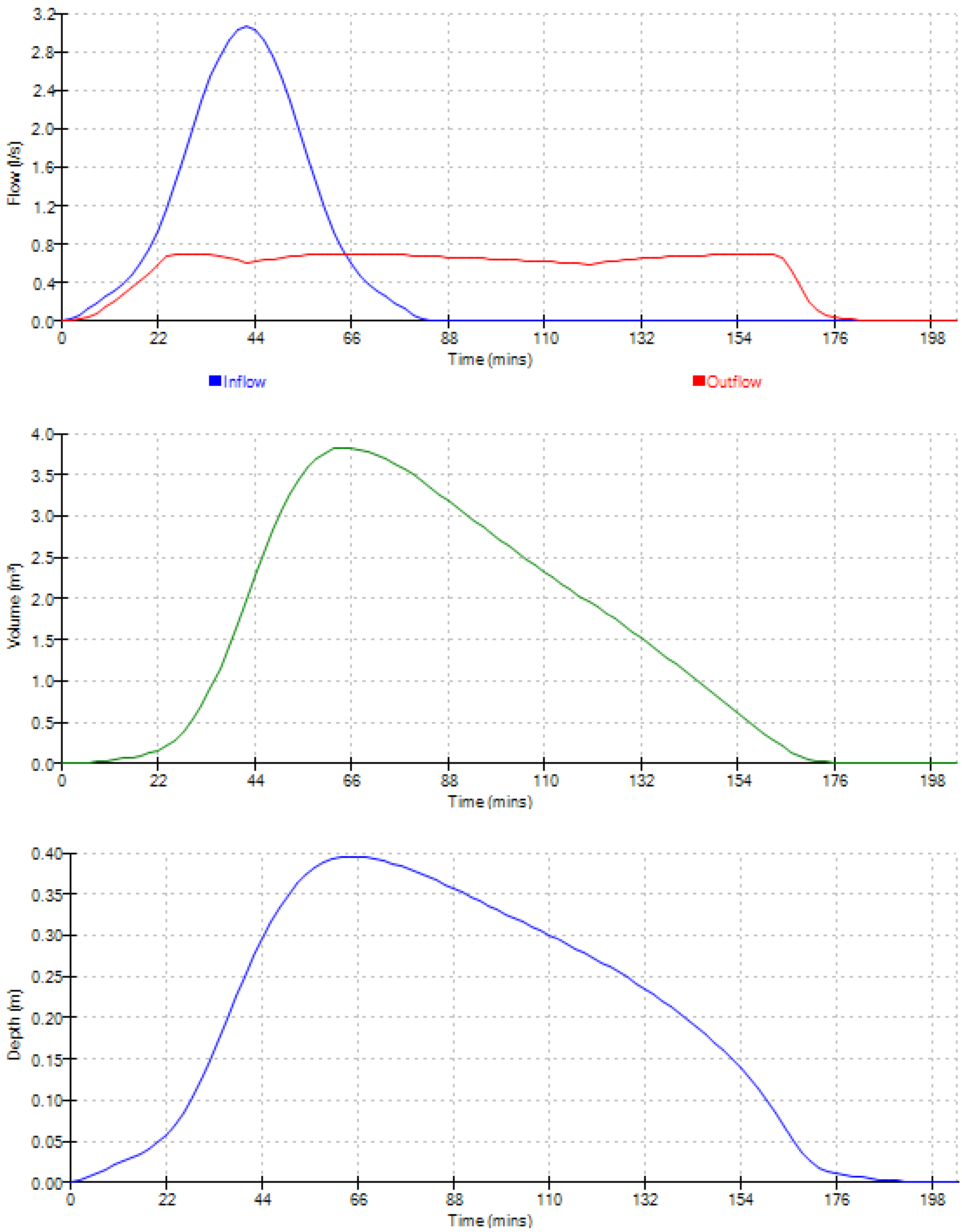
Unit Reference	MD-SHE-0046-7000-0400-7000
Design Head (m)	0.400
Design Flow (l/s)	0.7
Flush-Flo™	Calculated
Objective	Minimise upstream storage
Application	Surface
Sump Available	Yes
Diameter (mm)	46
Invert Level (m)	99.600
Minimum Outlet Pipe Diameter (mm)	75
Suggested Manhole Diameter (mm)	1200

Control Points	Head (m)	Flow (l/s)	Control Points	Head (m)	Flow (l/s)
Design Point (Calculated)	0.400	0.7	Kick-Flo®	0.270	0.6
Flush-Flo™	0.119	0.7	Mean Flow over Head Range	-	0.6

The hydrological calculations have been based on the Head/Discharge relationship for the Hydro-Brake® Optimum as specified. Should another type of control device other than a Hydro-Brake Optimum® be utilised then these storage routing calculations will be invalidated

Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)
0.100	0.7	1.200	1.1	3.000	1.7	7.000	2.6
0.200	0.7	1.400	1.2	3.500	1.8	7.500	2.7
0.300	0.6	1.600	1.3	4.000	2.0	8.000	2.8
0.400	0.7	1.800	1.4	4.500	2.1	8.500	2.9
0.500	0.8	2.000	1.4	5.000	2.2	9.000	2.9
0.600	0.8	2.200	1.5	5.500	2.3	9.500	3.0
0.800	0.9	2.400	1.6	6.000	2.4		
1.000	1.0	2.600	1.6	6.500	2.5		

Event: 60 min Winter



APPENDIX F BROCHURE FOR HYDRO BRAKE OPTIMUM

Design Data

Hydro-Brake® Optimum

Vortex Flow Control

Inspired by nature and engineered to deliver the perfect curve, the Hydro-Brake® Optimum is the most advanced vortex flow control available. There is no equivalent to the Hydro-Brake® Optimum when it comes to delivering the best possible hydraulic performance with a passive flow control.

With a wide range of configurations and options available, the Hydro-Brake® Optimum is able to provide precision flow control to suit the vast majority of applications.

Figure 1 - The Hydro-Brake® Optimum is designed and manufactured to deliver precise, repeatable flow control.

Precision Engineered Vortex Flow Controls

Each Hydro-Brake® Optimum is custom configured to suit the application and is manufactured under strict quality assurance procedures to deliver precise flow control to exacting requirements.

Every unit is backed by significant R&D investment to fine-tune the performance, meaning that the Hydro-Brake® Optimum is the only vortex flow control to have been independently certified by the BBA and WRc.

BBA APPROVAL INSPECTION TESTING CERTIFICATION

wrc approved PT/409/0417

Benefits

- Manufactured from high grade stainless steel.
- Future proof – adjustable or replaceable inlet plates available to alter flow rates post-installation.
- Configurations available to suit a wide variety of installations.
- Large cross sectional area at all heads.
- Simple installation.
- Self-activating.
- No moving parts or external power requirement.

Versatile and Flexible

At Hydro International, we pride ourselves on providing solutions that meet your requirements, rather than providing a standard solution and asking you to compromise on your project needs.

The Hydro-Brake® Optimum offers designers options to precision-engineer a vortex flow control to:

- Minimise upstream storage volumes.
- Maximise internal (inlet & outlet) cross sectional areas to prevent blockages.
- Build-in a climate change factor to allow for future changes in flow rate.

Furthermore, if you need to retrofit a flow control, our dedicated team of engineers can assist with providing a customised Hydro-Brake® Optimum suitable for installation into existing drainage infrastructure.

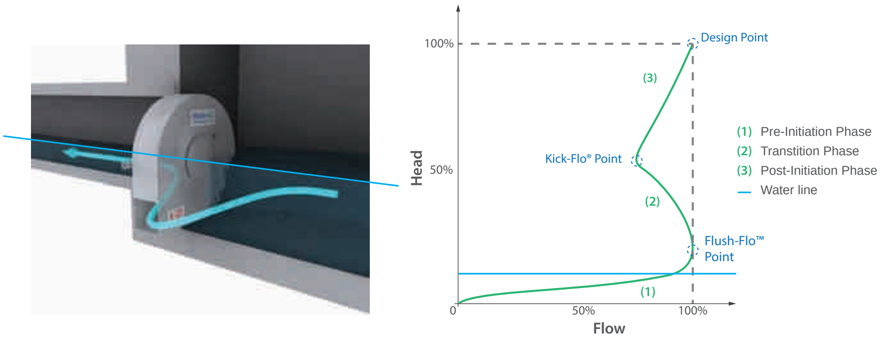
Design Data
Hydro-Brake® Optimum
Vortex Flow Control

Operating Principles

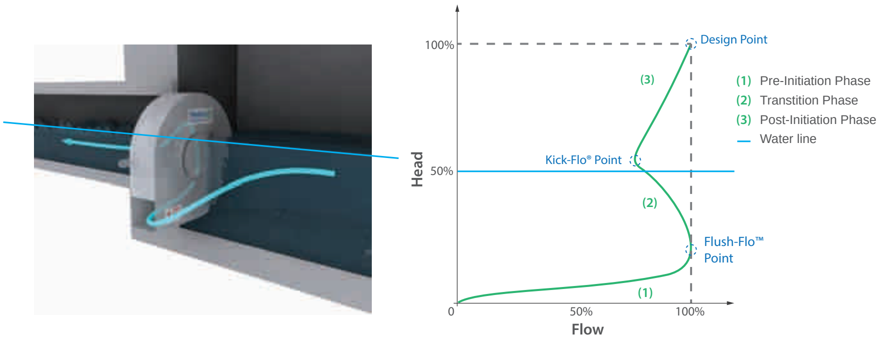
The hydraulic behaviour of the Hydro-Brake® Optimum is described by its hydraulic characteristic curve, which relates the discharge flow from the unit to the hydraulic head acting upon that unit.

The hydraulic characteristic curve consists of three distinct sections, each corresponding to a different governing flow control regime:

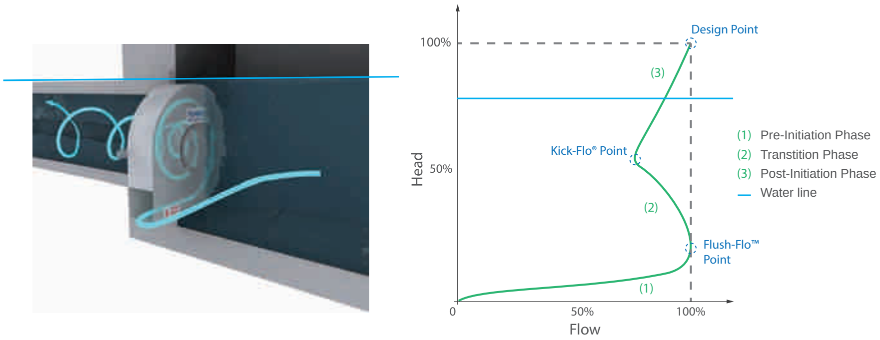
1. The pre-initiation phase – governed by orifice flow and defined on the characteristic curve as the region between the origin and the point at which the vortex begins to have a throttling effect (Flush-Flo™ point). In this region, the depth of water is below the soffit of the outlet orifice of the Hydro-Brake® Optimum.



2. The transition phase – governed by vortex formation and defined on the characteristic curve as the region between the Flush-Flo™ and the point at which the vortex has fully initiated (Kick-Flo® point). In this region the vortex will continually form and collapse. A trapped volume of air inside the Hydro-Brake® Optimum will exert a backpressure and cause the discharge rate to reduce even though the hydraulic head continues to increase.



3. The post-initiation phase – governed by stable vortex flow and defined on the characteristic curve as the region above the Kick-Flo® point. A stable vortex is formed and sustained. An air filled core at the centre of the vortex acts as a pseudo-physical flow restriction by reducing the cross sectional area available for the passage of water.



Design Flexibility

It is possible for the Design Point to be achieved using a number of different flow control configurations, each with a different hydraulic response or characteristic curve.

An in-depth understanding of the flow regimes and interactions at each stage of the hydraulic characteristic curve allows custom configuration of the Hydro-Brake® Optimum to achieve the hydraulic profile best suited to the site requirements.

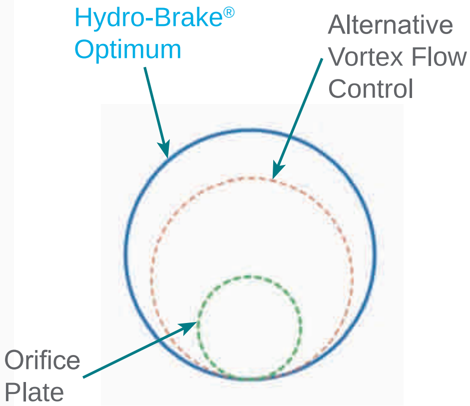
Hydro-Brake® Hotline: 01275 337937

stormwater@hydro-int.com

Resilience by Design

Hydro-Brake® Optimum has outlets (clearances) up to 20% larger than competitor products to minimise the risk of blockages. All units are fitted with a pivoting bypass door to enable full access to the internal chamber and the outlet structure in the event that a blockage does occur.

All Hydro-Brake® Optimum units can also be supplied with an adjustable or replaceable inlet to future-proof the device, allowing flows to be altered post-installation, to account for site expansion or climate change.



Expert Design Support Services

Hydro International's professional engineers work with you to provide expert technical and aftersales support to ensure your projects meet exacting design requirements and deliver the very best hydraulic controls for your site.

With over 35 years' experience of flow control knowledge and experience, Hydro International's design support team is available to advise on any aspect of water flow management, including detailed modelling of vortex flow controls and composite outlet structures.

Call the Hydro-Brake® Hotline on: 01275 337937 or email stormwater@hydro-int.com

Online Design Tool

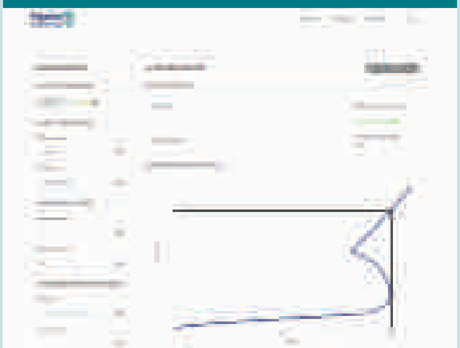
Engineers have the flexibility to try out any number of flow control iterations and explore their impact on hydraulic performance.

Our Online Design Tool allows you to quickly and easily compare a number of different flow control options for your site to develop the most robust and sustainable drainage solution possible.

The new tool now also has the added options to size and design the First Defense® and Downstream Defender® stormwater treatment separators, alongside the existing functionality to size and design Hydro-Brake® Optimum flow controls.

hydro-int.design

Visit: hydro-int.design



Full MicroDrainage® Compatibility

Engineers can carry out sizing and flow rate calculations and conduct hydraulic modelling of drainage networks containing Hydro-Brake® Optimum units using the industry-standard drainage design software, MicroDrainage®.

Easy to Install

Hydro-Brake® Optimum has a range of mounting options for ease of installation or can be supplied ready fitted into a manhole chamber (with or without a weir wall) for simple plug-and-play installation. There are no set-up or commissioning requirements.



The Hydro-Brake® Flow Control Series

As a brand leader for vortex flow controls for more than 30 years, Hydro International continues to set the standard in flow control management technologies. The Hydro-Brake® Flow Control Series is a comprehensive and versatile toolbox of precision-engineered devices for flow attenuation and control that can help deliver compliant schemes with scaleable, precision flow control performance.

Every device in the series is tested and manufactured to exacting standards and wherever possible, independently accredited to provide the reassurance of reliable, repeatable through-life operation.

Hydro-Brake® Orifice

The low-cost option for unconstrainted sites (shown with optional screen).

Hydro-Brake® Optimum

The vortex flow control with no equivalent, delivering Nature's Perfect Cuve with no moving parts and independently verified by the BBA and WRc.

Hydro-Brake® Agile

Precision engineered flow control for highly constrained applications.

Hydro-Brake® Flood Alleviation

The vortex controlled solution to watercourse flooding.

Patent: www.hydro-int.com/patents

Tel:+44 (0)1275 337 937 stormwater@hydro-int.com

Hydro International
Unit 2, Rivermead Court, Kenn Business Park, Windmill Road, Kenn, Clevedon, BS21 6FT

hydro-int.com

Nijhuis Industries UK & Ireland | info.uk@nijhuisindustries.com **|** www.nijhuissaurindustries.com/uk

Main Office: +44 (0)333 7000 007

Truro Office | Nanjerrick Court, Allet **|** Truro, Cornwall **|** TR4 9DJ | United Kingdom