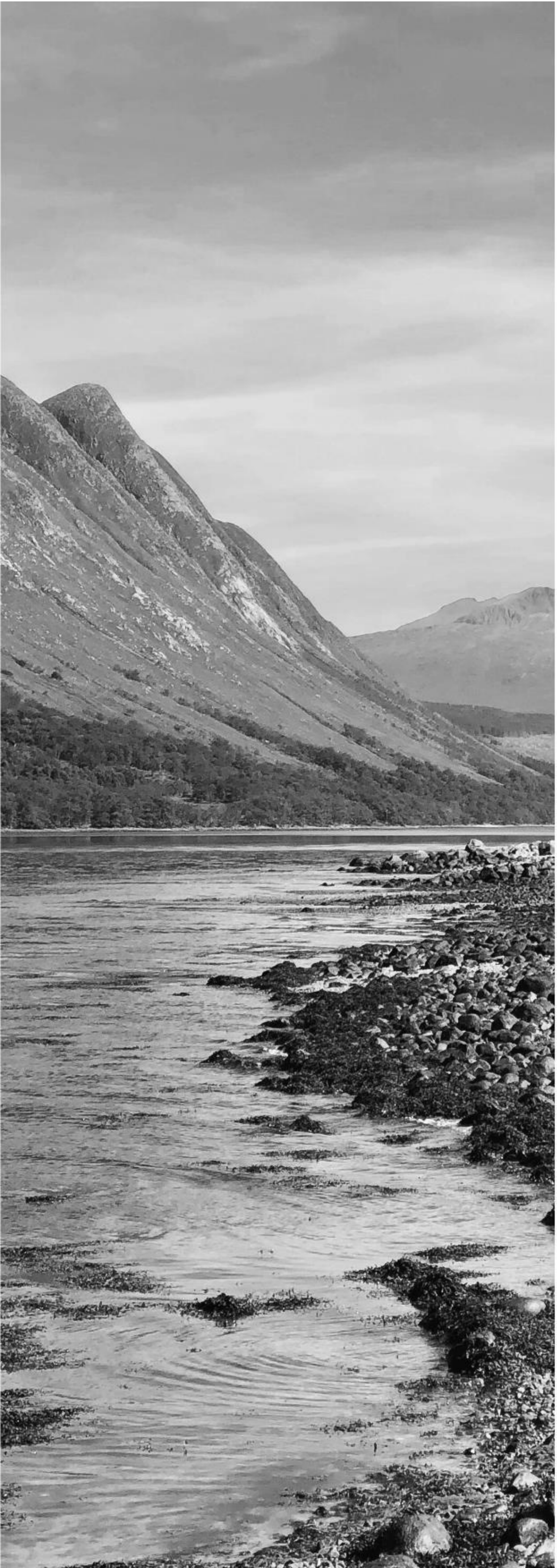

FLOOD RISK AND DRAINAGE ASSESSMENT (FRDA)

KEITHICK SOLAR FARM & 16MW BATTERY ENERGY STORAGE SYSTEM (BESS)

AE ASSOCIATES

21/04/2022

Gavia Environmental

Inveralmond Business Centre
Auld Bond Road
Perth
PH1 3FX
01738 718 685

54 Cook Street
Glasgow
G5 8JQ
0141 264 2891

16 Commerce Square
Lace Market
Nottingham
NG1 1HS
0115 695 0692

info@gavia-environmental.co.uk
www.gavia-environmental.co.uk

Report prepared for	AE Associates Kaimknowe Farm Glendevon FK14 7JZ
Project name	Keithick Solar Farm & 16MW Battery Energy Storage System (BESS)
Project number	P22035
Prepared by	Georgia Sakellariou
Approved by	Derwyn Lear

Revision History

Revision	Date	Prepared By	Reviewed By	Approved By	Comments
0	21/04/2022	Georgia Sakellariou	Derwyn Lear	Derwyn Lear	

Quality Assurance

This report has been prepared according to Gavia Environmental Quality Management Process. Gavia Environmental employs consultant scientists who are members of appropriate professional institutions and adhere to professional codes of conduct.

Disclaimer

This report is presented to AE Associates in respect of Flood Risk and Drainage Assessment (FRDA), and may not be used or relied on by any other person or by the client in relation to other matters not covered specifically by the scope of this report.

Notwithstanding anything to the contrary contained in the report, Gavia Environmental Ltd is obliged to exercise reasonable skill, care, and diligence in the performance of the services required by AE Associates and shall not be liable except to the extent that it has failed to exercise reasonable skill care and diligence, and this report shall be read and construed accordingly.

The report has been prepared by Gavia Environmental Ltd. No individual is personally liable in connection with the preparation of this report. By receiving this report and acting on it, the client or any other person accepts that no individual is personally liable whether in contract, tort, for breach of statutory duty or otherwise.

Contents

1 Introduction

1.1 Remit

Gavia Environmental Ltd ('Gavia') was commissioned by A&E Associates ('The Client') to produce a Flood Risk and Drainage Assessment (FRDA) for a proposed solar farm and battery energy storage system on a plot of land to the south-west of Coupar Angus, Perth and Kinross.

Appendices are provided within an accompanying document supporting this report.

1.2 Scope of Report

Due to the proximity of the site to the River Isla functional floodplain, a detailed assessment of flood risk has been undertaken to inform the design of the development. The following tasks have been undertaken within the remit of this report:

- An examination of the current and historical drainage patterns, including the soil classification of the site.
- Review of baseline flood risk, hydrological and hydrogeological conditions.
- A Level 3 Flood Risk Assessment including estimation of design flows for the adjacent River Isla using industry standard methodologies and 1D-2D modelling using Flood Modeller software.
- An estimation of pre-development and post-development runoff rates and volumes, including attenuation requirements for the critical rainfall event, for the 16MW BESS.
- Drainage modelling using Infodrainage software to determine sizing and placement of SuDS and other drainage infrastructure, for the 16MW BESS site.
- Flood extent mapping for the design flood event (1 in 200 year plus climate change) and design recommendations.

1.3 Proposed Development

The development is located at national grid reference (NGR) NO 20217 39700 to the south-west of Coupar Angus and will include a 16MW BESS and a 32MW Solar Farm. A 50MW BESS is also proposed to the east of the solar farm, however this is subject to a separate planning application.

Design information to inform this report was provided by email dated 06/04/2022.

1.4 Limitations

The flood modelling undertaken to inform this FRDA has been based solely on high resolution LiDAR data, and a topographic survey of the river channel has not been undertaken. This is considered acceptable for the proposed development due to:

- LiDAR data being more likely to underrepresent channel depths (due to restricted light penetration) and therefore a model built solely using LiDAR is likely to present a worst-case scenario in terms of out-of-bank flows.
- No in-stream structures are present requiring surveyed within the 1D domain.
- The nature of the development, i.e. solar panels raised >600mm above existing ground levels, would present a low risk in terms of impacts on floodplain conveyance and storage, and risk from flood damage, within shallow flood depths.
- A review of LiDAR data against recently collected surveyed data for the BESS site has indicates a high degree of accuracy within the LiDAR dataset.

A minimum depth of 0.1m has been applied to determining the extent of flooding.

The design flow estimation and mathematical modelling process involves the assumption of various conditions which add an element of uncertainty into the subsequent results. Where assumptions are required, a conservative approach has been adopted, this includes the estimation of design flows in order to assess for a worst-case scenario.

The risk of flooding cannot be totally eliminated as there is always the chance of flood events exceeding the estimated design flows or unforeseen conditions that alter the dynamics of the river or floodplain.

2 Policy, Guidance and Standards

2.1 Scottish Planning Policy

Scottish Planning Policy states: *"Development which would have a significant probability of being affected by flooding or would increase the probability of flooding elsewhere should not be permitted."*

The SPP divides flood risk into three categories. The risk framework identifies a low to no risk area where the annual probability of flooding is than 0.1% (1 in 1000 years), a low to medium risk area where the annual probability of flooding is between 0.1% and 0.5% (1 in 1000 to 1 in 200 years), and a medium to high-risk area where the annual probability of flooding is greater than 0.5% (1 in 200 years).

Within medium to high-risk areas in undeveloped and sparsely developed areas, additional development is generally not suitable.

2.2 Perth and Kinross Council

Local authority guidance (Perth and Kinross Council, 2021) requires an FRA to be undertaken for new proposed developments where a review of SEPA flood maps or historical flood data indicates a potential risk of flooding. The guidance requires finished floor levels (FFL) of a development to be a minimum of 600mm above the 200-year flood level including a climate change allowance (herein referred to as 'plus CC'). The guidance states that climate change allowances should be based upon the most recent SEPA published values.

In reference to drainage, Perth and Kinross Council requires a surface water drainage system for new developments which ensures post development runoff rates and volumes do not exceed the pre-development runoff rates and volumes for the critical rainfall events, up to and including the 1 in 200 year plus CC. The drainage system should further be designed to ensure (i) no surcharge during the 1 in 30 year event and (ii) any flooding from the 1 in 200 year event does not encroach within 600mm of property FFLs.

2.3 CAR Regulations

The Water Environment (Controlled Activities) (Scotland) Amended Regulations 2022 (CAR) include a requirement that surface water discharge must not result in pollution of the water environment. It also makes Sustainable Urban Drainage Systems (SuDS) a requirement for new developments, except for runoff from a single dwelling and discharges to coastal waters. The proposed development would be regulated under General Binding Rules (GBR) 10 which specifically requires that the site is 'drained by a SUD system equipped to avoid pollution of the water environment' (SEPA, 2022).

2.4 SEPA Flood Risk Guidance and Flood Maps

The latest version of SEPA 'Technical Flood Risk Guidance for Stakeholders' (SEPA, 2019a) has been consulted during preparation of the FRA. This guidance sets out the minimum requirements and methodologies expected to be adopted for an FRA.

The SEPA flood maps show the likely extent of flooding for high (1 in 10 year), medium (1 in 200 year) and low (1 in 1000 year) likelihood for fluvial, pluvial (surface water) and coastal flooding. It should be noted that SEPA flood maps are indicative, and a detailed assessment of flood risk is required for sites immediately outside or within the SEPA flood extent.

2.5 Climate Change

SEPA guidance on climate change allowances (SEPA, 2022) requires the inclusion of rainfall uplift allowances for surface water flooding and drainage assessments. The proposed development is within a catchment greater than $50km^2$, and so a 53% increase in peak rainfall intensity and fluvial flows must be applied to the 1 in 200-year critical rainfall event.

3 Consultation

3.1 SEPA

SEPA are the flooding regulator in Scotland and are responsible for monitoring river levels, rainfall, tidal predictions, and weather forecasts across Scotland to predict the likelihood and timing of flooding. SEPA also has a strategic role in managing flood risk and a duty to provide flood risk advice to Planning Authorities when consulted in relation to applications for development, where the Planning Authority considers there may be a risk of flooding.

SEPA have been consulted with regards to the proposed development and we are currently awaiting their response.

3.2 Perth and Kinross Council

Under the terms of the Flood Risk Management (Scotland) Act 2009, Perth and Kinross Council (PKC) has specific responsibilities in relation to flood prevention and planning. The Act requires co-ordination between organisations such as SEPA, Scottish Water (SW) and all Local Authorities as well as others to manage flood risk sustainably.

Perth and Kinross Council have been consulted via issue of an interim Technical Note dated 25/03/2022. Principally, the Technical Note set out the approach of conservatively using a LiDAR derived 1D/2D hydraulic model and locating all solar infrastructure outwith the mapped 1 in 200 year plus CC flood extents. Perth and Kinross Council responded by email dated 12/04/2022 stating they were time constrained to review in detail but did not see any concerns with the approach.

4 Desk Study

4.1 Site Description

The site consists of three parcels of land to the south of the River Isla and roughly 2km southwest of Coupar Angus, Perth and Kinross (NGR: NO 20362 39733). The site covers a combined area of approximately 65Ha.

The site is bordered by the River Isla, mixed woodland and agricultural fields. A minor road intersects the centre of the site. The land is currently used for arable farming. The majority of the land is proposed for solar infrastructure, with the BESS being located in the eastern corner of the southern parcel of land (refer to Figure 1, Appendix A). Site photographs are provided within Appendix B.

4.2 Topography

The site generally slopes southeast to northwest from roughly 62m AOD by the southern boundary to 40m AOD by the northern boundary adjacent to the River Isla. The topography within the site boundary is undulating with several minor topographic rises and depressions. The 16MW BESS is located at approximately 62m AOD.

4.3 Surface Water Features

The site is drained by a network of drainage channels located within woodland and adjacent to farm tracks and the minor road (refer to Figure 1, Appendix A). Subsurface field drains were also observed across the site. A pond was identified at Kemphill, which receives runoff from the network of drainage channels. The site entirely drains to the River Isla which is located directly north from the proposed development. A further description of the hydrology is provided within Section 6.

4.4 Historical Land Use

Historical mapping (Ordnance Survey 1908, 1970) indicates that the site has not undergone any alterations throughout the years. The drainage ditches associated with the minor road and farm tracks pre-date the earliest mapping available (1855) and appear to have been developed feed a water mill located at Kemphill.

4.5 Ground Conditions

BGS Mapping (BGS, 2022) indicates that the northern portion of the site is underlain by the Cromlix Mudstone Formation, a sedimentary bedrock formation of mudstone and siltstone of the Devonian period. On the southern part, the site is underlain by the Scone Sandstone Formation. These two parts are divided by the Central Scotland Late Carboniferous Tholeiitic Dyke Swarm which run through the central part of the site.

In terms of superficial geology, in its majority the site is underlain by glaciofluvial deposits (gravel, sand and silt). On the southern part, is also underlain by glacial till.

Trial pits that were established on 02/11/2021 and 03/11/2021 at the two locations of the proposed BESS sites revealed gravelly clay soils with poor infiltration potential (refer to Appendix E).

5 Basic Flood Risk Assessment

Fluvial, surface water, groundwater flooding has been reviewed in the following sections to determine whether the flood hazard is a viable risk to the proposed development and if a further assessment is required. Coastal flooding has been exempted from the assessment due to the site's inland setting.

5.1 Fluvial Flood Risk

According to the SEPA Flood Maps (SEPA, 2022), the site is partly affected by fluvial flooding from the River Isla. **Further assessment** is required to determine the flood risk. This further assessment is provided within Sections 6 and 7 below.

5.2 Surface Water Flood Risk

According to the SEPA Flood Maps (SEPA, 2022), localised pockets of surface water flooding are observed within and on the boundary of the southern parcel of land, and within a low point in the centre of the northern parcel of land. These areas are where solar infrastructure is proposed and the BESS site is shown to be on sloping ground not affected by surface water flooding. Solar panels will be raised above ground levels and are not considered to be sensitive to the localised shallow surface water flooding indicated by the SEPA flood maps. In addition, existing field drainage, not accounted for within the SEPA flood maps, likely reduces the risk of surface water flooding in these areas. SuDS are proposed for the BESS site which will minimise the risk of the development increasing downslope surface water flood risk. Overall, the site is considered to be at **little or no risk** of surface water flooding.

5.3 Infrastructural Flood Risk

Flooding from existing infrastructure such as reservoirs, drainage systems or flood defences can occur where capacity in the system is insufficient or when maintenance lapses. The site is not nearby or constricted by any infrastructural flooding risk. It is therefore considered infrastructural flooding is not a significant hazard and the site is at **little or no risk**.

5.4 Groundwater Flood Risk

According to the SEPA Flood Maps (SEPA 2022), the site is located within an area with a low likelihood that groundwater could influence the duration and extent of flooding from other sources. No significant excavations are assumed to be required and therefore no interaction with groundwater is expected. Percolation tests have indicated poor infiltration rates affecting the site, therefore groundwater conditions may increase the risk of surface water flooding within poorly draining depressions. However, as noted above the raised solar infrastructure is not considered to be sensitive from this flood mechanism. Overall, the site is considered to be at **little or no risk** from groundwater flooding.

6 Hydrological Assessment

A hydrological assessment has been undertaken to provide an estimate of the design flows within the River Isla. The catchment descriptors have been retrieved from the Flood Estimation Handbook (FEH) online web service and are presented in Appendix C.

6.1 River Isla Catchment Description

River Isla is a tributary of River Tay with a total upstream catchment area at the site of 1,187km^2 as shown in Diagram 1 below.

Diagram 1: FEH Catchment for River Isla

A summary of catchment descriptors is provided in Table 1. The catchment has a standard percentage runoff (SPRHOST) of 37.57% and base flow index (BFIHOST19) of 0.502 suggesting a moderate response to rainfall events and fairly reliable baseflow.

The catchment has a standard annual average rainfall (SAAR) of 1018 mm which is below the average for Scotland (the average Met Office statistics for 1961-1990 for Scotland is approximately 1470mm).

Table 1: Catchment Descriptors for River Isla

Descriptor	River Isla Catchment
NGR Location	NO 19250 39600
Area (km^2)	1,187
FARL	0.964
BFIHOST19	0.502
SPRHOST (%)	37.57
SAAR (mm)	1018

6.2 Design Flow Estimation

Two methods of flow calculation have been considered for use within the hydraulic model to determine flood extents, depths and velocities. These are the FEH Statistical method and the Revitalised Flood Hydrograph (ReFH2) model method.

SEPA generally recommend to take the worst-case scenario of the two methods as the design flow. The return period to design to is the 1 in 200-year event, plus an allowance for climate change. The latest SEPA guidance (SEPA 2022) recommends a 53% allowance for climate change is adopted for watercourses within the River Tay catchment.

6.2.1 FEH Statistical Method for River Isla

The statistical methods are those as published by the Institute of Hydrology (Robson and Reed 1999), with the updates included in the latest version of WINFAP-FEH (Kjeldsen et al. 2008). These methods require the estimation of a normalised flood frequency curve, termed the flood growth curve and the estimation of the normalising variable; the median annual flood, QMED.

The QMED for River Isla has been estimated from the catchment descriptors (QMEDcds) as 192.5 m^3/s.

Possible donor catchments to use for adjustment of QMED were sought on the basis of being geographically close; the general criteria is that the centroids of the donor and target catchments should preferentially be within 50km of one another. The similarity of catchment descriptors; Area, SAAR, FARL and BFIHOST were also considered. No suitable donor catchments were found during the analysis.

The final peak flows are presented in Table 2 below. These represent the QMED value (2-year return period) for a range of return periods up to the 200-year + climate change event. The design flow for the River Isla using the statistical method is therefore **715.14 m^3/s**.

Table 2: River Isla Estimated Design Flows (Statistical Method)

Return Period (years)	Design Flow (m^3/s)
2	192.51
10	281.45
25	331.50
50	372.70
100	417.74
200	467.41
200 + 53 % CC	**715.14**

6.2.2 ReFH2 Method

ReFH2 is a method for generating flood peak values and hydrographs for a given rainfall event based on catchment descriptors. ReFH2 effectively estimates flow rates with a FARL value set to 1.0 i.e. no storage is accounted for within the catchment. As the River Isla catchment has a FARL value of 0.964, using ReFH2 for flow estimation is more likely to generate representative flow estimates.

Peak flow estimation using ReFH2 are shown in Table 3.

Table 3: ReFH2 peak flow estimation

Return Period (years)	Peak flow (m^3/s)
2	287.52
10	444.22
25	536.60
50	612.85
100	697.07
200	790.48
200 + 53% CC	**1331.00**

6.3 Summary of Flows

ReFH2 flows will be used within hydraulic modelling for River Isla. This represents the most conservative approach.

7 Hydraulic Model

7.1 Hydraulic Model Build

A 1D/2D linked model has been developed for the River Isla utilising Flood Modeller software and 1m resolution LiDAR data from the publicly available Scottish Government Phase 1 dataset. In-channel cross sections have been extracted from the LiDAR dataset using the Cross Section Generator tool on Flood Modeller. A total of 52 sections have been incorporated into the 1D model, as shown in Diagram 2 below (for a full model layout refer to Figure 2, Appendix A). Flows have been derived utilising FEH statistical and ReFH2 methodologies, with the worst case adopted within the modelling. No topographic surveys of the watercourse channel have been undertaken and no in-stream structures are located along the modelled reach of the River Isla (as discussed in Section 1.4).

Roughness values, known as Manning's n, were determined based on aerials maps and onsite observations with reference to Chow (1959) and applied to the model to allow for energy losses due to friction. The channel of both watercourses was given a Manning's value of 0.035 representing a silt and gravel bed. Both banks were given a value of 0.05 representing the vegetation and fields. The downstream boundary condition was set as a normal depth with slope of 0.0001, the average gradient over the downstream cross sections.

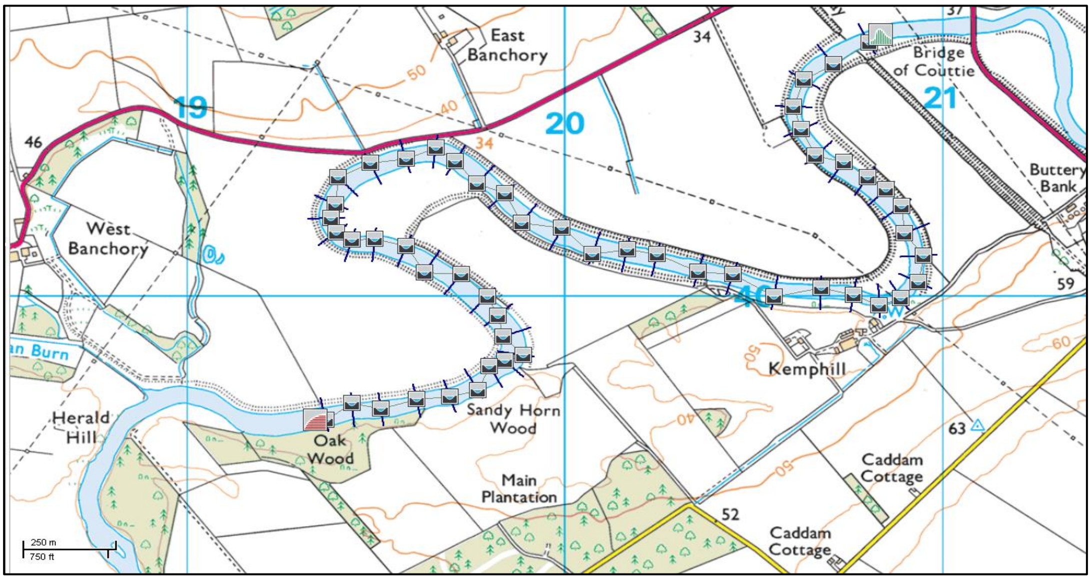

Diagram 2: Cross sections featured within the 1D Model.

7.2 Model Results

The model was run for a full range of flows from a 1 in 5 year event up to the design event (1 in 200 year event plus CC) (refer to Appendix D for 1D Model results). Figures 3 and 4 within Appendix A show the flood extents for the 1 in 200 year event and the design flood event, with the development area shown red.

During the design event, extensive out-of-bank flooding is observed on both banks of the River Isla, as indicated by the SEPA flood maps. Flooding of the A984 road is observed at the northern extent of the model domain, whilst primarily agricultural fields are observed to be flooded across the southern extent of the model domain. Flood embankments are observed to be breached during the 1 in 5 year event, indicating that they afford limited protection to the surrounding land from peak flow events.

Within the site boundary, a limited area of flooding during the design event is observed within the northern parcel of land adjacent to the River Isla. Flood levels during the design event and within the site boundary range from 35.26m AOD to 35.62mAOD, with a maximum depth of 4.2m observed directly at the site boundary. The topography is observed to steepen quickly within the site boundary, with elevations increasing by 7m over a distance of 100m from the site boundary, as was corroborated with site observations (Appendix B Photo 7). The results in only a limited area (~9000m^2) within the site boundary being affected by flooding during the design event.

7.3 Sensitivity Analysis

Model sensitivity analysis provides an illustration of the effect of changing key model parameters on the important model outputs by rerunning the model for a range of scenarios and changing one input parameter per each model run, the effect of each input on the model can be isolated. If model parameters are varied within the range of possible input values, then a sensitivity analysis can also provide an indication of uncertainty associated with the model predictions.

The 1D/2D model was run to include an increase in peak flow rates above the 1 in 200 year event, Manning's values increased by 10%, increasing the flows by 10% for the 200 year plus climate change event (refer to Figure 7 and Figure 8, Appendix A).

A summary of results is provided below:

- Increasing Manning's values by 10% throughout the model's channel and banks showed water levels to increase throughout the model and but increased the flood extent within the site boundary only slightly.
- Increasing flows by 10% showed increased water levels within the site boundary but did not have an impact on flood extents.

7.4 Fluvial Flood Risk Summary

The initial design provided to inform this FRDA indicates solar panels being located with the modelled design flood extent from the River Isla. The affected area represents approximately 1.5% of the total proposed solar farm, and the 16MW BESS is not shown to be affected by fluvial flooding. No land raising is proposed, and the solar panels are unlikely to have any impact on overall floodplain conveyance, however the assets will be at direct risk of flood damage in addition to their placement being contrary to the principles of Scottish Planning Policy. Mitigation is required in order for the development to be acceptable.

7.5 Fluvial Flood Risk Mitigation

It is recommended that all solar infrastructure is located outwith the modelled design flood event and above the maximum flood level (35.62mAOD). An additional freeboard on this level is not deemed necessary as the solar panels themselves will typically be elevated at least 600mm above ground levels.

8 Drainage Impact Assessment

8.1 Existing Drainage

The proposed site for the 16MW BESSS currently comprises an agricultural field with runoff currently directed northwards towards woodland where perimeter ditches are present. There is also an existing ditch adjacent to the minor road to the east of the 16MW BESS site.

A walkover of the fields where the solar farm is to be located has shown that existing runoff is primarily directed towards ditches alongside the minor road and directly to the River Isla along the northern boundary. Evidence of subsurface field drains and an apparent soakway was noted during the site visit. Refer to Appendix A Figure 1.

8.2 Drainage Strategy: Solar Farm

The solar farm will involve the placement of new impermeable surfaces within the site boundary associated with the solar panels. However, it is generally accepted that runoff from the solar panels can be allowed to fall to ground below where it will naturally infiltrate, with studies indicating that there is limited impact on overall runoff rates as a result of solar farm developments (Cook and McCuen 2013). No formal drainage is therefore proposed for the solar farm. Access tracks, where they are to be permanent, should incorporate SuDS in the form of a trackside swale and diffuse outfalls.

8.3 Drainage Strategy: 16MW BESS

8.3.1 Catchment Area

A catchment area of 0.275Ha has been estimated based on the design information provided. The current design information indicates the development will incorporate areas of semi-pervious hardstanding (compacted aggregate) and impermeable surfaces associated with the battery container units. A percentage impervious (PIMP) value of 80% has been applied given the development proposals.

8.3.2 Greenfield Runoff Rates

Greenfield runoff rates have been estimated for the 16MW BESS using ReFH2 software and point rainfall descriptors for grid reference NO 20585 39099. Greenfield runoff rates up to and including the 1 in 200 year event plus 39% allowance for climate change (herein referred to as 'CC') are provided within Table 4 below**Error! Reference source not found.**, based on the 0.275Ha catchment area derived from the design extent.

Table 4: Greenfield Runoff Rates (16MW BESS)

Return Period (years)	Peak flow (l/s)	Total Direct Runoff (m^3)
1	0.285	6.08
2	0.324	6.95
10	0.564	12.2
30	0.743	16.1
50	0.877	18.2
100	0.977	21.2

Return Period (years)	Peak flow (l/s)	Total Direct Runoff (m^3)
200	1.130	24.7
200 + 39% CC	**1.173**	**37.8**

8.3.3 Post Development Runoff Rates

Post development runoff rates, in the absence of SuDS attenuation, are provided within Table 5 below.

Table 5: Post Development Runoff Rates (16MW BESS)

Return Period (years)	Peak flow (l/s)	Total Direct Runoff (m^3)
1	0.353	6.14
2	0.396	7.09
10	0.672	13.2
30	0.891	17.9
50	1.010	20.5
100	1.190	24.4
200	1.4	29
200 + 39% CC	**2.22**	**46.8**

8.3.4 Proposed Discharge Locations

In accordance with CIRIA C753, the hierarchy for disposal of surface water runoff should be (i) infiltration to groundwater, (ii) discharge to surface waters and (iii) discharge to sewer.

Table 6 below provides a review of these options for the proposed 16MW site.

Table 6: Surface Water Disposal Options

Surface Water Disposal Method	Review	Method Suitable? (Y/N)
Infiltration to groundwater	Soakaway tests undertaken (Appendix E) did not record a valid Vp value as the observed water level did not sufficiently drain to below the 25% threshold. Therefore the soils provide insufficient infiltration to enable discharge to groundwater.	N
Discharge to surface waters	A drainage ditch was observed adjacent to the minor road to the north of the BESS site. Drainage modelling has identified that a sufficient fall is achievable to enable outfall to this feature. Therefore, this is assessed as the preferred option for disposal of surface water.	Y
Discharge to sewers	A search for Scottish Water assets has not been undertaken however it is considered unlikely that a surface water sewer would be present given the rural location.	N

8.3.5 Proposed SuDS

A swale to the north of the development has been determined as the most appropriate SuDS feature to provide attenuation of runoff given the topography and limited space between the BESS and downslope solar infrastructure. It is proposed that the BESS hardstanding is graded towards the swale which would receive runoff via lateral flows. The swale would be connected with the roadside drainage ditch via two manholes and a new pipe network, with flows controlled via a hydro-brake. The swale would be located above the groundwater level indicated by trial pits in the area and therefore is assumed not to require an impermeable liner.

The swale has been designed in accordance with CIRIA C753 and dimensions are outlined in Table 7 below. A

Table 7: Swale dimensions

Parameter	Value
Top width	6m
Base width	1.2m
Side slope	1:3
Depth	0.8m
Length	106m
Long slope	1:250
Storage provided	$305m^3$

8.3.6 Drainage Design Criteria

Drainage modelling has been undertaken using InfoDrainage software and a full audit report is provided within Appendix F. The design criteria has been informed by Perth and Kinross guidance (Perth and Kinross Council 2021). The design criteria is outlined in Table 8 below.

Table 8: Drainage design criteria

Parameter	Criteria
Post-development discharge rates	A 1l/s restricted discharge rate has been applied to the drainage network which would be achieved via a hydro-brake at the swale outlet. This is considered the minimum practicable discharge rate.
Post-development discharge volumes	The drainage network has been sized to ensure that the post development 1 in 200 year 6 hour rainfall volume does not exceed the pre development equivalent in line with CIRIA C753.
Surcharge criteria	The drainage network has been sized to ensure no surcharge from all events and durations up to and including the 1 in 30 year event
Flood criteria	The drainage network has been sized to ensure no flooding from all events and durations up to the 1 in 200 year event plus 39% allowance for climate change

8.3.7 Maintenance and Vesting

Key maintenance requirements as stated within CIRIA C753 for swales will include:

- Cut grass and manage other vegetation and nuisance plants (monthly during growing season).
- Inspect inlets, outlets and overflows for blockages and silt accumulation (monthly to every 6 months).
- Relevel uneven surfaces, repair erosion and reseed bare ground (as required).

The proposed SuDS and drainage network within the site boundary will be privately owned and maintained, with no requirement for any adoption.

9 Conclusions

The proposed Keithick Solar Farm and Battery Energy Storage System (BESS) development has been assessed in relation to major sources of flooding and a quantitative assessment of fluvial flooding has been provided. A 1D/2D linked model of the River Isla has been developed using Flood Modeller software and 1m resolution LiDAR data. Flows have been estimated using FEH statistical and ReFH2 methods, with the higher ReFH2 flows adopted within the modelling.

Approximately 1.5% of the site boundary has been identified to be affected by fluvial flooding during the 1 in 200 year plus 53% allowance for climate change event ("design flood event"). The area of flooding is located on the northern perimeter of the development area adjacent to the River Isla. Sensitivity analysis has demonstrated limited changes to the modelled flood extents, primarily due to topography increasing within the site boundary. Mitigation in the form of avoiding any development within the modelled design flood extent is proposed.

The development has been assessed to not be at a significant risk of surface water, groundwater or infrastructure flooding. Provided the mitigation in the form of avoiding all development within design flood extent is adopted, the development is not considered to be at a significant risk of fluvial flooding and therefore acceptable under the principles of Scottish Planning Policy.

An outline drainage design has been developed for the 16MW BESS site incorporating a swale sized to attenuate the 1 in 200 year plus 39% allowance for climate change rainfall event. All discharges are restricted to 1l/s and the drainage network has been sized to ensure no surcharge during the 1 in 30 year event. For the solar farm, no formal drainage is considered to be required as runoff from the installed panels is assumed to naturally infiltrate below the panels with limited impact on overall site runoff rates.

The drainage impact assessment demonstrates that SuDS are achievable given the development proposals and land available. A detailed drainage design following the principles set out within this report will be submitted to Perth and Kinross Council for approval prior to construction.

Overall, this report has demonstrated that there are no overriding impediments to the development being granted planning permission on the grounds of flood risk or surface water drainage, subject to the slight proposed changes to design footprint.

References

Chow, V. T. (1959). Open-channel hydraulics: New York, McGraw-Hill Book Co., 680 p.

Cook and McCuen (2013). Hydrologic response of Solar Farms. Journal of Hydrologic Engineering 18. pp 536-541.

Kjeldsen, T.R., Jones, D. A., and Bayliss, A.C. (2008). Improving the FEH Statistical procedures for flood frequency estimation.

Perth and Kinross Council (2021). Flood Risk and Flood Risk Assessments.

Robson, A.J. and Reed, D.W. (1999). Flood Estimation Handbook: Vol. 3 Statistical procedures for flood frequency estimation.

Scottish Government (2014). Scottish Planning Policy.

Scottish Water (2018). Sewers for Scotland 4th Edition.

SEPA (2019a). Technical Flood Risk Guidance for Stakeholders.

SEPA (2022). Climate change allowances for flood risk assessment in land use planning, Version 2

SEPA (2022). Flood Maps. Available online at: https://www.sepa.org.uk/environment/water/flooding/flood-maps/