Mallard Pass

Solar Farm

Mallard Pass Solar Farm

Environmental Statement Volume 2 Appendix 11.6: Water Resources and Ground Conditions - Surface Water Drainage Strategy

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1 INTRODUCTION

1.1 Background

This Outline Surface Water Drainage Strategy will be submitted as part of the Development Consent Order (DCO) application made by Mallard Pass Solar Farm Ltd (the Applicant) for the installation of a proposed Solar Farm (the Proposed Development) on land at Mallard Pass, Essendine, Lincolnshire.

The Proposed Development includes a range of infrastructure which varies in footprint and permeability. In order to effectively manage surface water runoff for the type of infrastructure this Outline Surface Water Drainage Strategy details the proposed surface water management measures if different aspects of the Proposed Development in accordance with the footprint and permeability of the infrastructure.

The measures within this Outline Surface Water Drainage Strategy will inform the detailed design of the surface water drainage measures which will be produced prior to the construction phase.

This Outline Surface Water Drainage Strategy has been produced in accordance with the following guidance:

- Department for Environment, Food and Rural Affairs (DEFRA), Sustainable Drainage Systems: Non-Statutory Technical Standards[1];
- Environment Agency (EA) Discharges to surface water and groundwater: environmental permits[2];
- Flood and Water Management Act 2010[3];
- National Planning Policy Framework (NPPF)[4];
- The SuDS Manual (C753)[5];
- Lincolnshire County Council (LCC), Lincolnshire Development Roads and Sustainable Drainage Design Approach[6];
- LCC, Guidance for Developers: CMP and SuDS Method Statement[7];
- LCC, Sustainable Drainage Design and Evaluation Guide[8];
- South Kesteven District Council (SKDC), Strategic Flood Risk Assessment[9]; and

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[1] Department for Environment, Food and Rural Affairs, Sustainable Drainage Systems: Non-Statutory Technical Standards (2015). [Online]. Available at: https://www.gov.uk/government/publications/sustainable-drainage-systems-non-statutory-technical-standards

[2] https://www.gov.uk/guidance/discharges-to-surface-water-and-groundwater-environmental-permits

[3] Flood and Water Management Act 2010 (2010). [Online]. https://www.legislation.gov.uk/ukpga/2010/29/introduction

[4] Ministry of Housing, Communities and Local Government (2021). [Online]. Available at: https://www.gov.uk/government/publications/national-planning-policy-framework--2

[5] CIRIA, The SuDS Manual (2015). [Online]. Available at: [redacted]

[6] Lincolnshire County Council, Lincolnshire Development Roads and Sustainable Design Approach (2021). [Online] Available at: https://www.lincolnshire.gov.uk/downloads/file/2061/lincolnshire-development-roads-and-sustainable-drainage-design-approach-november-2017

[7] Lincolnshire County Council, Guidance for developers CMP and SuDS Method Statement. [Online] Available at: https://www.lincolnshire.gov.uk/highways-planning/Guidance-for-developers/2

[8] Lincolnshire County Council, Sustainable Drainage Design and Evaluation Guide (2018). [Online] Available at: https://www.lincolnshire.gov.uk/downloads/file/1951/sustainable-drainage-design-and-evaluation-guide-pdfa

[9] South Kesteven District Council, Strategic Flood Risk Assessment (2017). [Online]. Available at: http://www.southkesteven.gov.uk/CHttpHandler.ashx?id=23092&p=0

- Peterborough City Council, Sustainable Drainage Design and Evaluation Guide[10] [11].

1.2 Order Limits

The Order limits described in ***Chapter 3: Description of Order limits***, of the ES **[EN010127/APP/6.1].**

The Order limits comprise the Solar PV Site, the Grid Connection Route, Mitigation and Enhancement Areas, Construction Compounds, and the Highways Works Site.

Section 2 of this document details the surface water drainage measures for the Onsite Substation.

The surface water drainage measures for the Solar PV Site, Grid Connection Route, Mitigation and enhancement areas and Site Access Works are detailed in Section 3 of this document.

1.3 Proposed Development

The Proposed Development is described in ***Chapter 5: Project Description of the ES.***

1.4 Surrounding Hydrological Network

The Order Limits is within the River Glen Basin District and operational catchment[12] and Welland Management Catchment[13].

The West Glen River bisects through the north and east of the Order Limits and flows north-west to south-east. The West Glen River is an EA designated Main River draining a catchment area of approximately 160 km².

The River Gwash is located approximately 50 metres (m) south of the Order Limits at its nearest point and flows west to east and ultimately discharges into the River Welland approximately 1 kilometre (km) south of the Order Limits.

Ordnance Survey (OS) mapping indicates open agricultural land drains located in the north of the Order Limits ultimately discharge into the West Glen River and land drains located in the south of the Order Limits ultimately discharge into the Greatford Cut (Drain) located approximately 3.5 km east of the Order limits.

The Order Limits is not shown to be located within the operational boundary of an Internal Drainage Board (IDB)[14].

During consultations between Arcus and LCC[15], as outlined on Table 1 of ***Appendix 11.3*** of the ES Appendices **[EN010127/APP/6.2]**, it was highlighted that LCC hold a memorandum of understanding with IDBs that operate within Lincolnshire, with IDBs acting as agent to the LLFA. The Order

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[10] Rutland County Council are working alongside Peterborough City Council on all SuDS schemes.

[11] Peterborough City Council, Sustainable Drainage Design and Evaluation Guide (2018). [Online] Available at: [redacted]

[12] Environment Agency, Catchment Data Explorer. [Online]. Available at: https://environment.data.gov.uk/catchment-planning/

[13] DEFRA, Trent Lower and Erewash Combined Management Plan (2019). [Online]. Available at: [redacted]

[14] Association of Drainage Authorities, Internal Drainage Boards Map. [Online]. Available at: [redacted]

[15] Email communications between R. Duff (Arcus) and I. Field (LCC) dated 18th January 2022 to 24th January 2022.

Limits is shown to fall within the extended operational boundaries of the Black Sluice and Upper Whitham IDBs.

1.5 Geology and Soils

Infiltration Testing has been carried out in the location of the Onsite Substation by Rogers Geotechnical Services (RGS) in March 2022, with the test pits logs indicating underlying geology comprises gravel and clay based strata at varying depths to a maximum depth of 2.6 m Below Ground Level (m BGL).

The Cranfield Soil and Agrifood Institute Soilscapes map indicates the soil across the Order Limits varies relative to proximity to watercourses. Soils are shown to comprise freely draining 'shallow lime-rich soils over chalk or limestone', naturally wet 'loamy and clayey floodplain soils with naturally high groundwater' and 'slowly permeable seasonally wet slightly acid but base-rich loamy and clayey soils' with impeded drainage.

The British Geological Survey (BGS) Geology of Britain Viewer[16] shows that the superficial geology varies across the Order Limits with the superficial deposits detailed in Table 1 and ***Figure 11.3*** of the ES.

Table 1: Superficial Geology within the Order Limits

Superficial Desposit	**Location**	**Strata**
Glacial sand and gravel	South of the Order Limits	Sand and gravel with rare clay interbeds; often cross-bedded; of glacial origin.
River terrace deposits	South, north and east of the Order Limits	Sand and gravel, locally with lenses of silt, clay or peat.
Till	West of the Order Limits	Unsorted and unstratified drift, generally overconsolidated, deposited directly by and underneath a glacier without subsequent reworking by water from the glacier. It consists of a heterogenous mixture of clay, sand, gravel, and boulders varying widely in size and shape
Alluvium	East of the Order Limits	General term for clay, silt, sand and gravel. It is the unconsolidated detrital material deposited by a river, stream or other body of running water as a sorted or semi-sorted sediment in the bed of the stream or on its floodplain or delta, or as a cone or fan at the base of a mountain slope

2 ONSITE SUBSTATION OUTLINE DRAINAGE STRATEGY

The Onsite Substation is located on a parcel of land south of the West Glen River approximately 500 m south of Essendine village to in the centre of the Order Limits as shown in Annex B.

The measures outlined in the following Sections will be implemented by the Applicant's Contractor to ensure that greenfield runoff rates are maintained

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[16] British Geological Survey, Geology of Britain Viewer. [Online]. Available at: https://mapapps.bgs.ac.uk/geologyofbritain/home.html?

during the construction and operational phases. The Applicant's Contractor will adhere to the following guidance, as outlined in the oCEMP:

- DEFRA: Sustainable Drainage Systems - Non-statutory technical standards for sustainable drainage systems;
- The Construction Industry Research and Information Association (CIRIA), Environmental Good Practice on Site (C741)[17];
- CIRIA, The SuDS Manual; and
- CIRIA, Control of Water Pollution from Linear Construction Sites (C649)[18].

2.1 Surface Water Discharge Method

In accordance with the drainage hierarchy within the SuDS Manual infiltration as a means of surface water management has been assessed as a preferential solution.

To assess the infiltration potential of the underlying strata at the Onsite Substation infiltration testing to Building Research Establishment (BRE) Digest 365 standard was carried out at the location of the Onsite Substation at six test pits (TP) in March 2022 by RGS with the infiltration testing report provided in Annex C.

To enable any potential soakaway to utilise the existing topography the surface water flow routing at the Onsite Substation Compound was derived from a 2D pluvial hydraulic model developed within Flood Modeller software. The 2D model utilises LiDAR data to 1 m resolution to confirm the low lying areas of the Onsite Substation.

To confirm the infiltration potential across the Onsite Substation Compound six test pits were excavated in relation to the varying geological settings and topography. The locations of the test pits (TPs) are shown in Plate 1.

The implementation of PV Arrays will not result in substantial increases in hardstanding footprint and the infiltration capacity across the Solar PV Site will behave as per the baseline scenario. As such infiltration testing has been conducted in the Onsite Substation to account for areas of proposed hardstanding.

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[17] CIRIA, Environmental Good Practice on Site C741 (2015). [Online]. Available at: [redacted]

[18] CIRIA, Control of Water Pollution from Linear Construction Sites C649 (2006). [Online]. Available at: [redacted]

Plate 1: Surface Water Flow Routes and Test Pits (redline – substation outline, green line – flow route model boundary)

Test Pit	Easting	Northing
01	504810	311555
02	504922	311468
03	504883	311630
04	504974	311566
05	505004	311650
06	504957	311705

Due to the poor soakage rate in TP1, TP3 and TP4 the infiltration tests could not be completed within the scope of BRE 365 and due to the negligible water movement within the test pit it was not possible to extrapolate results.

Infiltration was observed within TP2, TP5 and TP6 with the results of the testing are summarised in Table 2.

Table 2: Infiltration Testing Summary (taken from RGS Soakaway Letter Report C2457/22/E/3768)

Test Pit	Infiltration Rate (m/sec)	Drainage Characteristics
1	N/A*	Practically Impermeable
2	3.3×10^{-5} 2.0×10^{-5} $1.5 \times 10^{-5**}$	Good
3	*	Practically Impermeable
4	*	Practically Impermeable
5	**4.8×10^{-6}	Marginal
6***	6.0×10^{-6}	Good

** Negligible water level movement observed during test.*

*** Extrapolated result.*

**** Unable to fill pit to more than 1.29 m depth due to rate of outflow.*

Only TP2 and TP6 provide infiltration rates suitable for infiltration drainage in accordance with the parameters outlined in the SuDS Manual. The rate obtained for TP2 is based on the extrapolated rate obtained from previous results and the rate is therefore an approximation.

Acknowledging the varied infiltration potential across the Onsite Substation it is assessed that infiltration as a means of surface water drainage will not be feasible as localised geology significantly influences infiltration rates.

In accordance with the drainage heirarchy within the SuDS Manual surface water will be discharged at a controlled rate to the West Glen River.

2.2 Surface Water Runoff Rates

Greenfield runoff rates for the 2 ha of hardstanding within theOnsite Substation have been calculated using the Interim Code of Practice for SuDS (ICP SuDS) method[19] via Micro Drainage Software with rates shown in Table 3 and Annex D.

Table 3: Onsite Substation Greenfield Runoff Flow Rates (taken from Micro Drainage)

Return Period (years)	Q (l/s)
Q_{BAR}	0.1
1	0.1
30	0.3
100	0.5

The LCC Lincolnshire Development Roads and Sustainable Drainage Design Approach indicates discharge rates should be limited to the greenfield rates for the 1 in 1-year and 1 in 100-year events.

The design of a flow control to the rate of 0.1 l/s would not be feasible and would lead to blockage and maintenance issues due to the small size of any flow restriction device.

Section 9.6.6 of the LCC Sustainable Drainage Design and Evaluation Guide indicates that surface water flows can be controlled to a minimum of 0.5 l/s if shallow storage depths are utilised.

As such, the surface water drainage system will be designed to restrict surface water flows to the 1 in 100-year rate of 0.5 l/s.

2.3 Climate Change Allowances

The proposed drainage network will make allowances for climate change relative to the EA Climate Change Allowances for peak Rainfall in England[20] guidance which has been recreated in Table 4.

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[19] National SuDS Working Group, Interim Code of Practice for Sustainable Drainage Systems (2004). [Online]. Available at: [redacted] [Accessed 02/08/2021].

[20] Environment Agency, Climate Change Allowances for peak Rainfall in England. [Online]. Available at: https://environment.data.gov.uk/hydrology/climate-change-allowances/rainfall

Table 4: 1 % Annual Exceedance Rainfall Event for Welland Management Catchment.

Period	Central Allowance	Upper End Allowance
2050's	20 %	40 %
2070's	25 %	40 %

The Proposed Development will not be time-limited in terms of its operational lifetime, however for this assessment we have assumed a lifespan of approximately 40 years and a design life within the '2070s' period (i.e., between 2061 and 2100), as per other developments of a similar nature[21]. EA guidance states that where infrastructure has a lifetime between 2061 and 2100 the Central Allowance for 2070's should be applied and therefore the 25 % 2070's Central Allowance will be applied in accordance with the EA Flood Risk and Coastal Change Guidance for peak rainfall.

2.4 Proposed Receiving Watercourse

The modelled surface water flow routes shown in Plate 1 indicate that surface water falls to the south towards the West Glen River.

Arcus conducted a walkover across the location of theOnsite Substation in March 2022 and topography was shown to fall towards the watercourse where there are existing surface water discharge outlets as shown in Plate 2 and 3.

Plate 2: Fall Towards West Glen River (Taken from South looking South to North)

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[21] Cleve Hill Solar Park.

Plate 3: Outfalls into West Glen River

Surface water flows will, therefore, be directed to existing outfalls along existing topography towards the West Glen River in order to mimic the natural surface water drainage characteristics of the location of the Onsite Substation.

As the West Glen is a Environment Agency Main River an Environmental Permit will be sought at least three months prior to the construction phase.

2.5 Surface Water Attenuation

The surface water attenuation volume will be provided within the unbound free-draining subbase beneath the aggregate chippings, the areas beneath the infrastructure and access roads have been discounted as providing attenuation volume, providing a total area available of for attenuation of 1.36 ha.

Stone surfacing will be laid either in accordance with or similar to National Grid Design Standards and will comprise a minimum 300 mm deep unbound free-draining aggregate subbase and a minimum 75 mm top layer of stone chippings, which will allow storage of storm water with an example of subbase is shown in Plate 4.

Surface water will be channelled through the subbase network through a perforated piped system which will then connect to an outfall to the West Glen River. The piped system will include inspection chambers to facilitate maintenance programmes.

Plate 4: Subbase Example[22]

The free draining subbase has been designed in Micro Drainage software utilising cellular storage with design details in accordance with the SuDS Manual guidelines for cellular storage.

The porosity of a capping layer is defined by the type of fill material applied, with typical porosity values extracted from Micro Drainage shown in Plate 5. The aggregate is assessed to have a porosity value of 0.2 (*i.e.*, the lowest range within the graded gravel category).

Plate 5: Typical Porosity Values (Taken from Micro Drainage software)

Material	Porosity
Clean Stone	0.4 - 0.5
Uniform Gravel	0.3 - 0.4
Graded Sand or Gravel	0.2 - 0.3

In order to restrict surface water flows to 0.5 l/s an HydroBrake (or other flow restricting device) will be placed on the outfall of the pipes from the subbase. Consultation with the manufacturer of the HydroBrake flow control[23] has confirmed that flows can be limited to 0.2 l/s with design heads being a minimum of 25 mm providing that a protection case is located around the flow control device to minimise the potential for blockage.

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[22] York Flood Defence Scheme Compound – L. Nevins - 2021

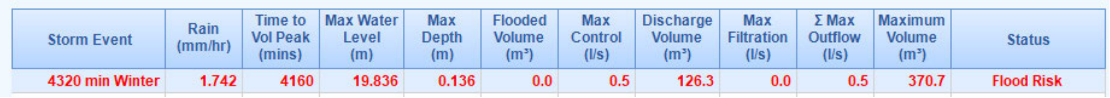
[23] Telephone communications between R. Duff (Arcus) and Hydro International, 15th September 2020.

The extent of the unbound free draining subbase excluding areas beneath impermeable infrastructure and access roads totals 1.36 ha with the following design parameters applied in Micro Drainage:

- Cover level: 20 m AOD;
- Depth: 0.300 m; and
- Area: 1.36 ha.

The structure is shown to provide suitable attenuation capacity during the 1 in 100-year (+25 %) critical event with maximum rates calculated at 0.5 l/s, as shown in Plate 6, with further drainage calculation outputs shown in Annex D. Due to the limited impermeable extents the surface water runoff and outfall rates generated are extremely low and flow rates leaving the system will be negligible demonstrating the porous nature of the Proposed Development.

Plate 6: 1:100 year (+25 %) critical event (Taken from Micro Drainage)



Storm Event	Rain (mm/hr)	Time to Vol Peak (mins)	Max Water Level (m)	Max Depth (m)	Flooded Volume (m³)	Max Control (l/s)	Discharge Volume (m³)	Max Filtration (l/s)	Σ Max Outflow (l/s)	Maximum Volume (m³)	Status
4320 min Winter	1.742	4160	19.836	0.136	0.0	0.5	126.3	0.0	0.5	370.7	Flood Risk

2.6 Exceedance Events

During an exceedance event which exceeds the 1 in 100-year (+25 %) event surface water flow routes will disperse as per the baseline scenario within the location of the Onsite Substation.

The Onsite Substation is located within an agricultural catchment with no residential or manned property on-site. Therefore, any exceedance will disperse within the extent of the Proposed Development, with no risk to people or the built environment.

2.7 Water Quality

The Proposed Development will not be an occupied facility and will be subject to maintenance visits and so will not be heavily trafficked. As such there will be limited potential for discharge of contaminants emanating from the Proposed Development, as outlined in Section 11.4 of ***Chapter 11: Water Resources and Ground Conditions*** of the ES.

2.8 Construction Phase

The nature of hydrological incidents that could result from construction activities will be mitigated through the implementation of construction phase drainage and the application of industry good practice as per CIRIA Guidance (C741)[24].

To limit the potential for sediment in associated runoff during the construction of the Proposed Development, construction good practice measures will be employed.

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[24] The Construction Industry Research and Information Association (CIRIA), (2015), Environmental Good Practice on Site Guide (C741), CIRIA: London.

The exact locations and implementation of drainage measures will be confirmed prior to the construction phase within a Detailed Drainage Strategy and will be confirmed through the appropriate consenting authority.

2.9 Operation and Management of Drainage Infrastructure

It will be the responsibility of the Applicant to maintain effective drainage measures and rectify drainage measures that are not functioning adequately. A nominated person will also have responsibility for reporting on the functionality of drainage measures.

Where impermeable areas remain through the operational phase, the drainage measures serving these areas will be checked on a regular basis. Should drainage measures require dredging or unblocking, this will be undertaken as soon as practicable by the Proposed Development operator or nominated personnel.

An outline management / maintenance plan is provided in Table 5. The subbase would have similar maintenance characteristics to pervious pavements due to the material filling used. Therefore, the maintenance schedule for pervious pavements sourced from the SuDS Manual has been used to represent the maintenance of the platform.

Table 5: Outline Long-term Maintenance schedule for the Aggregate Attenuation[25]

Maintenance schedule	**Required action**	**Typical frequency**
Regular Maintenance	Raking	Once a year, after autumn leaf fall, or reduced frequency as required, based on site-specific observations of clogging or manufacturers recommendations - pay particular attention to areas where water runs onto pervious surface from adjacent impermeable areas as this area is most likely to collect the most sediment
Occasional Maintenance	Stabilise and mow contributing and adjacent areas	As required
	Removal of weeds or management using glyphospate applied directly into the weeds by an applicator rather than spraying	As required – once per year on less frequently used pavements
Remedial actions	Remediate any landscaping which, through vegetation	As required

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[25] Based on Table 20.15 - Operation and maintenance requirements for pervious pavements of the SuDS Manual.

	maintenance or soil slip, has been raised to within 50 mm of the level of the stone	
	Remedial work to any depressions or rutting considered detrimental to the structural performance or a hazard to users, and replace lost jointing material	As required
	Rehabilitation of surface and upper substructure by remedial sweeping / raking	Every 10 to 15 years or as required (if infiltration performance is reduced due to significant clogging)

2.10 Timescales

Drainage measures outlined within this Outline Surface Water Drainage Strategy should be implemented as soon as practicable by the appointed Construction Contractor but in any event before the construction of any impermeable surfaces at the Substation which are proposed to drain into the approved drainage system.

Measures such as drainage pipes should be installed at the same time as the excavations, or as soon as practicable thereafter.

3 PV ARRAYS AND PV STATIONS OUTLINE DRAINAGE STRATEGY

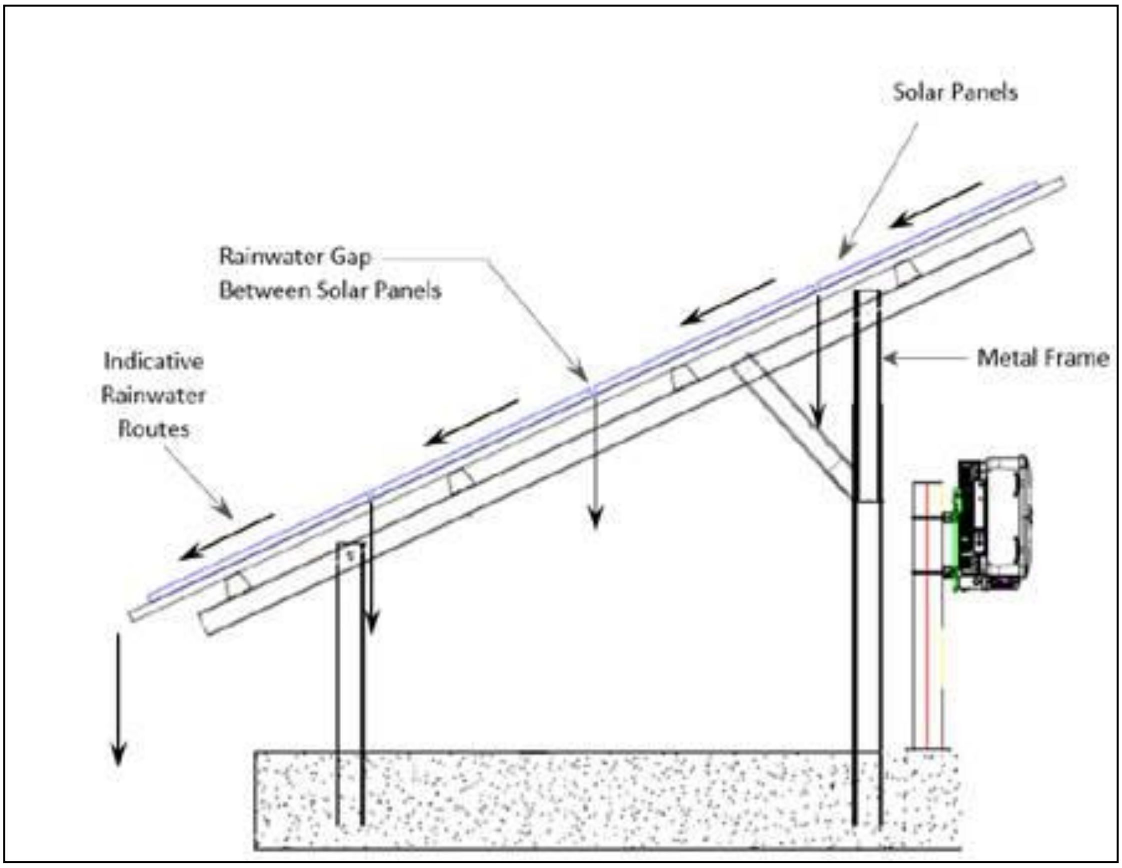
3.1 PV Arrays

The PV Array will comprise rows of solar panel modules mounted on metal frames and pile driven into the ground to limit the footprint of PV array units.

The panels would be mounted at approximately 0.8 m from the ground at the lowest point rising to up to no more than 3.3 m at the highest point.

Installation of the PV arrays does not involve the introduction of hardstanding at ground level meaning the superficial cover for the majority of the Order Limits will remain the same as the baseline. Additionally, the PV array tables will have regular rainwater gaps to prevent water being concentrated along a single drip line. As such, rainfall landing on the solar panels will drain through rainwater gaps and infiltrate into the ground beneath and between each row of panels, as shown in Plate 7.

Plate 7: Typical PV Array



The PV arrays have the potential to concentrate rainfall under the drip line leading to channelization and compaction of soils which can establish preferential flow routes for surface water in extreme events.

Research in the United States by Cook & McCuen[26] outlines that solar panels do not have a significant effect on runoff volumes or peak flows however where ground beneath panels is bare there may be an increase in peak discharge.

Other research studies quantified this increase ranging from 1.5 % to 8.6 %, depending on site specific parameters.

A succinct quantitative assessment has been undertaken to identify runoff in litres per second (l/s) from the PV Arrays compared to the baseline scenario based on the equation below:

Rainfall Depth (1 in 100 year 360 minute storm) x area of PV arrays x Soil Index / time (seconds).

The rainfall depths have been calculatedusing the Flood Estimation Handbook (FEH)[27] method for the location of the Order Limits with outputs shown in Plate 8 plus a 25 % increase to account for climate change.

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[26] "Hydrologic Response of Solar Farms." J. Hydrol. Eng., 18(5), 536–541. 2013

[27] UK Centre for Ecology and Hydrology (CEH), Flood Estimation Handbook. [Online]. Available at: [redacted]

Plate 8: FEH Rainfall Depth Output

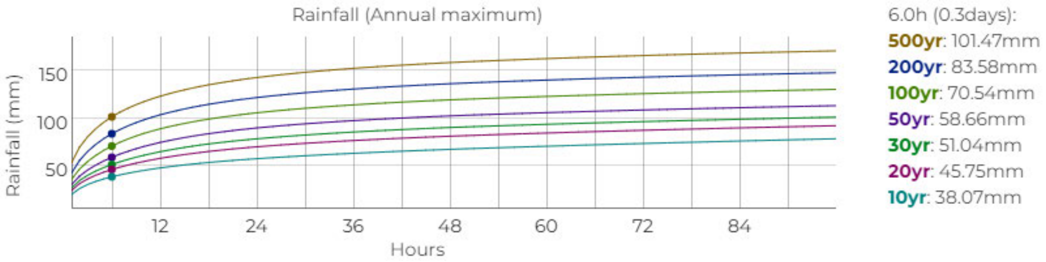

Table 7: Runoff Calculations for PV Arrays

Baseline Scenario						
Rainfall Depth (m)	**Order Limits Area (m²)**	**Soil Index[28]**	**Volume (m³)**	**Volume (l)**	**Time (seconds)**	**l/s**
0.088	9,060,000	0.15	119,592	119,592,000	21,600	5,536
With Development Scenario						
Rainfall Depth (m)	**Area without PV arrays (m²)**	**Soil Index**	**Volume (m³)**	**Volume (l)**	**Time (seconds)**	**l/s**
0.088	4,430,000	0.15	58,476	58,476,000	21,600	2,707
Rainfall Depth (m)	**Area with PV arrays (m²)**	**Soil Index**	**Volume (m³)**	**Volume (l)**	**Time (seconds)**	**l/s**
0.088	4,630,000	0.9[29]	366,696	366,696	21,600	16,976

As a result of the installation of PV panels, this calculation suggests that surface water runoff rates may increase by 14,147 l/s across the PV panel footprint compared to the baseline, which would equate to an approximate 256 % percent increase in runoff rates.

The raised nature of PV Arrays will not prevent soil from absorbing rainwater as the panels will not be placed directly on the ground and each PV Row will be separated, with the same area of soil available for infiltration as per the baseline scenario. Therefore the calculated increase does not represent the impact of the PV Arrays on surface water runoff.

Once rainfall has fallen off a PV Array, the water will be able to spread and flow along the ground under the PV Arrays evenly into the rain-shadow of the row below, so as to mobilise the same percentage of the ground for infiltration as was available prior to the installation of PV Arrays.

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[28] Based on the Institute of Hydrology, Flood Studies Report Method (1995).

[29] Taken as 0.9 to represent impermeable nature of PV arrays

Water will drip off each PV Module with small gaps between modules. This means that the surface area to drip line length ratio will be the same as for "traditional" solar array layouts which use the same modules.

Whilst the Natural England Technical Information Note 101 (TIN101) "*Solar Parks: maximising environmental benefits*"[30] has been archived, the principles relating to solar parks, their siting, their potential impacts and mitigation requirements for the safeguarding of the natural environment are still relevant.

TIN101 states:

"The key to avoiding increased run-off and soil into watercourses is to maintain soil permeability and vegetative cover. Permeable land surfaces underneath and between panels should be able to absorb rainfall as long as they are not compacted and there is some vegetation to bind the soil surface".

Apart from the construction of the substation compound (addressed in Section 2), heavy machinery will only be used during delivery. All vehicles would follow the onsite access tracks wherever possible. Where vehicles are required to travel off the access tracks this may lead to a temporary compaction of soils. The localised topography within each parcel of the Proposed Development generally comprises gentle gradients and hence increased runoff would be unlikely to lead to fast moving surface water and consequent erosion except on the small areas of steeper slopes immediately adjacent to parts of the West Glen River.

TIN101 highlights the effect of slope on runoff rates and soil erosion by concluding that:

"the risks of run-off and soil erosion are lowest on low gradient land with cohesive soils and highest on dry, sandy and steeply sloping soil surfaces."

The energy of the flow which drains from PV Arrays will be greater than that of the rainfall. Therefore, this could result in erosion under the driplines and possibly lead to ground instability. In addition, intensification of the runoff from panels, along the 'drip line', into small channels / rivulets, could be exacerbated where PV Arrays are not positioned in alignment with topography.

In order to avoid increased erosion rates, the grass beneath the panels would be well maintained throughout the lifetime of the Proposed Development.

During the operational phase the likelihood of soil erosion occurring as a result of the Development is therefore assessed to be minimal During the construction phase, unnecessary soil disturbance on saturated soils would be avoided in order to minimise soil compaction.

As such the area under the drip line should be seeded with a suitable grass mix, as shown in Plate 9, to prevent rilling (incisions in soil caused by concentrated water flow) and an increase in surface water runoff rates.

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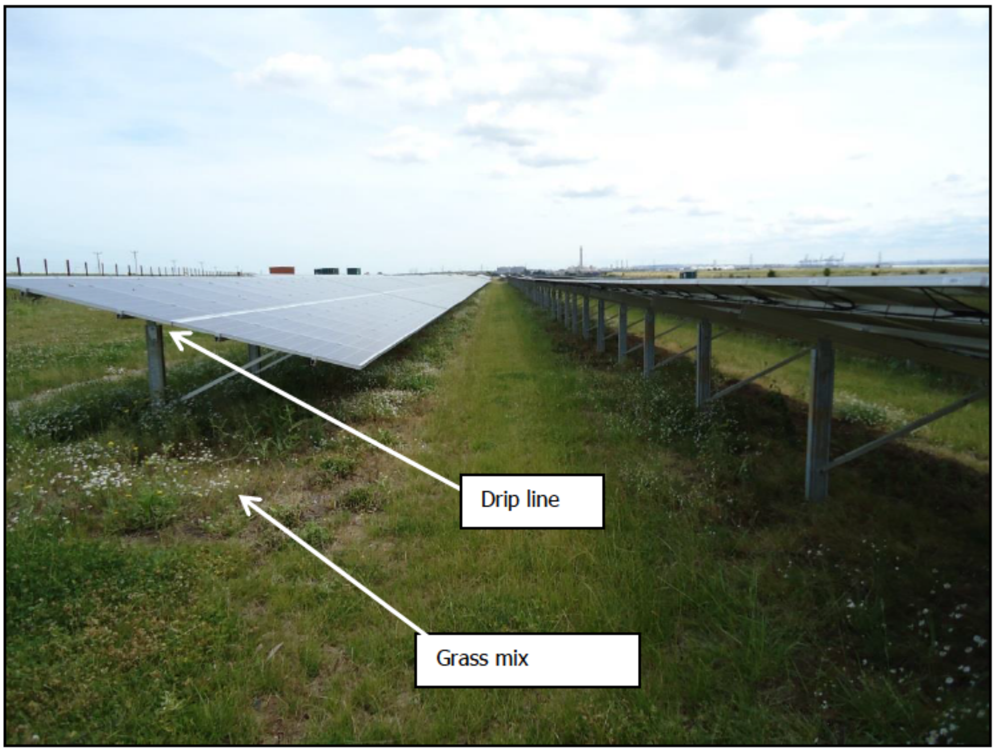
[30] Natural England Technical Information Note 101 "*Solar Parks: maximising environmental benefits*" [online] Available at: [redacted] [Accessed 11/04/2018].

Plate 9: Establishing Grass Mix Under PV Drip Line[31][32]



The localised flat topography within the parcels of the Proposed Development is generally flat meaning rainfall will not drain quickly down slope and will preferentially infiltrate where it lands under the drip line. Should the rate of infiltration within the soils be exceeded then the velocity of any standing water

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[31] Photograph taken 6 months after construction of Malmaynes Solar Farm, Medway, UK. 2016 (L. Nevins)

[32] Delfzijl Solar Park, Netherlands (Arcus site visit 2016. M. Bird)

that does begin to form will be slow, giving a greater likelihood that it will be absorbed by the drier land under the panels.

The baseline superficial geology cover is predominately clay soils overlain by a mix of superficial soils which are tilled or left as stubble for large parts of the year which is likely to limit infiltration and promote surface water runoff leading to concentrations of surface water entering the surrounding hydroglogical network. The proposed grass and vegetation cover during the operational period of the Proposed Development is likely to generate lesser surface water runoff rates.

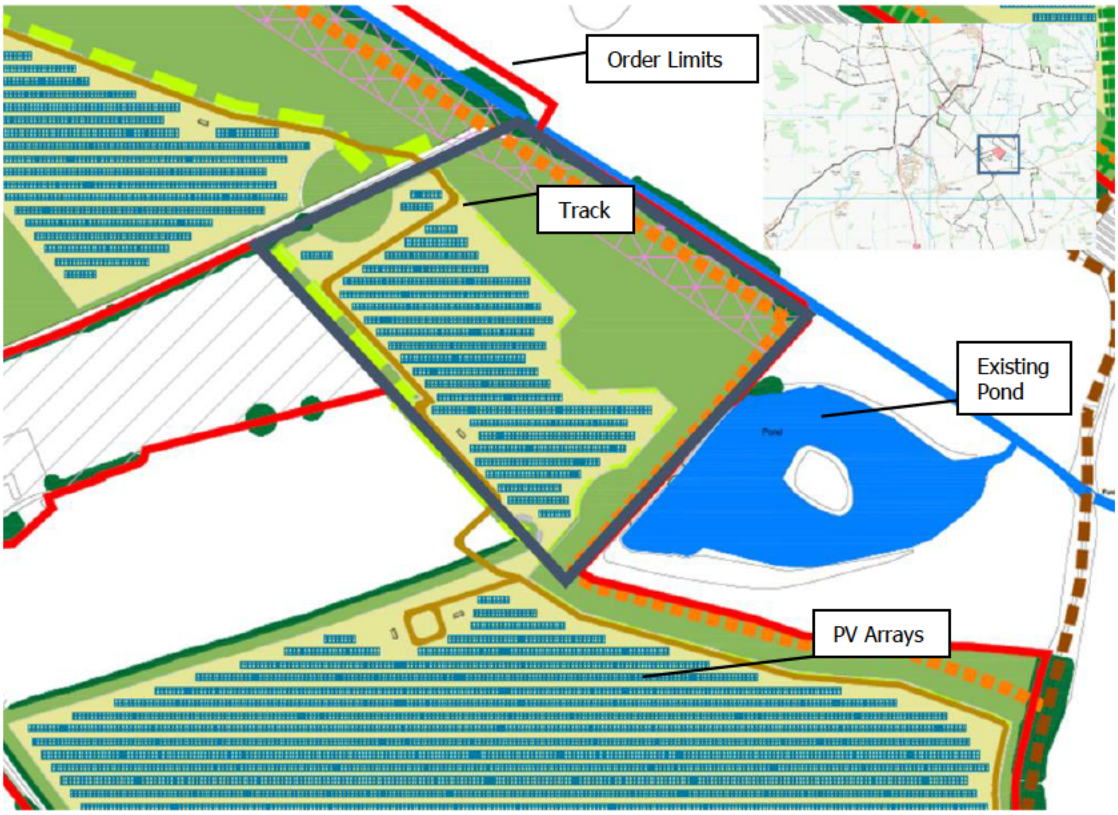
As part of the mitigation measures to be implemented as part of the Proposed Development perimeter areas will comprise planting and vegetation with a minimum 6 m buffer from all watercourses. This offset will create an area of dense planting which will intercept and slow down surface water along flow routes prior to entering watercourses due to the friction of the planting.

To demonstrate the potential impact of surface water runoff through the planted buffer zones a 2D model has been developed within Flood Modeller software to assess surface water flow characteristics.

An area to the east of the Order Limits at NGR E 505649, N 311173 which comprises existing agricultural land leading to open surface water drains (Model Study Area) has been selected to as the study area within the model with the area shown in Plate 10. The Model Study Area is located on the southern bank of the West Glen River with an open land drain located on the western boundary.

The area selected represents the existing agricultural land use across the Order Limits and an area which will include PV Arrays, therefore providing a demonstration of how PV Arrays will influence surface water flows across the Proposed Development.

Plate 10: Surface Water Model Study Area (Shown in Grey Polygon)



The assessment of the Model Study Area demonstrates the impact of the Proposed Development on surface water flow characteristics. The Model Study Area is assessed to represent large areas of the Solar PV Site (i.e., agricultural land with PV Arrays and planting) and therefore provides a scaled down representation of how the Proposed Development will interact with surface water runoff.

The Model Study Area will comprise PV Arrays and perimeter planting as part of the Proposed Development and has been selected following public consultations identifying existing downstream surface water flooding issues in surrounding villages i.e., villages to the east of the Proposed Development. Whilst surface water flooding within the villages does not directly emanate from the Solar PV Site this assessment outlines how the Proposed Development will not lead to increases in surface water runoff into the existing hydrological network.

To assess the potential impact of the Proposed Development on surface water flow characteristics the existing surface elevations have been represented using 1 m resolution LiDAR data which indicates elevations within the Model Study Area fall south to north towards the West Glen River.

Onsite investigations indicate that the existing land use of the Model Study Area is agricultural land with no arable and leading to a vegetated slope towards the West Glen as shown in Plate 11.

Plate 11: Land Use of Model Study Area

Acknowledging the agricultural land use the existing terrain is represented through a Manning's Roughness Values (N value) of 0.03 (short grass pasture) with the watercourse embankment represented through an N value of 0.035 (high grass pasture) based on Chow 1959[33].

The existing surface water flow routes are shown to direct towards the West Glen as per the topographic fall of the Model Study Area as shown in Plate 12 with the thicker vegetation associated with the banks shown to lead to interception of surface water along the flow routes.

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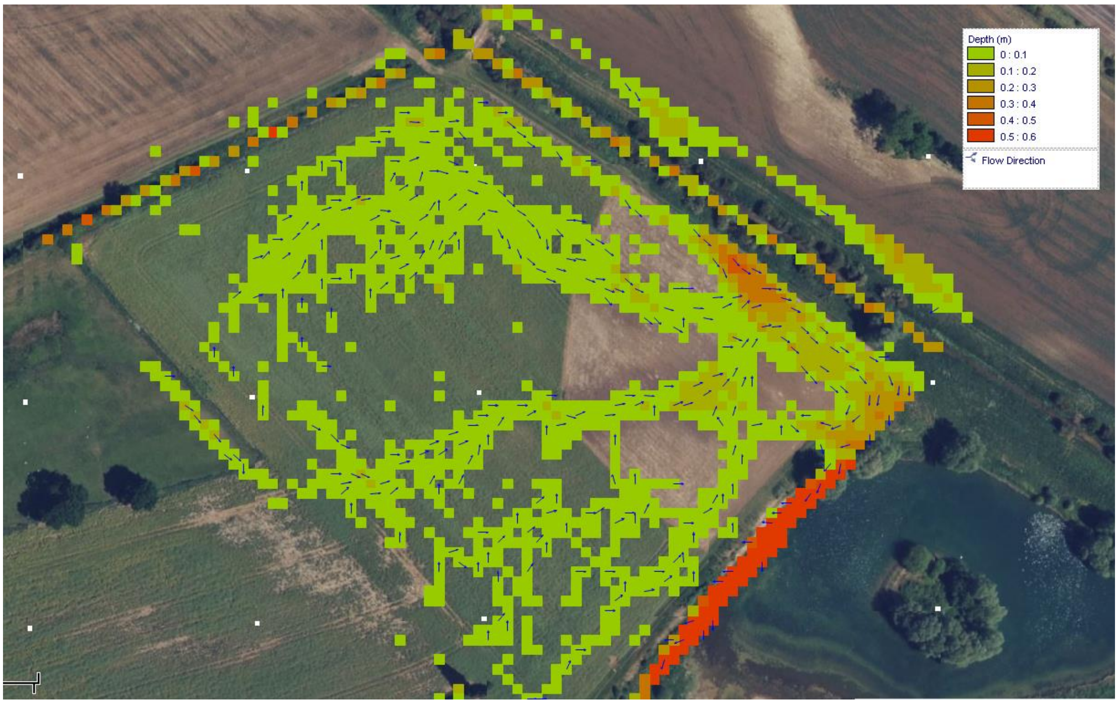
[33] Chow, Manning's N Values for Channels, closed Conduits Flow Partially Full and Corrugated Metal Pipes (1959). [Online]. Available at: [redacted]

Plate 12: Model Study Area Baseline Surface Water Flow Characteristics



The Mitigation and Enhancement Areas within the Model Study Area have been represented through a N value of 0.05 (scattered brush, heavy weeds) which accounts for the denser vegetation and planting proposed.

Incorporating the increases friction from planting within the Mitigation and Enhancement Areas is shown to increase the levels of surface water within the Model Study Area and increase the concentration of flows within the vegetation along existing flow routes as shown in Plate 13.

Therefore, the introduction of planting within the Mitigation and Enhancement Areas will increase the interception potential of surface water within the Solar PV Site relative to the existing land use.

Plate 13: Model Study Area with Planting Surface Water Flow Characteristics

3.2 Solar Stations

Solar Stations will be located across the extent of the Solar PV Site to facilitate the connection of PV Arrays to the energy distribrution infrastructure.

Solar Stations will be underlain and bounded by a graded aggregate as shown in Plate 10.

In areas where graded aggregate will be installed there will be an improvement in the overall ability to slow the conveyance of surface water due to superficial deposit regrading during the construction phase and the introduction of stone aggregate with voids as opposed to the baseline superficial cover of clay-based strata.

The aggregate base will provide localised interception and attenuation of surface water runoff from the Solar Stations which will prevent any significant increase in surface water runoff.

3.3 Internal Access Tracks

The existing hard-surfaced tracks which run throughout the Solar PV Site will be utilised as the primary route where possible and additional secondary access tracks will be constructed where connectivity is required. Permeable crushed aggregate (e.g., Type 2 aggregate) will be used for any new access tracks, as shown in Plate 14, which will allow surface water to percolate through the access tracks and release into the soils and along existing flow routes as per the current scenario.

Plate 14: Typical Type 2 Aggregate at Solar Farm[34]

4 HIGHWAY WORKS SITE

The Highway Works Site will comprise areas beyond the Solar PV Site which are being considered for cable route connections and temporary/permanent improvements to existing highways to facilitate the construction and decommissioning of the Proposed Development.

The minor extent of the Highway Works Site limits the potential impacts on surface water runoff to the construction phase. Construction phase drainage measures, as outlined in Section 2.8, will be implemented to prevent sediment increase in associated runoff.

Jointing pits will be installed at regular intervals along the Grid Connection Route to facilitate the installation and connection of cables beneath the existing roads within the route.

The minor extents of the Highways Works Site are limited to the adopted highway extents and verges and therefore will not result in any perceptible increase in surface water runoff.

5 FOUL DRAINAGE

During construction of the Proposed Development, foul water will be disposed of via 'Port-a-loo' type facilities and disposed of via a licenced waste carrier.

During the operational phase there is capacity for permanent staff members to be located at the office and welfare facilities. The welfare facilities at the plant building will comprise toilets and a kitchen with foul waters emanating from both facilities.

---

[34] Arkwright Solar Farm - Chesterfield. As-built drainage Survey. Arcus 2016 (L. Nevins)

Due to the rural setting discharge to a foul sewer is assessed as being unfeasible. Foul water associated with the Proposed Development will therefore be stored via an onsite foul solution (e.g., cesspits, porta-loo) which will then either be taken offsite by a licensed carrier or managed through an appropriate permit.

Should foul water be stored via cesspits they will be managed, inspected and drained by a licensed courier who will then dispose of the waste offsite. The cesspits will either meet the general binding rules for the operation of a cesspit or the EA will be consulted to obtain a permit for the operation of the cesspits.

6 POTABLE WATER

To serve the welfare and office facilities within the Proposed Development potable water may be required.

Due to the rural setting of the Solar PV Site and Order Limits a connection to an existing clean water outlet via Anglian Water is not feasible.

Therefore potable water will be sourced from a licensed provider with potable water to be stored within the confines of the welfare and office facilities. The potable water storage will be stored within a industry standard confined vessel (e.g., a demineralised water butt).

7 PUBLIC RIGHT OF WAY DRAINAGE

LCC commented within the LCC Scoping Opinion, as detailed in Appendix 11.3 of the ES, that the Proposed Development may potentially impact on land drainage within the vicinity of the Order Limits and the possible drainage changes on the Public Right of Way (PRoW) should be assessed.

The measures outlined with this Outline Surface Water Drainage Strategy will prevent any significant increase in surface water runoff and the flows entering the existing hydrological network will be at similar rates to the existing scenario. As such there will be no impacted on the drainage characteristics along the PRoW.

8 CONCLUSION

Following implementation of the surface water drainage measures detailed in this document the introduction of hard-standing associated with the Proposed Development will not lead to an increase in discharge rates above greenfield levels for a 1 in 100-year return period. .

The Primary Substation will involve the installation of approximately 0.36 ha of impermeable elements which will be located within a compound underlain by a free draining sub-base.

The unbound free-draining subbase will discharge to the West Glen River with a flow restriction device without surcharge and out of system flooding during the 1 in 100-year (+25 %) year events, as demonstrated by outputs from Micro Drainage.

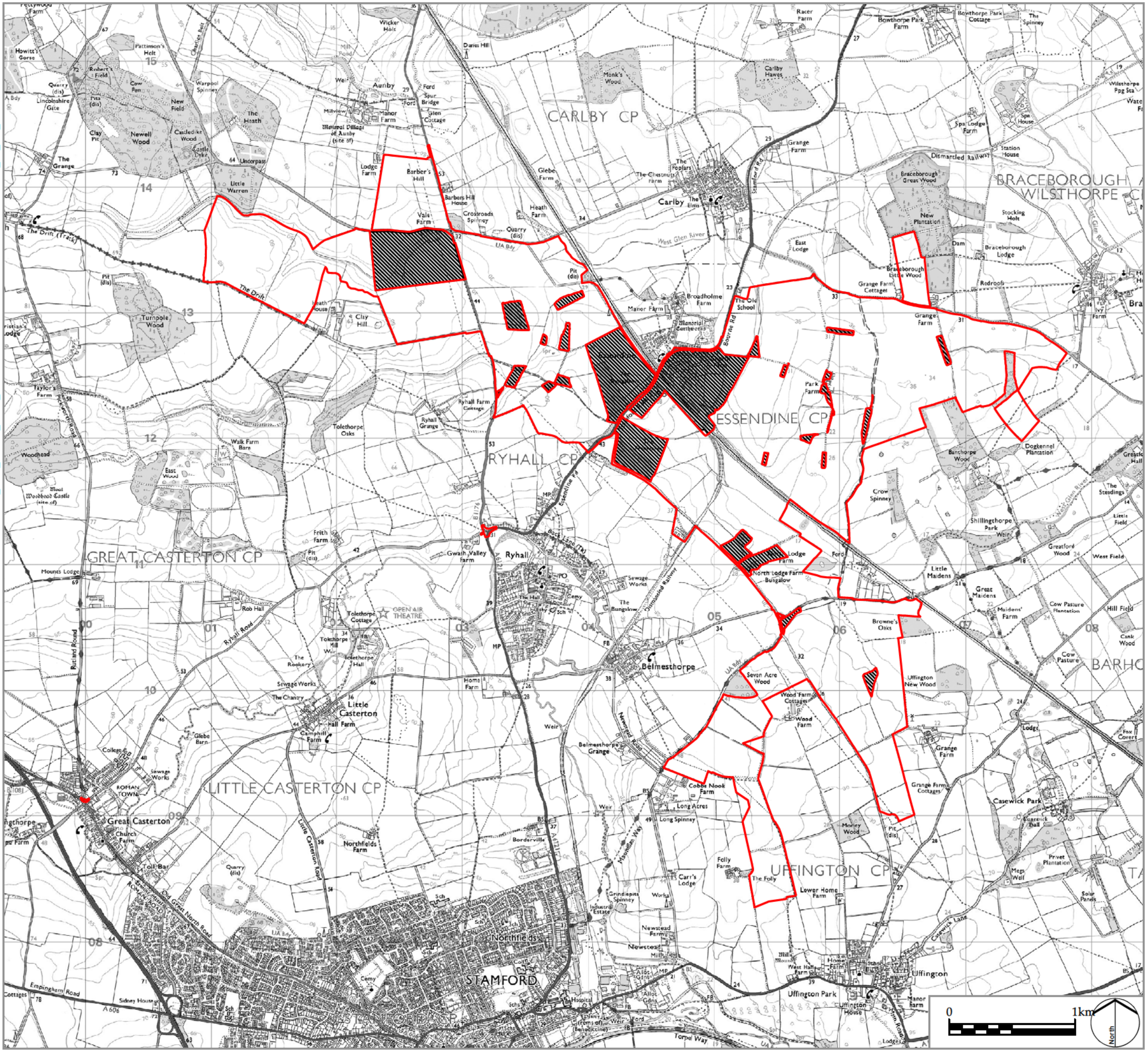
Following implementation of the proposed mitigation measures, the limited introduction of hard-standing associated with the Proposed Development will not lead to an increase in surface water runoff from the Onsite Substation above greenfield levels in up to and including the 1 in 100-year (+25 %) return period.

Solar Stations will be underlain and bounded by a graded aggregate which will provide localised interception and attenuation of surface water runoff and prevent any significant increase in surface water runoff.

The PV Arrays will not result in an increase in hardstanding areas and therefore will not significantly increase surface water runoff rates. The PV Arrays will have multiple drip lines along the face to allow surface water to disperse evenly with native planting to be located beneath PV Arrays to preventing channelization and alterations to surface water flow routes.

ANNEX A – ORDER LIMITS LOCATION PLAN

Z:\7863_NSIP_SOLAR_FARM_CONFIDENTIAL\8GIS\PROJECTS\ES FIGURES\7863_SK_601_SITE LOCATION PLAN.MXD



Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009
APFP Regulation: 5(2)(a)

PINS REFERENCE NUMBER
EN010127

LEGEND

☐	Order Limits
▨	Areas outside the Order limits

P0	DCO Submission		RP	06/11/22
REV.	DESCRIPTION		APP.	DATE

Mallard Pass
Solar Farm

PROJECT TITLE
MALLARD PASS SOLAR FARM

DRAWING TITLE
Figure 1.1: Order limits

ISSUED BY	Oxford	T: 01865 887050	
DATE	Nov 2022	DRAWN	AG
SCALE @A3	1:30,000	CHECKED	PD
STATUS	Final	APPROVED	RP

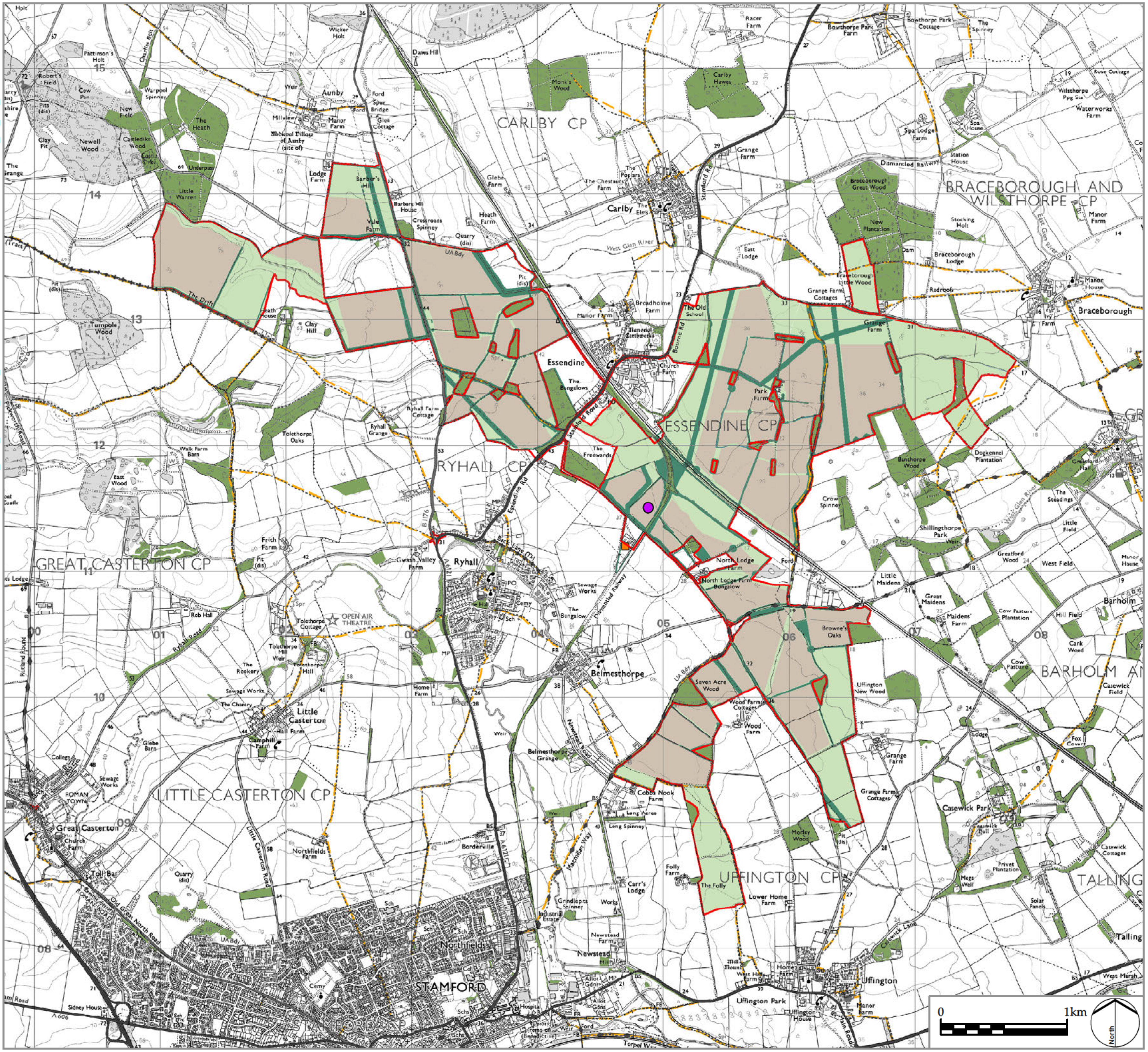
DWG. NO. **7863_SK_601** **REV: P0**

No dimensions are to be scaled from this drawing.
All dimensions are to be checked on site.
Area measurements for indicative purposes only.

Sources: Ordnance Survey

ANNEX B – PROPOSED DEVELOPMENT LAYOUT PLAN

Z:\7863_NSIP_SOLAR_FARM_CONFIDENTIAL\8GIS\PROJECTS\ES FIGURES\7863_SK_607_CONCEPT PLAN.MXD



Infrastructure Planning (Applications:
Prescribed Forms and Procedure) Regulations 2009
APFP Regulation: 5(2)(a)

PINS REFERENCE NUMBER
EN010127

LEGEND

Site Features

- 🟥 Order limits
- ■ National Grid Ryhall Substation
- - - Public Right of Way
- 🟩 Woodland, hedgerows, trees, field boundaries and ditches

Concept Masterplan Proposals

- 🟫 Solar PV Site
- 🟩 Mitigation and Ehancement Areas
- 🟩 Offsets to woodland, trees, hedgerows, ditches, utilities and Public Rights of Way
- ● Onsite Substation

P0	DCO Submission	RP	06/11/22
REV.	DESCRIPTION	APP.	DATE

Mallard Pass
Solar Farm

PROJECT TITLE
MALLARD PASS SOLAR FARM

DRAWING TITLE
Figure 4.3: Concept Masterplan

ISSUED BY	Oxford	T: 01865 887050	
DATE	Nov 2022	DRAWN	AG
SCALE @A3	1:30,000	CHECKED	RP
STATUS	Final	APPROVED	RP

DWG. NO. 7863_SK_607 REV: P0

No dimensions are to be scaled from this drawing.
All dimensions are to be checked on site.
Area measurements for indicative purposes only.

Sources: Ordnance Survey

ANNEX C – INFILTRATION TESTING REPORT

Environmental
Geotechnical
Specialists

RGS

SOAKAWAY LETTER
REPORT

job number C2457/22/E/3768

date 31/03/2022

site address
Site off Stamford Road
Nr Stamford Village
Peterborough

written by I. Sakoor

checked by R.A. Palmer

issued by R.A. Palmer

Rogers Geotechnical Services Ltd
[redacted]
Offices 1 & 2, Barncliffe Business Park, Near Bank, Shelley,
Huddersfield, West Yorkshire HD8 8LU.

QMS ISO 9001 : 2015 REGISTERED

QMS ISO 14001 : 2015 REGISTERED

QMS ISO 45001 : 2018 REGISTERED

Registered Member

UKAS TESTING

GEOTECHNICAL
ENVIRONMENTAL

Report on Soakaway Testing

Location:	Site off Stamford Road, Nr Stamford Village, Peterborough.
For:	Arcus Consultancy Services Ltd
Report No.	C2457/22/E/3768 Report Date: March 2022

For and on behalf of **Rogers Geotechnical Services Ltd**

[redacted]	[redacted]
Imran Sakoor BEng FGS Geo-environmental Engineer	**Rob Palmer** MSc FGS ACIEH Senior Geo-environmental Engineer

Report Summary[1]

Item	Comments	Section
Geology	Superficial: River Terrace Deposits and alluvium beneath north-eastern part. Solid geology: Blisworth Limestone Formation within south-western corner of site. Upper Lincolnshire Limestone Member present below northern corner of the site. Majority underlain by Rutland Formation.	4.
Strata Conditions	Generally cohesive soils encountered across the site, with localised beds of gravel and cobbles. Sand horizons also present.	5.
Groundwater	None.	5.
Suitability of Soakaways	Soakaways not suitable for the majority of the site. However, soakaways could be utilised within River Terrace Deposits in northern part of the site.	7.

---

[1] This summary should not be relied upon to provide a comprehensive review. All of the information contained in this document should be considered.

1. Introduction

We thank you for your request to undertake percolation testing at the above mentioned site and take pleasure in enclosing the results of this work. The investigation was undertaken on the 21st and 22nd March 2022 in accordance with your instruction to proceed. This report describes the work undertaken, presents the data obtained and discusses the results of the tests

2. Limitations

The recommendations made and opinions expressed in this report are based on the ground conditions revealed by the site works, together with an assessment of the site. Whilst opinions may be expressed relating to sub-soil conditions in parts of the site not investigated, for example between trialpit positions, these are for guidance only and no liability can be accepted for their accuracy.

This report has been prepared in accordance with our understanding of current best practice. However, new information or legislation, or changes to best practice may necessitate revision of the report after the date of issue.

3. Fieldworks

Six trial pits were excavated in order to undertake soakaway testing, the positions of which are shown in Appendix 1. The soakaway tests were undertaken at the base of the pit at depths rational to the construction of soakaways. The soils exposed in the trial pits were logged on site in general accordance with BS5930: 2015 +A1: 2020, and full descriptions are given on the trialpit records which are presented in Appendix 2.

Once excavations were completed, the trial pits were carefully re-instated with the arisings. Whilst every care was taken during the infilling process, including compacting of the infill at regular intervals with the back-acting arm of the excavator, it should be appreciated that some mounding of the surface may have resulted. Moreover, the infilled soils may be subjected to settlement over time, such that a depression in the surface may also occur. Therefore, the locations of any pits undertaken in this investigation should be conveyed to the current site user, as the mounds or depressions associated with the pits may present a risk to current site operations. Furthermore, it must be realised that the infilled pits represent an area of disturbance within the site soils, thus the soils at the pit locations may vary characteristically compared to the undisturbed ground. As such, foundations placed in this disturbed material may not perform as anticipated.

4. Geology

The available published geological data for the site has been examined and the following table presents the anticipated geology.

Table 1: Geological Data for the Site

Strata Type	Strata Name[2]	Previous Name[3]	Description[3]
Superficial Geology	None indicated beneath the majority of the site.		
	North-Eastern Corner of the Site		
	River Terrace Deposits	-	Sand and gravel, locally with lenses of silt, clay or peat. [Generic description].
	Alluvium	-	Soft to firm normally consolidated, compressible silty clay but can contain layers of silt, sand, peat and basal gravel. A stronger, desiccated surface zone may be present.
Solid Geology	**South Western Part of the Site**		
	Blisworth Limestone Formation	White Limestone	Pale grey to off-white or yellowish limestones with thin marls and mudstones, fossiliferous, bioturbated peloidal, ooidal and shell-fragmental more-or-less argillaceous packestones and wackestones.
	Majority of the Site		
	Rutland Formation	Glentham Formation	Interpreted as a succession of upto seven shallowing upward, essentially delta-type rhythms, comprising ideally of a grey marine mudstone passing up into non-marine mudstone and siltstone, with a greenish-grey rootlets bed at the top.
	Northern Corner of the Site		
	Upper Lincolnshire Limestone Member	Hilbaldstow Beds	Limestone, overwhelmingly dominated by high-energy ooidal and shell fragmental grainstones, but includes secondary recrystallised and micritised lithologies.

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[2] Sources: British Geological Survey (NERC) Map Sheets 157; Stamford; Solid and Drift Edition, and Geology of Britain Viewer [*online resource from* [redacted]

[3] Sources: British Geological Survey (NERC) Lexicon of Named Rock Units [*online resource from* [redacted]]

5. Strata Conditions

In accordance with the geology of the area, the succession has been shown to include the following:

Table 2: Generalised Strata Profile

Depth m below ground level to underside of layer	**Strata Type**	**Positions Layer Revealed**	**Groundwater Strikes** m below ground level
0.1 – 0.3	TOPSOIL	All	None
0.6 – +1.75	GRAVEL and COBBLES	TP01, TP02, TP03, TP05	None
2.3	CLAY	TP01	None
1.4 - +1.5	Very sandy GRAVEL/Gravelly SAND	TP05, TP06	None
1.5 – +2.6	Slightly sandy silty CLAY	TP01, TP03, TP04, TP05	None

'+' denotes that the strata extended below the termination depth of the investigated positions, thus the extent of the deposit is only proven to the depths indicated.

In general, the soils were found to comprise clays with localised beds of sand. Due to similarities of the solid geology types indicated to be present below the site, the exact geology could not be determined with the data obtained in this investigation. Notwithstanding this, the soils within all positions except TP06 are likely to represent either the Rutland Formation or the Bilsworth Formation. Within TP06, the soils are considered likely to represent superficial River Terrace Deposits.

6. Insitu Testing

6.1 Soakaway Tests

On reaching the elected soakaway test depth, the pit was trimmed and squared as much as practicable. Water was then introduced into the pit at a controlled rate to prevent collapse of the sides and the level monitored at time intervals relative to a reference bar at ground level. The results obtained from the soakaway tests are presented at Appendix 3 and are summarised below:

Table 3: Soakaway Test Results

Location	**Soakage Area Dimensions (average) (m)**	**Depths of soaked strata (m)**	**Soil Description (of soaked strata)**	**Infiltration Rate (m/sec)**	**Drainage Characteristics**
TP1	0.45 x 2.5	1.68 to 2.6	Side – CLAY Base – Sandy silty CLAY.	*	Practically Impermeable

TP2	0.6 x 3.0	0.33 to 0.60	Side – Clayey GRAVEL and COBBLES. Base – Clayey GRAVEL and COBBLES.	3.3×10^{-5} 2.0×10^{-5} $^{+}1.5 \times 10^{-5}$	Good
TP3	0.45 x 2.5	1.33 to 1.75	Side – Slightly sandy silty CLAY. Base – Very clayey GRAVEL and COBBLES.	*	Practically Impermeable
TP4	0.45 x 2.75	2.04 to 2.28	Side – Sandy CLAY. Base – Sandy CLAY.	*	Practically Impermeable
TP5	0.45 x 2.4	1.50 to 2.05	Side – Slightly sandy slightly gravelly CLAY. Base – Slightly sandy slightly gravelly CLAY.	$^{+}4.8 \times 10^{-6}$	Marginal
$^{++}$TP6	0.45 x 2.60	1.29 to 1.50	Side – Sandy GRAVEL. Base – Sandy GRAVEL.	6.0×10^{-6}	Good

*Negligible water level movement observed during test. $^{+}$Extrapolated result. $^{++}$Unable to fill pit to more than 1.29m depth due to rate of outflow – see below.

Within TP1, TP3 and TP4, the tests could not be completed within the scope of the method provided in BRE Digest 365 due to the poor soakage rate of the exposed soils. Due to the negligible water movement it was not possbile to extrapolate the results obtained in order to obtain a soil infiltration rate. As such, it is considered that the soils in these locations possess practically impermeable drainage characteristics.

For the third test within TP2 and the test undertaken within TP5, the water level did not achieve a fall from 75% to 25% of the effective depth of the storage volume in both trialpits. Notwithstanding this, in view of the steady movement of the water level for the duration of the test, the infiltration rate has been estimated by extrapolating the available data points.

It should be also appreciated that within TP06, a whole bowser (1000 litres) was pumped into the trialpit. During the majority of the infilling process, the pit remained empy i.e. the drainage was so effective that the pit did not fill initially. For reference, the volume of TP06 was 1.75m³. If the pit was say impermeable (water tight), the water level would be sat at 0.85m depth if 1000 litres was pumped into the trialpit. However, given the water was leaving the pit so quickly, the water level only ever reached a level of 1.29m after 1000 litres was pumped in. This suggests that over 43% of the water pumped in to the trialpit had already exited the pit (drained away) before the time (test) even started. As such, the result presented in Table 3 may be slightly onerous.

7. Discussion

It should be appreciated that the results of the soakaway testing indicate variable drainage characteristics across the site. Notwithstanding this, it is noted that the majority of the site is underlain by cohesive soils. Test results within the cohesive soils indicated primarily practically impermeable infiltration conditions. From the four tests undertaken within cohesive soils only TP5 indicated marginal conditions. As such, it is unlikely that soakaways could be utilised for the majority of the site.

The testing undertaken within the cobbles and gravel layer in TP2 indicate good drainage conditions. However, it should be appreciated that on the basis of the ground conditions revealed across the site, it is likely that this material represents a discrete horizon and is likely to be underlain by clays. In view of this it is likely that this stratum possesses a limited storage volume and thus is unlikely to be suitable for constructing a soakaway within.

Notwithstanding this, good drainage conditions were indicated within TP6. Indeed, the percolation rate was such that the pit could not be filled any higher than 1.29m bgl. With respect to the ground conditions, it is considered that the soils at this location are representative of the superficial River Terrace Deposits.

On the basis of the above, it is considered that the use of soakaways will be unlikely for the majority of the site. However, it is considered that soakaways could be successfully employed within the River Terrace Deposits present within the northern portion of the site. Given the variable and generally poor infiltration rates for the majority of the site, it may be necessary to install drainage to channel surface water to soakaways constructed within the River Terrace Deposits within the northern part of the site. It should be noted that anecdotal evidence suggests that land drains are already in place and directed to that part of the site.

8. References

- Building Research Establishment (BRE) Digest 365, *Soakaway Design*, September 1991.

- British Standards Institution (2015 +A1: 2020) BS 5930: *Code of practice for ground investigations*, B.S.I., London.

- Barnes, G. (2000). *Soil Mechanics Principle and Practice.* 2nd ed. London: Macmillan Press Ltd, p.47.

Appendix 1

Site Plan

Test Pit	Easting	Northing
01	504810	311555
02	504922	311468
03	504883	311630
04	504974	311566
05	505004	311650
06	504957	311705

Notes:

Investigation positions approximated from site operative's notes.

Environmental
Geotechnical
Specialists

Rogers Geotechnical Services Ltd

Offices 1 & 2, Barncliffe
Business Park,
Near Bank,
Shelley,
Huddersfield,
HD8 8LU

Telephone: 0843 50 66 87

[redacted]

Client:

Arcus Consultancy Services Ltd

Job Number:

C2457/22/E/3768

Project Details:

Site off Stamford Road, Nr
Stamford Village, Peterborough

Scale: Not to scale - reference only

Appendix 2

Trialpit Records

Trial Pit Log

Trialpit No	**TP01**
Sheet 1 of 1	
Project Name:	Stamford
Project No.	C2457/22/E/3768
Co-ords:	-
Level:	
Date	
Location:	B1176 Stamford Village, Peterborough
Client:	Arcus Consultancy Services Ltd
Dimensions (m):	2.5 × 0.45
Depth	2.60
Scale	1:50
Logged	RAP

Water Strike	Samples and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description
	Depth	Type	Results				
				0.10		▨	TOPSOIL (Firm brown slightly organic slightly sandy slightly gravelly silty CLAY with low cobble content. Gravel is subrounded to subangular fine to coarse of limestone (Reworked weathered fraction).
				0.65		▨	Medium dense brown clayey angular and tabular coarse GRAVEL and COBBLES of limestone. [POSSIBLE RUTLAND FORMATION].
						▨	Firm brown CLAY. [POSSIBLE RUTLAND FORMATION].
				1.20		▨	Firm dark grey CLAY. [POSSIBLE RUTLAND FORMATION].
				2.30		▨	Firm grey sandy silty CLAY with occasional weathered limestone lithorelicts. [POSSIBLE RUTLAND FORMATION].
				2.60			End of pit at 2 60 m

Remarks:

Stability: Good

[redacted]

Trial Pit Log

Trialpit No
TP02
Sheet 1 of 1

Project Name: Stamford	Project No. C2457/22/E/3768	Co-ords: - Level:	Date
Location: B1176 Stamford Village, Peterborough		Dimensions (m): 3 × 0.6 Depth 0.60	Scale 1:50
Client: Arcus Consultancy Services Ltd			Logged RAP

Water Strike	Samples and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description
	Depth	Type	Results				
				0.30		▨	TOPSOIL (Firm brown slightly organic slightly sandy slightly gravelly silty CLAY with low cobble content. Gravel is subrounded to subangular fine to coarse of limestone. Rare fossil shells (Reworked weathered fraction).
				0.60		⁘	Very dense brown clayey angular and tabular coarse GRAVEL and COBBLES of limestone. [POSSIBLE BLISWORTH LIMESTONE FORMATION].

End of pit at 0 60 m

1 2 3 4 5 6 7 8 9 10

Remarks: Effectively refused at 0.6m. Excavator with teeth had very slow progress.

Stability: Good

Trial Pit Log

Trialpit No
TP03
Sheet 1 of 1

Project Name: Stamford	Project No. C2457/22/E/3768	Co-ords: - Level:	Date
Location: B1176 Stamford Village, Peterborough		Dimensions (m): 2.5 × 0.45 Depth 1.75	Scale 1:50
Client: Arcus Consultancy Services Ltd			Logged RAP

Water Str ke	Samples and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description
	Depth	Type	Results				
				0.20		▨	TOPSOIL (Brown slightly organic sandy silty CLAY).
				1.50		✕	Firm brown slightly sandy silty CLAY. [POSSIBLE RUTLAND FORMATION].
				1.75		∘	Brown very clayey tabular coarse GRAVEL and COBBLES of limestone. [POSSIBLE RUTLAND FORMATION].

End of pit at 1.75 m

Remarks:

Stability: Good

Trial Pit Log

Trialpit No
TP04
Sheet 1 of 1

Project Name: Stamford	Project No. C2457/22/E/3768	Co-ords: - Level:	Date
Location: B1176 Stamford Village, Peterborough		Dimensions (m): 2.75 × 0.45 Depth 2.28	Scale 1:50
Client: Arcus Consultancy Services Ltd			Logged RAP

Water Str ke	Samples and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description
	Depth	Type	Results				
				0.20		▨	TOPSOIL (Brown slightly organic sandy silty CLAY).
				2.28			Firm brown sandy CLAY. Sand is fine. Occasional thin sand horizons. [POSSIBLE RUTLAND FORMATION].
							End of pit at 2 28 m

Remarks:

Stability: Good

Trial Pit Log

Trialpit No
TP05
Sheet 1 of 1

Project Name: Stamford	Project No. C2457/22/E/3768	Co-ords: - Level:	Date
Location: B1176 Stamford Village, Peterborough		Dimensions (m): 2.4 × 0.45 Depth 2.00	Scale 1:50
Client: Arcus Consultancy Services Ltd			Logged RAP

Water Strike	Samples and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description
	Depth	Type	Results				
				0.20		▨	TOPSOIL (Firm brown slightly organic slightly sandy slightly gravelly silty CLAY with low cobble content. Gravel is subrounded to subangular fine to coarse of limestone. Rare fossil shells (Reworked weathered fraction).
				0.60		▨	Firm brown slightly sandy silty CLAY. [POSSIBLE UPPER LINCOLNSHIRE LIMESTONE MEMBER].
				1.00		▨	Medium dense brown clayey angular and tabular coarse GRAVEL and COBBLES of limestone. [POSSIBLE UPPER LINCOLNSHIRE LIMESTONE MEMBER].
				1.40		▨	Medium dense brown clayey silty very gravelly fine and medium SAND. Gravel is rounded to angular fine to coarse of flint limestone and quartz. [POSSIBLE UPPER LINCOLNSHIRE LIMESTONE MEMBER].
				2.00		▨	Stiff brown slightly sandy slightly gravelly silty CLAY. Sand is fine and medium. Gravel is sub angular and subrounded fine to coarse of various lithologies. [POSSIBLE UPPER LINCOLNSHIRE LIMESTONE MEMBER].
							End of pit at 2 00 m

Remarks:

Stability: Good

Trial Pit Log

Trialpit No
TP06
Sheet 1 of 1

Project Name: Stamford	Project No. C2457/22/E/3768	Co-ords: - Level:		Date
Location: B1176 Stamford Village, Peterborough		Dimensions (m): Depth 1.50	2.6 0.45	Scale 1:50
Client: Arcus Consultancy Services Ltd				Logged RAP

Water Strike	Samples and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description	
	Depth	Type	Results					
				0.20		▨	TOPSOIL (Firm dark brown organic sandy silty CLAY).	
				0.70		░	Firm brown clayey silty fine to coarse SAND. [RIVER TERRACE DEPOSITS].	
				1.50		▒	Brown silty sandy angular to rounded fine to coarse GRAVEL of limestone flint and quartz. Low cobble content. [RIVER TERRACE DEPOSITS].	1
							End of pit at 1 50 m	
								2
								3
								4
								5
								6
								7
								8
								9
								10

Remarks:

Stability: Good

Appendix 3

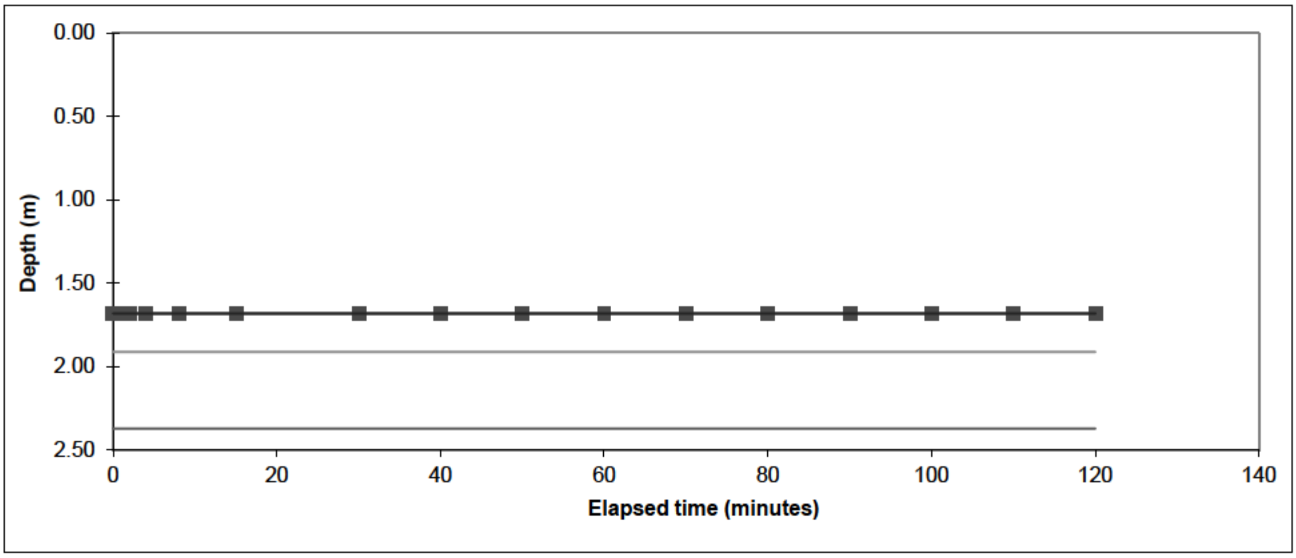
Soakaway Results

Rogers Geotechnical Services L

Soakaway Test

Trial Pit No: TP1 Test No: 1 Date: 22/03/2022
Length (m): 2.500 Datum Height: 0.00 m agl
Width (m): 0.45 Granular infill: None
Depth (m): 2.60 Porosity of infill: 1 (assumed)

Elapsed time (minutes)	Water Depth (m below datum)	Elapsed time (minutes)	Water Depth (m below datum)
0	1.680	50	1.680
1	1.680	60	1.680
2	1.680	70	1.680
4	1.680	80	1.680
8	1.680	90	1.680
15	1.680	100	1.680
30	1.680	110	1.680
40	1.680	120	1.680



Start water depth for analysis (mbgl):	1.68		
75% effective depth (mbgl):	1.91	Elapsed time (mins):	#N/A
50% effective depth (mbgl):	2.14		
25% effective depth (mbgl):	2.37	Elapsed time (mins):	#N/A
Base of soakage zone (mbgl):	2.60		

Volume outflow between 75% and 25% effective depth (m³):
Mean surface area of outflow (m^2): 3.84
(side area at 50% effective depth + base area)
Time for outflow between 75% and 25% effective depth (mins):

Soil infiltration rate (m/s):	**Test incomplete as 25% effective depth not achieved. Unable to reliably determine soil infiltration rate.**

Remarks Results processed following BRE 365 (2007).

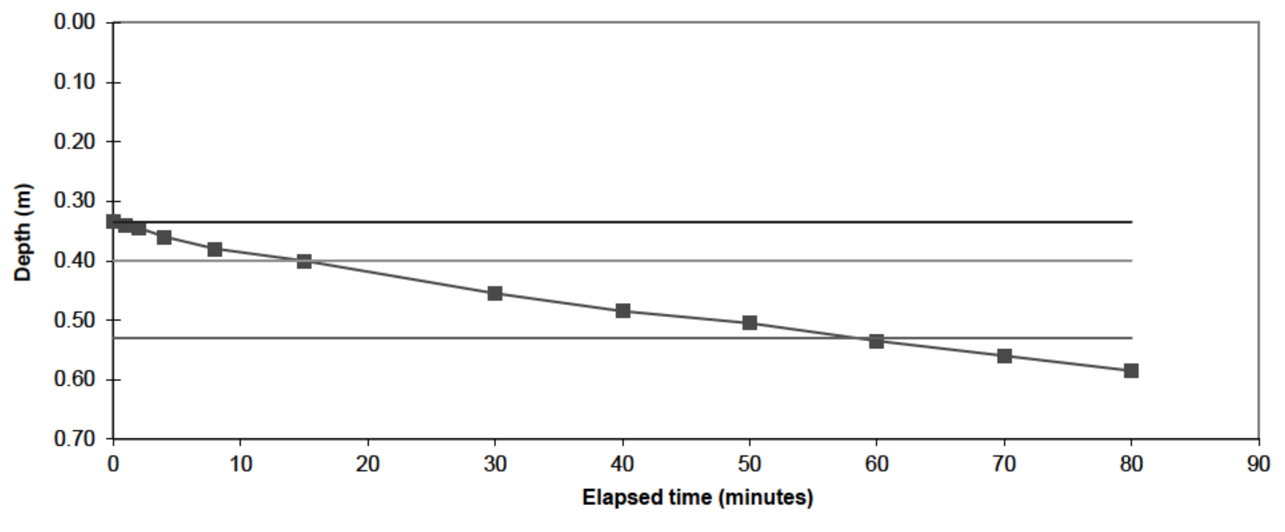
Client:	Arcus Consultancy Services Ltd	**Job No:**
Site:	Site off Stamford Road, Nr Stamford Village, Peterborough	C2457/22/E/3768

Rogers Geotechnical Services L

Soakaway Test

Trial Pit No: TP2
Test No: 1
Date: 22/03/2022
Length (m): 3.000
Datum Height: 0.00 m agl
Width (m): 0.60
Granular infill: None
Depth (m): 0.60
Porosity of infill: 1 (assumed)

Elapsed time (minutes)	Water Depth (m below datum)	Elapsed time (minutes)	Water Depth (m below datum)
0	0.335	50	0.505
1	0.340	60	0.535
2	0.345	70	0.560
4	0.360	80	0.585
8	0.380		
15	0.400		
30	0.455		
40	0.485		



Start water depth for analysis (mbgl):	0.34		
75% effective depth (mbgl):	0.40	Elapsed time (mins):	15.0
50% effective depth (mbgl):	0.47		
25% effective depth (mbgl):	0.53	Elapsed time (mins):	58.3
Base of soakage zone (mbgl):	0.60		

Volume outflow between 75% and 25% effective depth (m³): 0.234
Mean surface area of outflow (m^2): 2.74
(side area at 50% effective depth + base area)
Time for outflow between 75% and 25% effective depth (mins): 43.3

Soil infiltration rate (m/s): **3.3E-5**

Remarks Results processed following BRE 365 (2007).

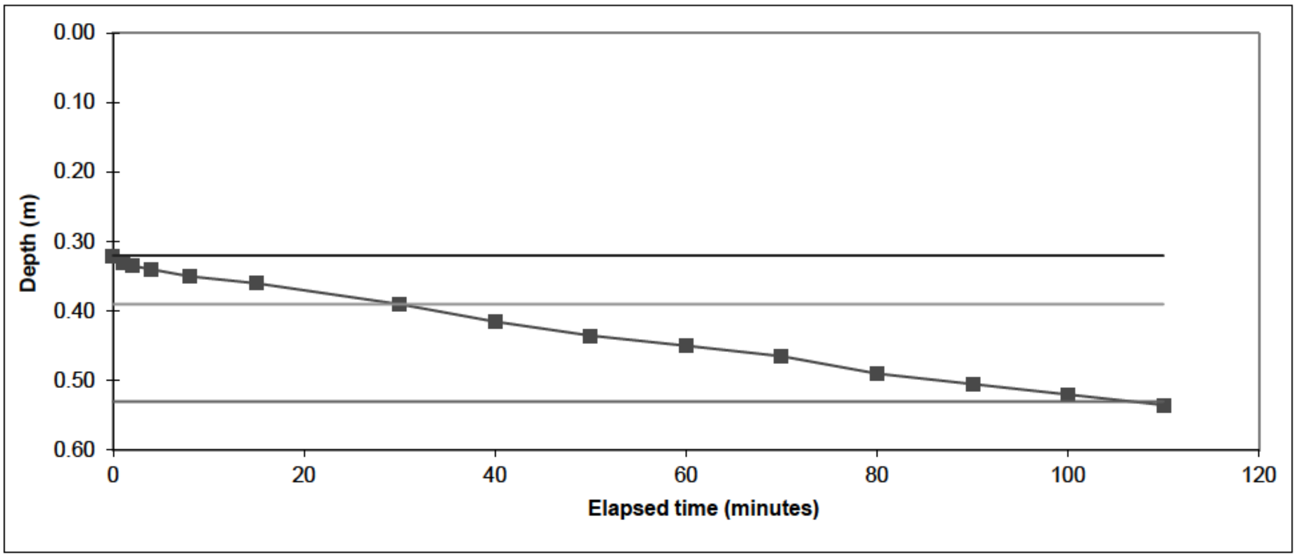
Client:	Arcus Consultancy Services Ltd	**Job No:**
Site:	Site off Stamford Road, Nr Stamford Village, Peterborough	C2457/22/E/3768

Rogers Geotechnical Services L

Soakaway Test

Trial Pit No:	TP2	Test No:	2	Date:	22/03/2022
Length (m):	3.000	Datum Height:	0.00 m agl		
Width (m):	0.60	Granular infill:	None		
Depth (m):	0.60	Porosity of infill:	1	(assumed)	

Elapsed time (minutes)	Water Depth (m below datum)	Elapsed time (minutes)	Water Depth (m below datum)
0	0.320	50	0.435
1	0.330	60	0.450
2	0.335	70	0.465
4	0.340	80	0.490
8	0.350	90	0.505
15	0.360	100	0.520
30	0.390	110	0.535
40	0.415		



Start water depth for analysis (mbgl):	0.32		
75% effective depth (mbgl):	0.39	Elapsed time (mins):	30.0
50% effective depth (mbgl):	0.46		
25% effective depth (mbgl):	0.53	Elapsed time (mins):	106.7
Base of soakage zone (mbgl):	0.60		

Volume outflow between 75% and 25% effective depth (m³):	0.252
Mean surface area of outflow (m^2): (side area at 50% effective depth + base area)	2.81
Time for outflow between 75% and 25% effective depth (mins):	76.7

Soil infiltration rate (m/s):	**2.0E-5**

Remarks Results processed following BRE 365 (2007).

Client:	Arcus Consultancy Services Ltd	**Job No:**
Site:	Site off Stamford Road, Nr Stamford Village, Peterborough	C2457/22/E/3768

Rogers Geotechnical Services L

Soakaway Test

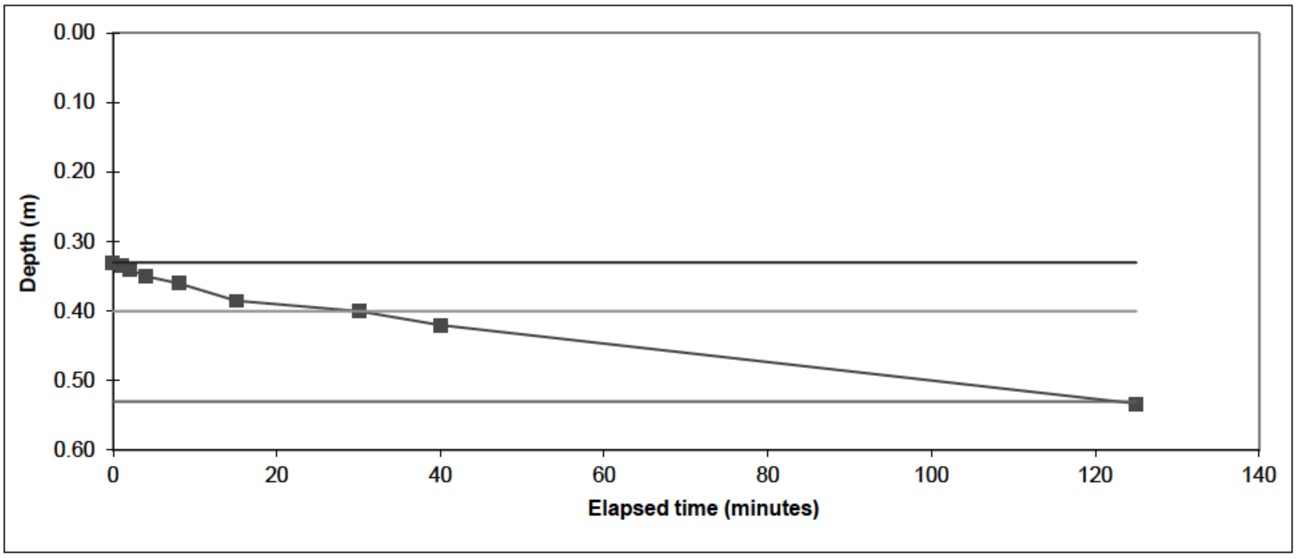
Trial Pit No: TP2 Test No: 3 Date: 22/03/2022

Length (m): 3.000 Datum Height: 0.00 m agl

Width (m): 0.60 Granular infill: None

Depth (m): 0.60 Porosity of infill: 1 (assumed)

Elapsed time (minutes)	Water Depth (m below datum)	Elapsed time (minutes)	Water Depth (m below datum)
0	0.330		
1	0.335		
2	0.340		
4	0.350		
8	0.360		
15	0.385		
30	0.400		
40	0.420		
125	*0.533*		



Start water depth for analysis (mbgl):	0.33		
75% effective depth (mbgl):	0.40	Elapsed time (mins):	30.0
50% effective depth (mbgl):	0.47		
25% effective depth (mbgl):	0.53	Elapsed time (mins):	122.7
Base of soakage zone (mbgl):	0.60		

Volume outflow between 75% and 25% effective depth (m³):	0.234
Mean surface area of outflow (m^2): (side area at 50% effective depth + base area)	2.74
Time for outflow between 75% and 25% effective depth (mins):	92.7

Soil infiltration rate (m/s):	**1.5E-5**

Remarks Results processed following BRE 365 (2007).
Result extrapolated from 40 minutes.

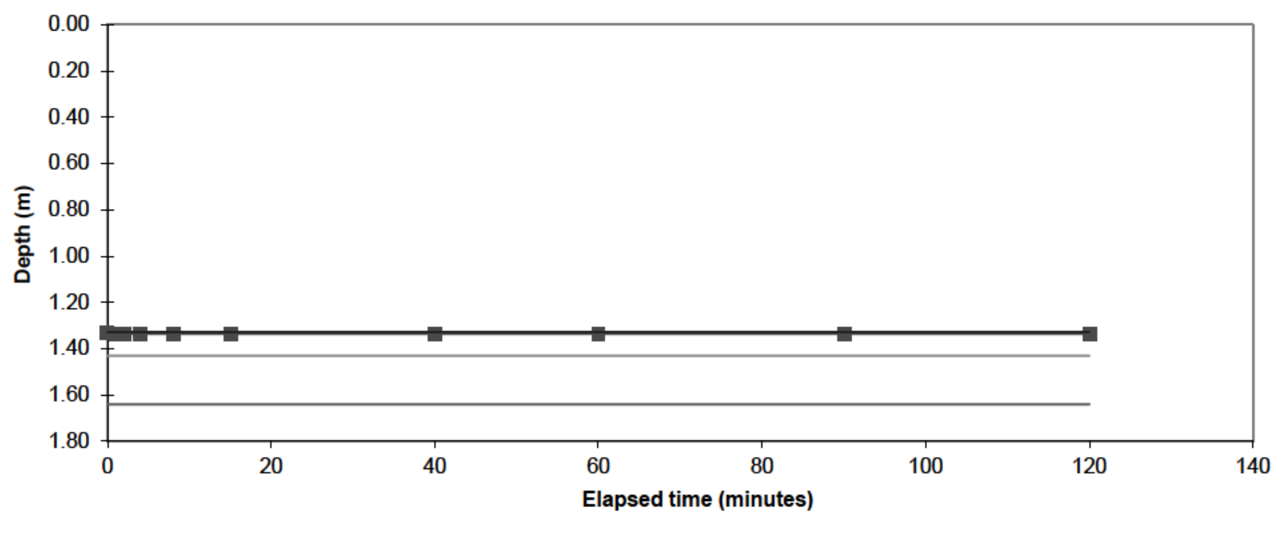
Client:	Arcus Consultancy Services Ltd	**Job No:**
Site:	Site off Stamford Road, Nr Stamford Village, Peterborough	C2457/22/E/3768

Rogers Geotechnical Services L

Soakaway Test

Trial Pit No:	TP3	Test No:	1	Date:	22/03/2022
Length (m):	2.500	Datum Height:	0.00 m agl		
Width (m):	0.45	Granular infill:	None		
Depth (m):	1.75	Porosity of infill:	1	(assumed)	

Elapsed time (minutes)	Water Depth (m below datum)	Elapsed time (minutes)	Water Depth (m below datum)
0	1.329	40	1.336
1	1.336	60	1.336
2	1.336	90	1.336
4	1.336	120	1.336
8	1.336		
15	1.336		
40	1.336		



Start water depth for analysis (mbgl):	1.33		
75% effective depth (mbgl):	1.43	Elapsed time (mins):	#N/A
50% effective depth (mbgl):	1.54		
25% effective depth (mbgl):	1.64	Elapsed time (mins):	#N/A
Base of soakage zone (mbgl):	1.75		

Volume outflow between 75% and 25% effective depth (m³):

Mean surface area of outflow (m^2): 2.36

(side area at 50% effective depth + base area)

Time for outflow between 75% and 25% effective depth (mins):

Soil infiltration rate (m/s):	**Test incomplete as 25% effective depth not achieved. Unable to reliably determine soil infiltration rate.**

Remarks Results processed following BRE 365 (2007).

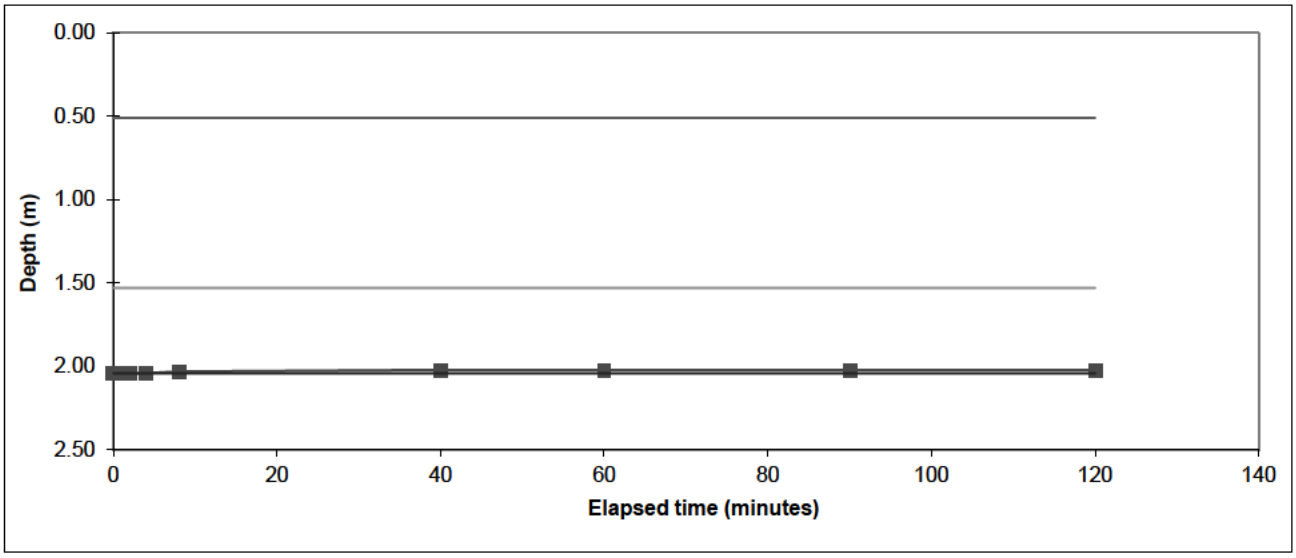
Client:	Arcus Consultancy Services Ltd	**Job No:**
Site:	Site off Stamford Road, Nr Stamford Village, Peterborough	C2457/22/E/3768

Rogers Geotechnical Services L

Soakaway Test

Trial Pit No: TP4 Test No: 1 Date: 22/03/2022
Length (m): Datum Height: 0.00 m agl
Width (m): Granular infill: None
Depth (m): Porosity of infill: 1 (assumed)

Elapsed time (minutes)	Water Depth (m below datum)	Elapsed time (minutes)	Water Depth (m below datum)
0	2.040	90	2.020
1	2.040	120	2.020
2	2.040		
4	2.040		
8	2.030		
40	2.020		
60	2.020		



Start water depth for analysis (mbgl): 2.04
75% effective depth (mbgl): 1.53 Elapsed time (mins): #N/A
50% effective depth (mbgl): 1.02
25% effective depth (mbgl): 0.51 Elapsed time (mins): #N/A
Base of soakage zone (mbgl): 0.00

Volume outflow between 75% and 25% effective depth (m³): 0.000
Mean surface area of outflow (m^2): 0.00
(side area at 50% effective depth + base area)
Time for outflow between 75% and 25% effective depth (mins): #N/A

Soil infiltration rate (m/s):	**#N/A**

Remarks Results processed following BRE 365 (2007).

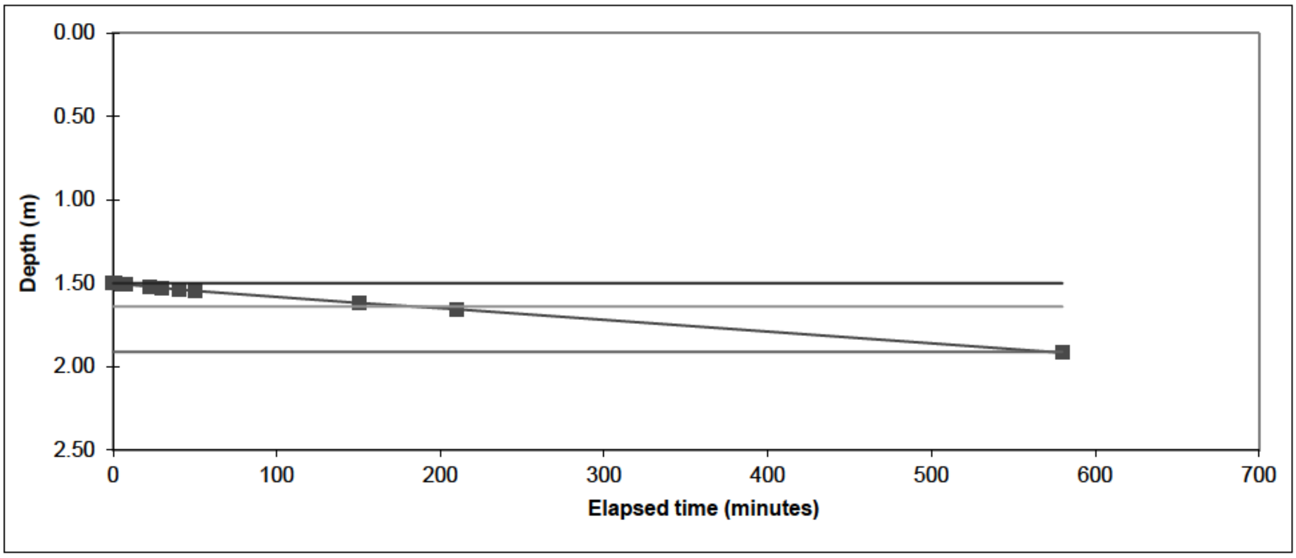
Client:	Arcus Consultancy Services Ltd	**Job No:**
Site:	Site off Stamford Road, Nr Stamford Village, Peterborough	C2457/22/E/3768

Rogers Geotechnical Services L

Soakaway Test

Trial Pit No: TP5
Test No: 1
Date: 22/03/2022
Length (m): 2.420
Width (m): 0.45
Depth (m): 2.05
Datum Height: 0.00 m agl
Granular infill: None
Porosity of infill: 1 (assumed)

Elapsed time (minutes)	Water Depth (m below datum)	Elapsed time (minutes)	Water Depth (m below datum)
0	1.500	40	1.535
1	1.500	50	1.545
5	1.505	150	1.618
8	1.508	210	1.656
22	1.519	*580*	*1.916*
30	1.528		



Start water depth for analysis (mbgl): 1.50
75% effective depth (mbgl): 1.64 Elapsed time (mins): 184.7
50% effective depth (mbgl): 1.78
25% effective depth (mbgl): 1.91 Elapsed time (mins): 571.5
Base of soakage zone (mbgl): 2.05

Volume outflow between 75% and 25% effective depth (m³): 0.294
Mean surface area of outflow (m^2): 2.64
(side area at 50% effective depth + base area)
Time for outflow between 75% and 25% effective depth (mins): 386.8

Soil infiltration rate (m/s): **4.8E-6**

Remarks Results processed following BRE 365 (2007).
Results extrapolated from 210 minutes.

Client: Arcus Consultancy Services Ltd
Site: Site off Stamford Road, Nr Stamford Village, Peterborough
Job No: C2457/22/E/3768

Rogers Geotechnical Services L

Soakaway Test

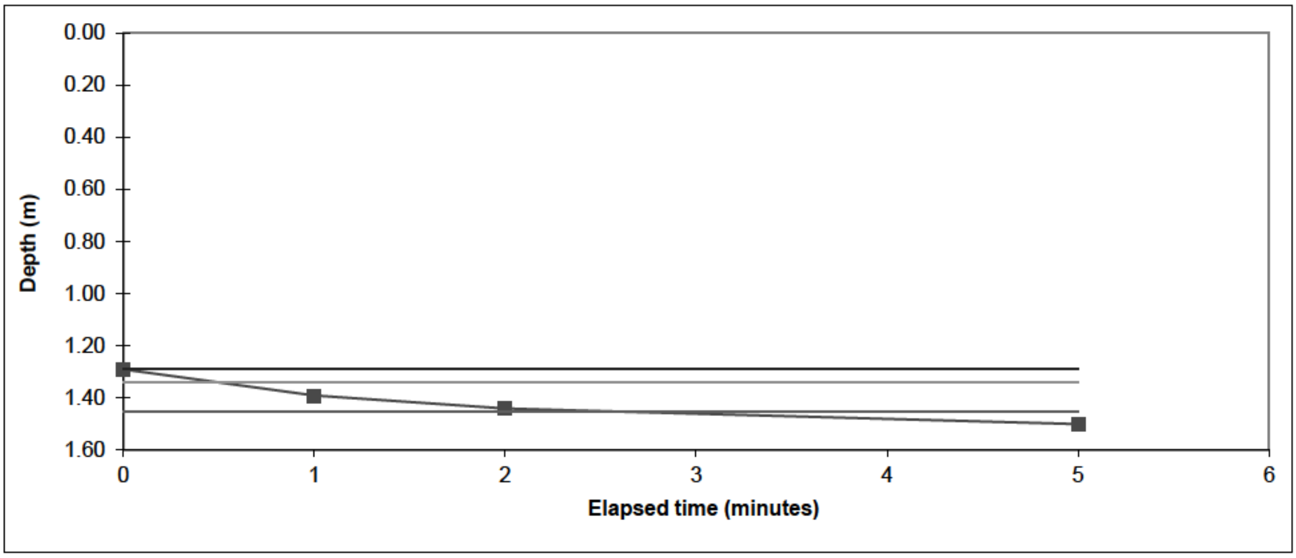
Trial Pit No: TP6 Test No: 1 Date: 22/03/2022

Length (m): 2.600 Datum Height: 0.00 m agl

Width (m): 0.45 Granular infill: None

Depth (m): 1.50 Porosity of infill: 1 (assumed)

Elapsed time (minutes)	Water Depth (m below datum)	Elapsed time (minutes)	Water Depth (m below datum)
0	1.290		
1	1.390		
2	1.440		
5	1.500		



Start water depth for analysis (mbgl):	1.29		
75% effective depth (mbgl):	1.34	Elapsed time (mins):	0.5
50% effective depth (mbgl):	1.40		
25% effective depth (mbgl):	1.45	Elapsed time (mins):	2.5
Base of soakage zone (mbgl):	1.50		

Volume outflow between 75% and 25% effective depth (m³):	0.129
Mean surface area of outflow (m^2): (side area at 50% effective depth + base area)	1.78
Time for outflow between 75% and 25% effective depth (mins):	2.0

Soil infiltration rate (m/s):	**6.0E-4**

Remarks Results processed following BRE 365 (2007).
It should be noted that during the initial stages of filling, the water exited the pit rapidly.

Client:	Arcus Consultancy Services Ltd	**Job No:**
Site:	Site off Stamford Road, Nr Stamford Village, Peterborough	C2457/22/E/3768

ANNEX D – ONSITE SUBSTATION MICRODRAINAGE OUTPUTS

ICP SUDS Mean Annual Flood

Input

```
Return Period (years)   100          Soil    0.150
           Area (ha) 0.430         Urban    0.000
           SAAR (mm)   598  Region Number Region 5
```

Results l/s

```
QBAR Rural 0.1
QBAR Urban 0.1

Q100 years 0.5

   Q1 year 0.1
  Q30 years 0.3
 Q100 years 0.5
```

Summary of Results for 100 year Return Period (+25%)

Half Drain Time : 6219 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	19.735	0.035	0.0	0.3	0.3	96.5	Flood Risk
30 min Summer	19.747	0.047	0.0	0.4	0.4	126.6	Flood Risk
60 min Summer	19.758	0.058	0.0	0.5	0.5	158.1	Flood Risk
120 min Summer	19.770	0.070	0.0	0.5	0.5	190.5	Flood Risk
180 min Summer	19.777	0.077	0.0	0.5	0.5	209.3	Flood Risk
240 min Summer	19.782	0.082	0.0	0.5	0.5	222.3	Flood Risk
360 min Summer	19.788	0.088	0.0	0.5	0.5	240.3	Flood Risk
480 min Summer	19.793	0.093	0.0	0.5	0.5	253.6	Flood Risk
600 min Summer	19.797	0.097	0.0	0.5	0.5	263.9	Flood Risk
720 min Summer	19.800	0.100	0.0	0.5	0.5	272.2	Flood Risk
960 min Summer	19.805	0.105	0.0	0.5	0.5	285.0	Flood Risk
1440 min Summer	19.811	0.111	0.0	0.5	0.5	301.5	Flood Risk
2160 min Summer	19.816	0.116	0.0	0.5	0.5	315.0	Flood Risk
2880 min Summer	19.818	0.118	0.0	0.5	0.5	321.6	Flood Risk
4320 min Summer	19.819	0.119	0.0	0.5	0.5	323.9	Flood Risk
5760 min Summer	19.818	0.118	0.0	0.5	0.5	320.9	Flood Risk
7200 min Summer	19.817	0.117	0.0	0.5	0.5	317.5	Flood Risk
8640 min Summer	19.815	0.115	0.0	0.5	0.5	313.5	Flood Risk
10080 min Summer	19.814	0.114	0.0	0.5	0.5	309.1	Flood Risk
15 min Winter	19.740	0.040	0.0	0.3	0.3	108.1	Flood Risk

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
15 min Summer	119.975	0.0	21.4	27
30 min Summer	78.809	0.0	29.4	42
60 min Summer	49.331	0.0	64.7	72
120 min Summer	29.845	0.0	75.5	132
180 min Summer	21.952	0.0	79.4	192
240 min Summer	17.551	0.0	80.9	250
360 min Summer	12.742	0.0	81.0	370
480 min Summer	10.156	0.0	79.8	490
600 min Summer	8.511	0.0	78.4	610
720 min Summer	7.364	0.0	77.0	730
960 min Summer	5.855	0.0	74.2	968
1440 min Summer	4.232	0.0	68.6	1448
2160 min Summer	3.054	0.0	146.5	2164
2880 min Summer	2.420	0.0	138.5	2884
4320 min Summer	1.742	0.0	123.0	4320
5760 min Summer	1.378	0.0	278.3	4960
7200 min Summer	1.148	0.0	264.5	5688
8640 min Summer	0.989	0.0	249.5	6392
10080 min Summer	0.871	0.0	234.4	7160
15 min Winter	119.975	0.0	24.7	27

Summary of Results for 100 year Return Period (+25%)

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Σ Outflow (l/s)	Max Volume (m^3)	Status
30 min Winter	19.752	0.052	0.0	0.4	0.4	141.8	Flood Risk
60 min Winter	19.765	0.065	0.0	0.5	0.5	177.1	Flood Risk
120 min Winter	19.778	0.078	0.0	0.5	0.5	213.5	Flood Risk
180 min Winter	19.786	0.086	0.0	0.5	0.5	234.7	Flood Risk
240 min Winter	19.792	0.092	0.0	0.5	0.5	249.3	Flood Risk
360 min Winter	19.799	0.099	0.0	0.5	0.5	269.7	Flood Risk
480 min Winter	19.805	0.105	0.0	0.5	0.5	284.8	Flood Risk
600 min Winter	19.809	0.109	0.0	0.5	0.5	296.5	Flood Risk
720 min Winter	19.812	0.112	0.0	0.5	0.5	306.0	Flood Risk
960 min Winter	19.818	0.118	0.0	0.5	0.5	320.6	Flood Risk
1440 min Winter	19.825	0.125	0.0	0.5	0.5	340.0	Flood Risk
2160 min Winter	19.831	0.131	0.0	0.5	0.5	356.4	Flood Risk
2880 min Winter	19.834	0.134	0.0	0.5	0.5	365.0	Flood Risk
4320 min Winter	19.836	0.136	0.0	0.5	0.5	370.7	Flood Risk
5760 min Winter	19.835	0.135	0.0	0.5	0.5	368.2	Flood Risk
7200 min Winter	19.833	0.133	0.0	0.5	0.5	361.4	Flood Risk
8640 min Winter	19.830	0.130	0.0	0.5	0.5	354.6	Flood Risk
10080 min Winter	19.828	0.128	0.0	0.5	0.5	348.1	Flood Risk

Storm Event	Rain (mm/hr)	Flooded Volume (m^3)	Discharge Volume (m^3)	Time-Peak (mins)
30 min Winter	78.809	0.0	32.8	42
60 min Winter	49.331	0.0	71.7	72
120 min Winter	29.845	0.0	80.7	130
180 min Winter	21.952	0.0	82.8	188
240 min Winter	17.551	0.0	82.7	248
360 min Winter	12.742	0.0	81.5	366
480 min Winter	10.156	0.0	80.2	484
600 min Winter	8.511	0.0	78.8	602
720 min Winter	7.364	0.0	77.4	720
960 min Winter	5.855	0.0	74.6	956
1440 min Winter	4.232	0.0	69.4	1428
2160 min Winter	3.054	0.0	147.6	2124
2880 min Winter	2.420	0.0	140.2	2824
4320 min Winter	1.742	0.0	126.3	4160
5760 min Winter	1.378	0.0	283.9	5472
7200 min Winter	1.148	0.0	270.2	6632
8640 min Winter	0.989	0.0	256.5	6840
10080 min Winter	0.871	0.0	243.0	7768

Rainfall Details

Rainfall Model	FSR	Winter Storms	Yes
Return Period (years)	100	Cv (Summer)	0.750
Region	England and Wales	Cv (Winter)	0.840
M5-60 (mm)	19.500	Shortest Storm (mins)	15
Ratio R	0.400	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+25

Time Area Diagram

Total Area (ha) 0.430

Time From:	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**
0	4	0.143	4	8	0.143	8	12	0.143

Model Details

Storage is Online Cover Level (m) 20.000

Cellular Storage Structure

Invert Level (m) 19.700 Safety Factor 2.0
Infiltration Coefficient Base (m/hr) 0.00000 Porosity 0.20
Infiltration Coefficient Side (m/hr) 0.00000

Depth (m)	**Area (m²)**	**Inf. Area (m²)**	**Depth (m)**	**Area (m²)**	**Inf. Area (m²)**
0.000	13600.0	0.0	0.300	13600.0	0.0

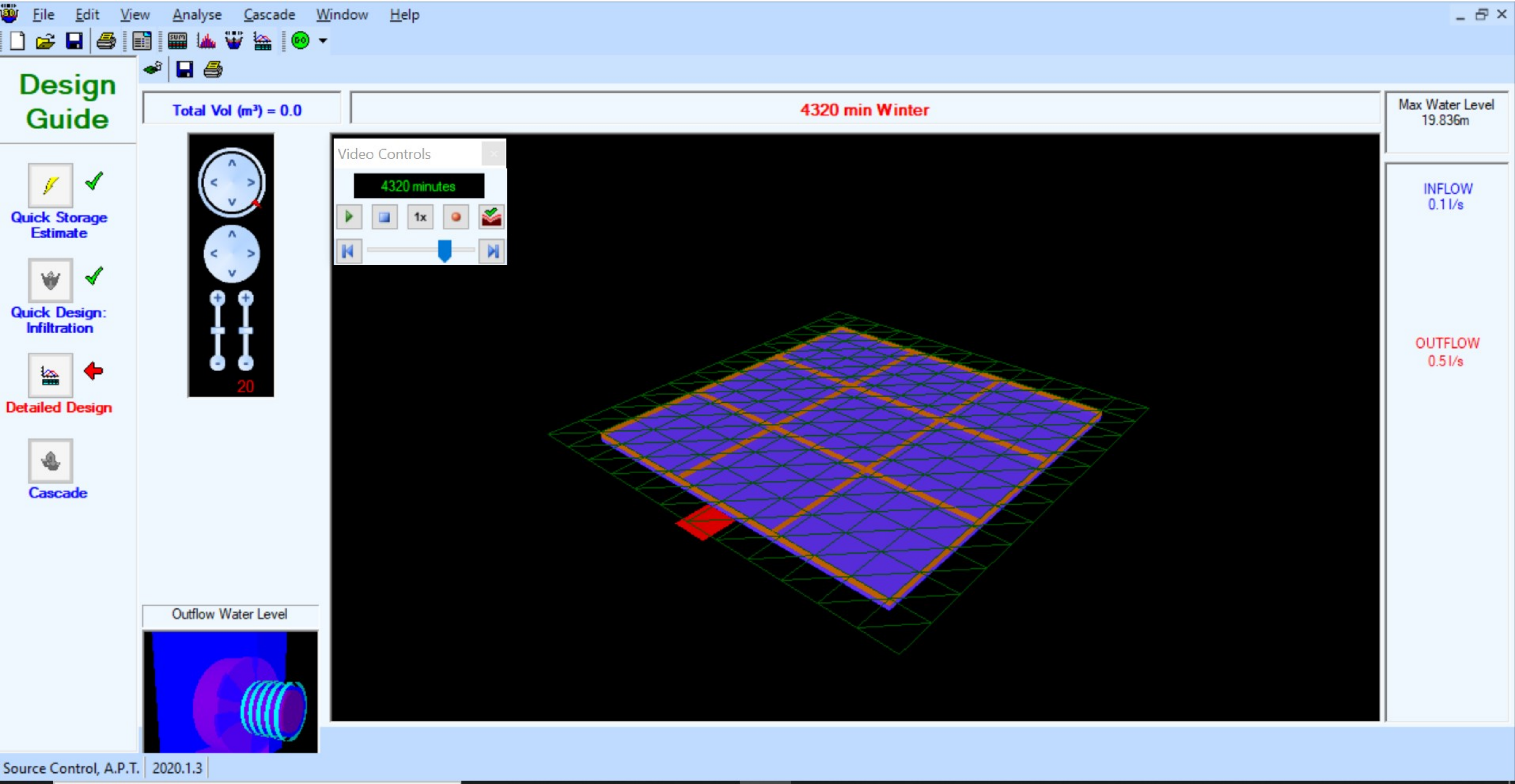
Hydro-Brake® Optimum Outflow Control

Unit Reference	MD-SHE-0041-5000-0300-5000
Design Head (m)	0.300
Design Flow (l/s)	0.5
Flush-Flo™	Calculated
Objective	Minimise upstream storage
Application	Surface
Sump Available	Yes
Diameter (mm)	41
Invert Level (m)	19.700
Minimum Outlet Pipe Diameter (mm)	75
Suggested Manhole Diameter (mm)	1200

Control Points	**Head (m)**	**Flow (l/s)**
Design Point (Calculated)	0.300	0.5
Flush-Flo™	0.084	0.5
Kick-Flo®	0.206	0.4
Mean Flow over Head Range	-	0.4

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	0.5	1.200	0.9	3.000	1.4	7.000	2.1
0.200	0.4	1.400	1.0	3.500	1.5	7.500	2.2
0.300	0.5	1.600	1.0	4.000	1.6	8.000	2.3
0.400	0.6	1.800	1.1	4.500	1.7	8.500	2.3
0.500	0.6	2.000	1.2	5.000	1.8	9.000	2.4
0.600	0.7	2.200	1.2	5.500	1.9	9.500	2.5
0.800	0.8	2.400	1.3	6.000	2.0		
1.000	0.8	2.600	1.3	6.500	2.0		



Total Vol (m³) = 0.0

4320 min Winter

Max Water Level 19.836m

4320 minutes

INFLOW 0.1 l/s

OUTFLOW 0.5 l/s

Source Control, A.P.T. 2020.1.3