LT14 Western Isles HVDC - Arnish Moor FRA Level 3

Flood Risk Assessment Report

October 2024

This page left intentionally blank for pagination.

Mott MacDonald
Moray House
16-18 Bank Street
Inverness IV1 1QY
United Kingdom

T +44 (0)1463 239323
mottmac.com

LT14 Western Isles HVDC - Arnish Moor FRA Level 3

Flood Risk Assessment Report

October 2024

Issue and Revision Record

Revision	Date	Originator	Checker	Approver	Description
P01	15/10/24	J Barr	L Cload	H. Shrive	First Issue

Document reference: 109647 **|** P01 **|** 109647-MMD-ARNI-XX-RP-CE-0005

Information class: Standard

Contents

Glossary

Annual Exceedance Probability (AEP): The probability that a given rainfall total accumulated over a given duration will be exceeded in any one year.

Design Flood: a flood event of a given annual flood probability, which is river flooding likely to occur with a 0.1% annual probability (a 1 in 1000 chance each year); or tidal flooding with a 0.1% annual probability (1 in 1000 chance each year); or surface water flooding likely to occur with a 0.1% annual probability (a 1 in 1000 chance each year), plus an appropriate allowance for climate change.

Essential Infrastructure: SEPA's Flood Risk Planning Guidance defines Essential infrastructure, also known as critical infrastructure. They must be built where it is necessary for operation, which frequently means building within Flood Zones with a high or medium risk of flooding. Given the 'essential' nature of these projects, they are generally permitted within all Flood Zones so long as they provide suitable mitigation. Examples of this include energy plants, transport, evacuation routes, and water treatment works.

Flood Risk: a combination of the probability and the potential consequences of flooding. Areas at risk of flooding are those at risk of flooding from any source, now or in the future. Sources include rivers and the sea, direct rainfall on the ground surface, rising groundwater, overwhelmed sewers and drainage systems, reservoirs, canals and lakes and other artificial sources. Flood risk also accounts for the interactions between these different sources.

Flood Risk Areas Scotland: For areas at risk of river and sea flooding, this is principally land within Medium Likelihood and High Likelihood areas that will be at risk of flooding in the future. It can also include an area within Low Likelihood which SEPA or the local planning authority has notified as having critical drainage problems.

Flood Risk Management Plans (FRMP): The Regulations require that Flood Risk Management Plans are put in place for each Flood Risk Area. These plans will set objectives and measures to help manage flood risk. The plans will also link to the local strategies required by the FWMA. The Flood Risk Management (Scotland) Act 2009 requires that National and Local Authorities and partners led by SEPA to prepare 14 flood risk management strategies that together form the first national plan for flood risk management in Scotland.

Flood and Water Management Act 2010 (FWMA). UK Act of Parliament relating to the management of the risk concerning flooding and coastal erosion.

Local Flood Risk Management Strategy (LFRMS): There is 14 local flood risk authorities in Scotland. Along with 14 strategies there are 42 formal flood protection schemes proposed between 2016 and 2021. The strategies explain what causes flooding in high-risk areas as well as the impacts when flooding does occur. This information is used as a basis for better decision-making across flood risk management organisations.

NPF4: Scottish Government's National Planning Framework 4. It sets out the spatial principles, regional priorities, national developments, and national planning policy in Scotland.

Scottish Environment Protection Agency (SEPA): The Scottish Environment Protection Agency is Scotland's environmental regulator and national flood forecasting, flood warning and strategic flood risk management authority.

Surface Water Management Plan (SWMP): is a plan which outlines the preferred surface water management strategy in a given location and is developed by Local Authorities in consultation with local partners responsible for surface water management and drainage. In this context, surface water flooding describes flooding from sewers, drains, groundwater, and runoff from land, small watercourses and ditches that occurs as a result of heavy rainfall.

SSEN: Scottish & Southern Electricity Networks. Energy company in the UK also involved in electricity transmission and distribution.

Executive Summary

The Flood Risk Assessment considers the area of the proposed Arnish Moor HVDC Site, adjacent to three unnamed watercourses centred at National Grid Reference (NGR) NB 40460 32028. The proposed development being assessed is the HVDC compound which is proposed to be constructed on part of the Site.

Peak flows in the watercourse have been assessed using the methodologies outlined in the Flood Estimation Handbook (FEH). The estimates from the Revitalised Flood Hydrograph 2 (ReFH2) Method have been adopted and used in the hydraulic modelling.

Flood levels at the site have been calculated using a two-dimensional computational model of the watercourse using the TUFLOW software package. The underlying Digital Terrain Model (DTM) has been based on the available 0.5m grid LiDAR data.

This study shows that the subject Site is partially flooded with flooding from both the northern and southern watercourses expected to cover some areas within the Site’s boundary. However, the areas which are affected by flooding are low lying and close to the watercourses. The HVDC Platform is located at higher ground elevation and is located outside of the functional floodplain.

It is noted that the western part of the site is lower than the predicted flood level and is defended by natural ground. The ability of the natural ground to provide a water retaining function should be confirmed.

The proposed design plans to fill in and incorporate the drainage of one of the watercourses into onsite SUDS drainage. The location of the basins shall consider the functional floodplain of the remaining two unnamed watercourses.

The proposed development is not located within the fluvial floodplain and will therefore not adversely affect flood risk elsewhere. Surface water drainage will use appropriate sustainable drainage systems to ensure no increase in runoff over the greenfield runoff rate (Qbar) from the subject site and managing flow paths, so flood risk elsewhere is not affected.

1 Introduction

1.1 Background

Mott MacDonald has been commissioned by Scottish & Southern Electricity Networks (SSEN) to undertake a Flood Risk Assessment (FRA) to support a planning application for the Arnish Moor HVDC Convertor site.

Arnish Moor site is part of the wider Western Isles HVDC project. It is proposed to construct a sub-sea High Voltage Direct Current (HVDC) cable link from the Arnish Point (Isle of Lewis) to Scottish mainland (Dundonell, Highland). Following a site selection process, SSE have identified the Arnish Moor site to take forward to house the 525kV Bipole Converter Station and 400kV / 132kV AC Substation. The HVDC cable landfall location is situated at the Arnish site and the proposed a cable corridor follows the local road. The Proposed Development is to facilitate the transmission of electricity from renewable generators, with several wind farms in the early phase of development, whilst providing energy security for the Isles of Lewis and Harris. The Western Isles HVDC project will play a key role in helping achieve Net-Zero targets.

1.2 Scope and purpose of study

A FRA[1] Level 1 was carried out by Mott MacDonald in September 2024, where all potential sources of flood risk have been reviewed. The FRA Level 1 concluded that the site is potentially at risk of fluvial flooding from the small unnamed watercourses which run along both the northern and southern boundary lines and it was recommended to assess the fluvial flood risk of these watercourses by detailed hydraulic modelling.

The scope of this FRA Level 3 is to quantify the fluvial flood risk from the unnamed watercourses along the northern and southern boundaries.

This document should be read in conjunction with the previous FRA Level 1 document, where further information on all assessed flood sources is presented.

[1] 109647-MMD-ARNI-XX-RP-CE-0005 Western Isles-Arnish Moor Site FRA Level 1.docx

2 Flood Risk Policy and Guidance

2.1 National Planning Policy Framework

Policy 22 of the Scottish Government's National Planning Framework 4 (NPF4[2]) discusses flood risk in relation to new development.

a) Development proposals at risk of flooding or in a flood risk area will only be supported if they are for:

i. Essential infrastructure where the location is required for operational reasons;
ii. Water compatible uses;
iii. Redevelopment of an existing building or Site for an equal or less vulnerable use;
iv. Redevelopment of previously used sites in built up areas where the LDP has identified a need to bring these into positive use and where proposals demonstrate that long term safety and resilience can be secured in accordance with relevant SEPA advice

The protection offered by an existing formal flood protection scheme or one under construction can be accounted for when determining flood risk. In such cases, it will be demonstrated that:

- All risks of flooding are understood and addressed;
- There is no reduction in floodplain capacity, increased risk for others, or a need for future flood protection schemes in the area;
- The development remains safe and operational during floods;
- Flood resistant and resilient materials and construction methods are used;
- Future adaptations can be made to accommodate the effects of climate change

Additionally, for development proposals meeting criteria part iv), where flood risk is managed at Site rather than avoided these will also require:

- The first occupied/utilised floor, and the underside of the development if relevant to be above the flood risk level and have an additional allowance for freeboard;
- That the proposal does not create an island of development and that safe access and egress to the site remains attainable

b) Small scale extensions and alterations to existing buildings will only be supported where they will not significantly increase flood risk.

c) Development proposals will:

i. Not increase the risk of surface water flooding to others or be at risk itself;
ii. Manage all rain and surface water through sustainable urban drainage systems (SUDS) which should form part of and integrate with proposed and existing blue-green infrastructure. All proposals should presume no surface water connection to the combined sewer;
iii. Seek to minimise the area of impermeable surface

d) Development proposals will be supported if they can be connected to the public water mains. If connection is not feasible the applicant will need to demonstrate that water for drinking water

[2] National Planning Framework 4 - gov.scot (www.gov.scot)

purposes will be sourced from a sustainable water source that is resilient to periods of water scarcity.

e) Development proposals which create expand or enhance opportunities for natural flood risk management including blue and green infrastructure will be supported.

NPF4 is complemented by the flowing policy documents:

- Planning Advice Note (PAN) 61: 'Planning and Sustainable Urban Drainage Systems'
- Planning Advice Note (PAN) 69: 'Planning and Building Standards Advice on Flooding'
- SEPA Planning Authority Protocol (Policy 41) 'Development at Risk of Flooding: Advice and Consultations'
- SEPA Technical Flood Risk Guidance for Stakeholders v13 (June 2022)
- SEPA Flood Modelling Guidance for Responsible Authorities
- SEPA Climate change allowances for flood risk assessment in land use planning version 5 (August 2024)
- CIRIA guidance document C624: 'Development and Flood Risk'

SEPA's Technical Flood Risk and Guidance for Stakeholder's characterises areas in terms of flood risk in its 'Risk Framework' as follows:

- Little or no risk area (annual probability of flooding of less than 0.1% (1 in 1000 years)) – no general constraints
- Low to medium flood risk (0.1% to 0.5% (1 in 1999 to 1 in 200 years)) – suitable for most development but not essential civil infrastructure
- Medium to high-risk area (0.5% (1 in 200) or greater) – In built up areas these may be suitable provided flood prevention measures to the appropriate standard exist are currently under construction or are planned as part of a long-term strategy. If built development is permitted appropriate measures to manage flood risk will be required and the loss of flood storage capacity mitigated.

The functional floodplain is described as having a 'greater than 0.5% (1 in 200 years) probability of flooding in any year'.

An allowance for 'freeboard' to account for uncertainties in the modelling results, wave action, etc is generally added onto the indicative flood levels. SEPA recommends a minimum freeboard of 500mm to 600mm[3].

Estimated flood wate levels have been calculated for the 0.5% and 0.1% Annual Exceedance Probability (AEP) flood events (1 in 200-year and 1 in 1000-year return periods) including an allowance for climate change.

[3] SEPA Guidance Note entitled: '*Technical Flood Risk Guidance for Stakeholders, V7'.*

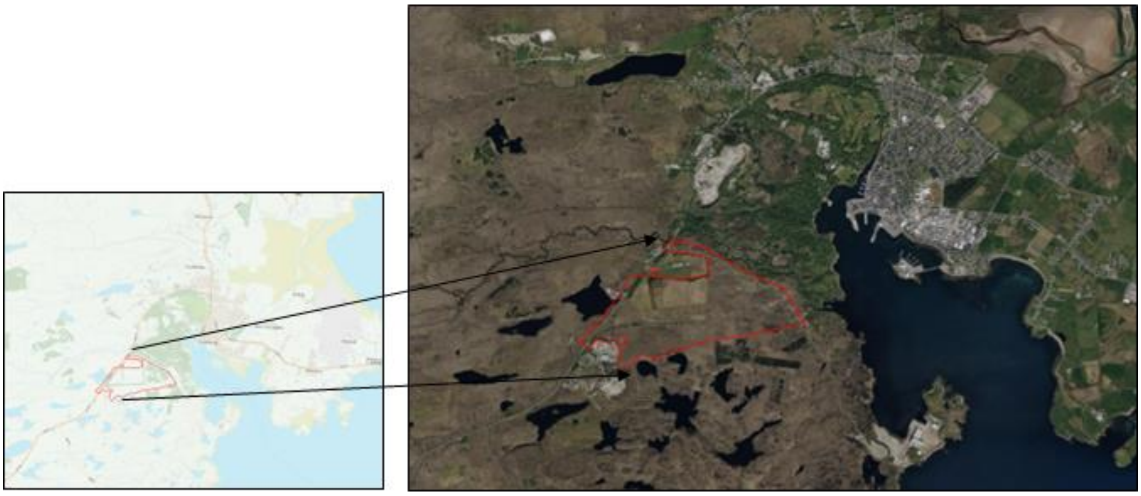
3 Site Description

3.1 Study Area Description

The proposed Arnish Moor Site is located approximately 1km south-west of Stornoway on the Isle of Leis, Scotland. It is approximately 3km inland from the Arnish landfall location.

The Site is centred at National Grid Reference (NGR) NB 40460 32028, approximately Easting: 14063, Northing: 931771 and can be accessed via the A859 road. This site is surrounded by grassy and rocky open fields that are not cultivated for agricultural use. The land cover is comprised predominately of peat, heather, grass, etc. At the northern Site boundary there is the River Creed watercourse which runs parallel to the boundary. The Site is not located within the River Creed floodplain. On the east side the A859 runs parallel to the site boundary.

Figure 3.1: Site Location



Source: Contains OpenStreetMap data © Copyright OpenStreetMap Contributors (2023) and ©2023 Microsoft Corporation ©2023 Maxar © CNES (2023) Distribution Airbus DS.

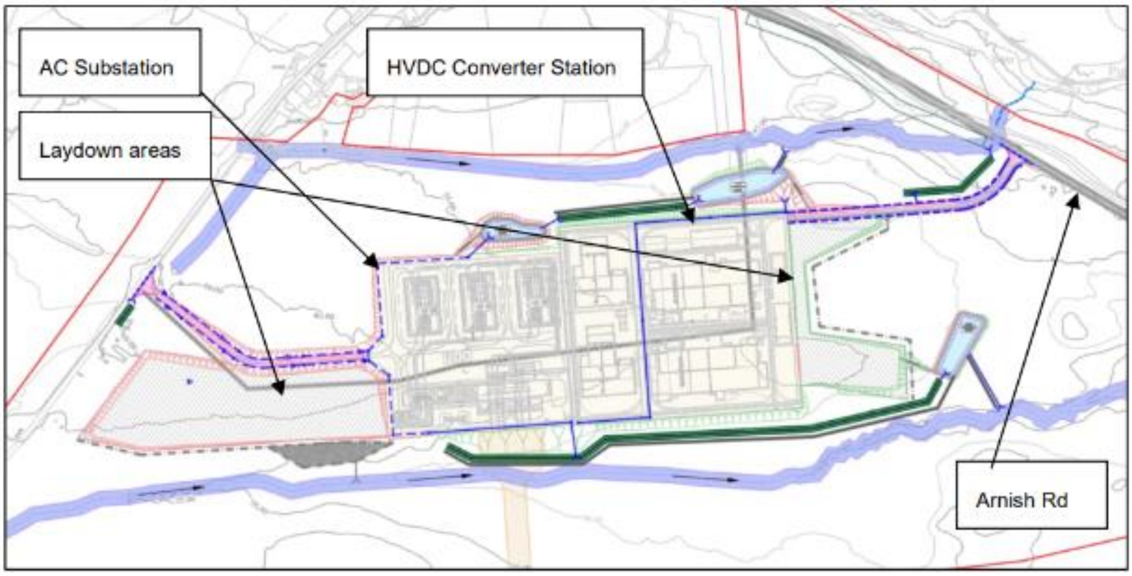
The total area of the Site is around 1.27km^2 and is situated on a generally hilly moorland area. North-west of the proposed Site there is an existing Stornoway Substation, and just south of the Site's boundary is the Western Isles motorcross track.

Road A859 is located west of the Site and is the only access route. On the northern side of the Site there are existing residential properties located along the A859 and the RLB is shaped to avoid those areas.

3.2 Proposed Development Description

The design of buildings and facilities within the site is in the optioneering phase and need to be confirmed. However, the proposed facilities for the site that are known so far have been described. The site will be equipped with a 525 kV HVDC Converter Station and a 400kV/132kV AC Substation, along with associated facilities, equipment, and access roads.

Figure 3.2: Proposed Site Layout



Source: Proposed Permanent Surface Water Layout – 109647-MMD-ARNI-XX-DR-CE-0003.

A new 400kV / 132 kV AC substation is to also be provided by SEE in conjunction to the Western Isles HVDC Link. The AC Substation is to facilitate the step up of any renewable generators into the Converter Station.

The interface between the AC Substation and Convertor Station platform is to be defined by SEE. Presently the AC Substation is assumed to be on the same platform with an independent drainage network.

Along with the permanent platform for HVDC Converter and AC Substation there are temporary compounds for the construction phase, land provisions for screening and drainage features, storing areas, etc. Compounds are to provide enough space for offices, parking, and a laydown area.

No works that would affect flood risk or are vulnerable to flooding are proposed to the west of the A859.

The proposed Platform Surface Levels (PSL's) are as follows:

- Converter Station/AC Substation platform – 55.50 mAOD.
- Laydown area 2 – 55.50 mAOD
- Laydown area 3 – 55.50 mAOD

4 Flood Risk Assessment

4.1 Potential Flood Sources

The main potential sources of flood risk to a development are as identified in Table 4.1.

Table 4.1: Categories of Flood Risk

Category	Mechanism
Fluvial flooding	Flooding caused by the exceedance of the flow capacity of the channel of a nearby watercourse. Fluvial flooding is often associated with heavy rainfall and excess water spills onto the river floodplains.
Coastal and tidal flooding	Flooding caused by high astronomical tide, storm surges, wave action and local bathymetric effects, often in combination. In estuaries and watercourses affected by tide locking flooding can occur as a result of high tidal levels and high fluvial levels in combination.
Pluvial flooding (Overland flow)	Flooding caused by the flow of water over the ground surface that has not reached a natural or artificial drainage channel. Occurs when intense rainfall exceeds the infiltration capacity of the ground or when the ground is highly saturated and is unable to accommodate any further water.
Groundwater flooding	Flooding caused by raised groundwater levels usually following prolonged periods of rain (which may be slow to recede). High groundwater levels may result in increased overland flow flooding. This type of flooding is usually associated with catchments with poor substrate and/or aquifers.
Flooding from artificial drainage systems	Flooding caused by blockage or the overloading of pipes, sewers, canals and drainage channels or failure of pumping stations. This flooding typically follows heavy rainfall or as a result of high-water levels in a receiving watercourse.
Flooding from infrastructure failure	Flooding caused by the structural, hydraulic, or geological failure of infrastructure which retains, transmits, or controls the flow of water. Examples include reservoirs, canals, flood defence structures, underground conduits (e.g., sewers), water treatment tanks and hydropower dams.

Adapted from: *CIRIA (2004) Development and Flood Risk, C624, Box 2.3*[4]

4.2 Conclusions from FRA level 1

The FRA[5] Level 1 concluded there are no record of historical flooding to the Site and that there are no known existing flood defences.

The FRA Level 1 assessed all sources of flood risk at the Site. The assessment concluded that the Site is not at risk of flooding from coastal and tidal flooding, groundwater flooding or flooding from artificial drainage.

The SEPA Surface Water flood risk maps show that there are some small and localised areas of surface water flooding on the Site due the existing topography. The Proposed Development will modify the existing topography, but the impact on surface water flooding is minor and

[4] Item Detail (ciria.org)

[5] 109647-MMD-ARNI-XX-RP-CE-0005 Western Isles-Arnish Moor Site FRA Level 1.docx

considered appropriate to be addressed through the design of the onsite drainage system. Therefore, surface water would be addressed as part of the drainage impact assessment.

The FRA Level 1 also concluded that there is a risk of flooding due to fluvial sources and a low potential due to infrastructure failure due to reservoir failure from the nearby Loch Cnoc a'Choilich. However, it was deemed that the infrastructure failure is a low risk and that flooding due to this source is addressed as part of the fluvial flood risk from the small unnamed watercourses running along the northern and southern borders of the site. These watercourses have upstream catchments which are less than $3km^2$ and therefore are not assessed within the SEPA fluvial maps. It has therefore been recommended to carry out a detailed hydraulic model of the unnamed watercourses to establish the extent of flood risk.

The FRA Level 1 also states that one of the unnamed watercourses, called Watercourse 2 in that assessment does not need a detailed hydraulic model as the flow path shall be filled in and the flow considered as part of the onsite sustainable urban drainage system (SUDS). As such the detailed modelling seen in this report focuses on Watercourses 1 (to the north of the Site) and 3 (to the south of the Site).

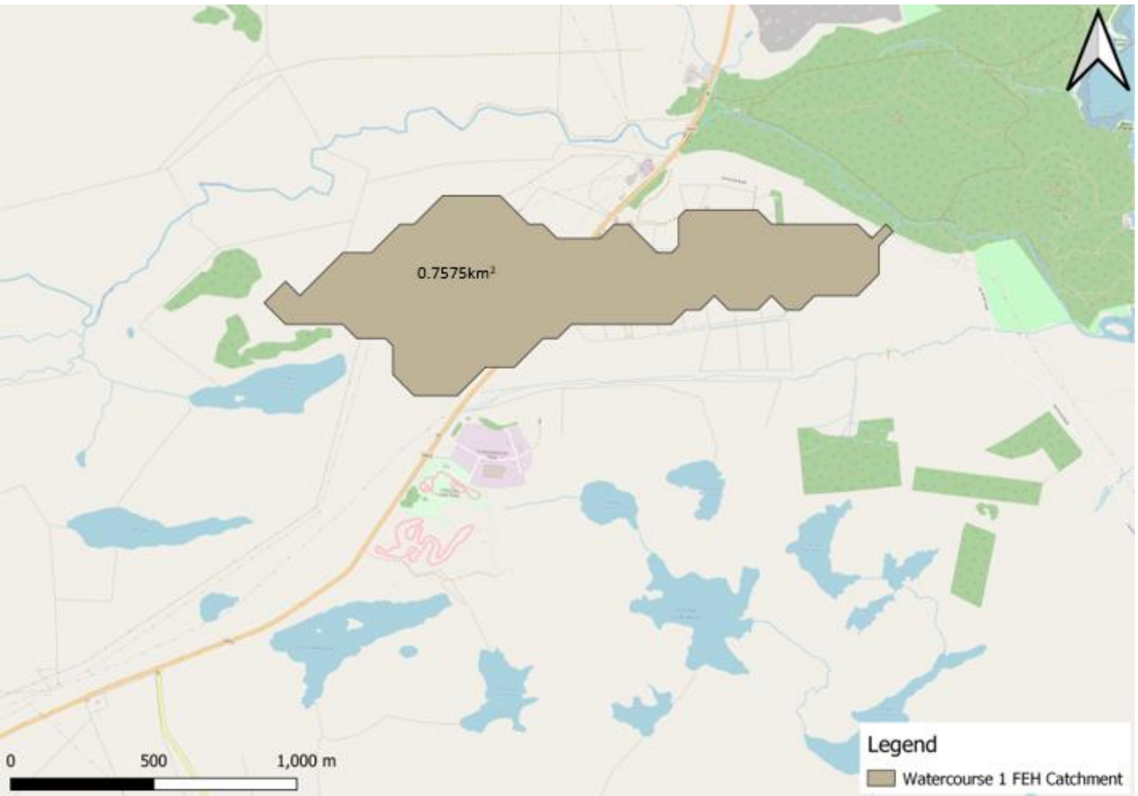
5 Hydraulic Modelling of the Unnamed Watercourses

5.1 Modelling Approach

A 2D hydraulic model has been constructed using the TUFLOW software package to quantify flood risk from the unnamed watercourses running along the northern and southern boundary of the Site.

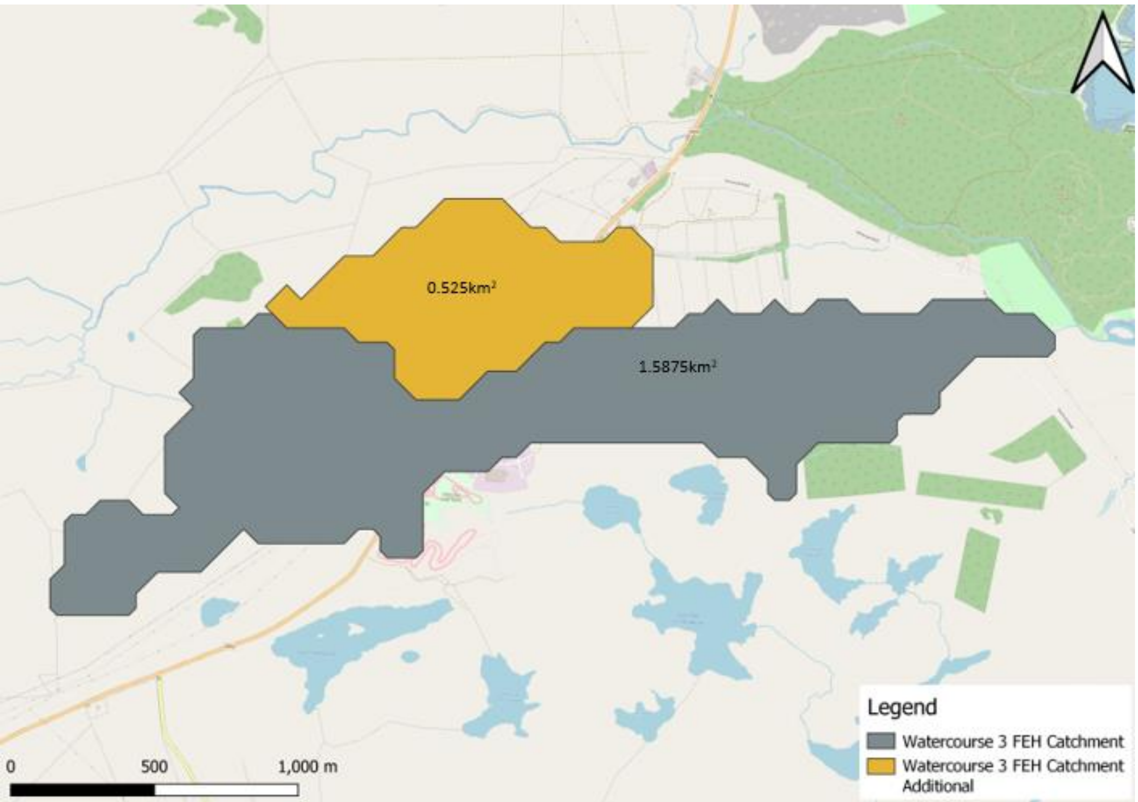
Loch Cnoc a'Choilich is upstream of the watercourses 1 and 3. Both watercourses are drained from the loch, but it is uncertain how they flow in an extreme flood event. As a conservative approach, the catchment of the loch has been double counted into both watercourses. Therefore, the area for the watercourse 3 is calculated using two separate FEH catchments and subsequently two separate ReFH2 analyses. These two analyses have been summed to provide a singular peak flow hydrograph. The total FEH catchment area of the watercourse 1 is approximately 0.76km^2. The catchment area of the watercourse 3 is approximately 2.11km^2. The catchment boundaries are shown in Figure 5.1 and Figure 5.2.

Figure 5.1: Unnamed Watercourse 1 (Northern) Catchment Area



Source: © OpenStreetMap contributors; Contains OS data © Crown copyright and database rights (2024)

Figure 5.2: Unnamed Watercourse 3 (Southern) and Additional Catchment Areas



Source: © OpenStreetMap contributors; Contains OS data © Crown copyright and database rights (2024)

5.2 Data Source

To undertake this study the following available data and information were collated and analysed:

- Western Isles Arnish Moor Site FRA Level 1
- LiDAR data available on 0.5m grid[6]
- Topographical survey
- Ordnance Survey Maps
- Data extracts from the FEH Webservice[7]
- SEPA Flood Maps[8]

[6] Scottish LiDAR Remote Sensing datasets | Scottish Government

[7] Map - FEH Web Service (ceh.ac.uk)

[8] Flood Risk Management Maps (sepa.org.uk)

5.3 Hydrological analysis

5.3.1 High flow estimation methodology

The flood estimation methods as outlined in the Flood Estimation Handbook (FEH) have been adopted to assess extreme flows in the subject watercourse. The choice of method is dependent on a variety of factors, such as:

- catchment size and location.
- extent of urbanisation within the catchment.
- availability of gauged records.
- catchment permeability; etc.

In this FRA, the FEH Revitalised Flood Hydrograph 2 (ReFH2) and Institute of Hydrology Report no.124 (IoH124) Method have been used to estimate flood flows in the unnamed watercourse at the Site.

5.3.1.1 ReFH2 Method

The Revitalised Flood Hydrograph 2 (ReFH2) model has been developed for modelling flood events. The ReFH model is a rainfall-runoff model, and the latest version (ReFH 2.3 model) uses the FEH22 design rainfall.

Three ReFH2 inflows were developed one for Watercourse 1 and two for Watercourse 3. The two for Watercourse 3 were combined to include the inflow from the FEH catchment of Loch Cnoc a'Choilich.

The storm duration generated within the ReFH2 model was 4.25 hours. The 75% winter storm profile with a timestep of 0.25 hours was used to calculate peak flows for the subject catchments.

5.3.1.2 IoH124 method

The IoH124 method uses a general model to estimate the Index Flood (QBAR) and general growth factors, which is applied to all catchment across the North of Scotland.

The IoH124 method is also best suited for the rural catchment of size between 0.5km^2 to 25km^2. The subject catchments are of size 0.76km^2 (Watercourse 1), 1.59km^2 (Watercourse 3), and 0.53km^2 (Watercourse 3 additional area).

5.3.2 Impact of climate change

In accordance with the lates SEPA guidance[9] for climate change on river catchments, the peak rainfall intensity in the subject catchment (in the Western Isles) has been increased by 48% (with a time horizon to 2080). The peak rainfall intensity has been used for the climate change uplift has been chosen due to the small size of the upstream catchments, that being under 30km^2 as per the guidance.

5.3.3 Design flows

The ReFH2 method uses the latest hydrological model and therefore, it has been chosen as the leading method for the subject catchment. The peak design flows are provided in Table 5.1.

The full summary of the hydrological analysis is provided in Appendix A.

[9] climate-change-allowances-guidance.docx (live.com)

Table 5.1: ReFH2 Rainfall-Runoff - Flood Flow Peak at Site Location (m³/s)

Return Period	Peak design flow Watercourse 1	Peak design flow Watercourse 3 Combined
1% AEP (or 1 in 100yr) flood event	1.79	4.71
0.5% AEP (or 1 in 200yr) flood event	2.06	5.45
0.1% AEP (or 1 in 1000yr) flood event	2.76	7.28
0.5% AEP+CC (or 1 in 200yr) flood event + cc 48% uplift applied	3.22	8.53
0.1% AEP+CC (or 1 in 1000yr) flood event + cc 48% uplift applied	4.38	11.59

Source: ReFH2

5.4 TUFLOW model development

A 2D hydraulic model has been constructed using the TUFLOW software package (TUFLOW 2020-10-AD) to quantify flood risk from the two unnamed watercourses. TUFLOW is a one-dimensional (1D) and two-dimensional (2D) flood and tide simulation software. It simulates the complex hydrodynamics of floods and tides using the full 1D St Venant equations and the full 2D free-surface shallow water equations.

Two-dimensional modelling is specifically beneficial where the hydrodynamic behaviour in coastal waters, estuaries, rivers, floodplains, and urban drainage environment have complex 2D patterns that would otherwise be awkward to represent in one dimension using traditional 1D network models. Storage volumes are implicitly included within the 2D modelling approach based on the surface geometry and water flows.

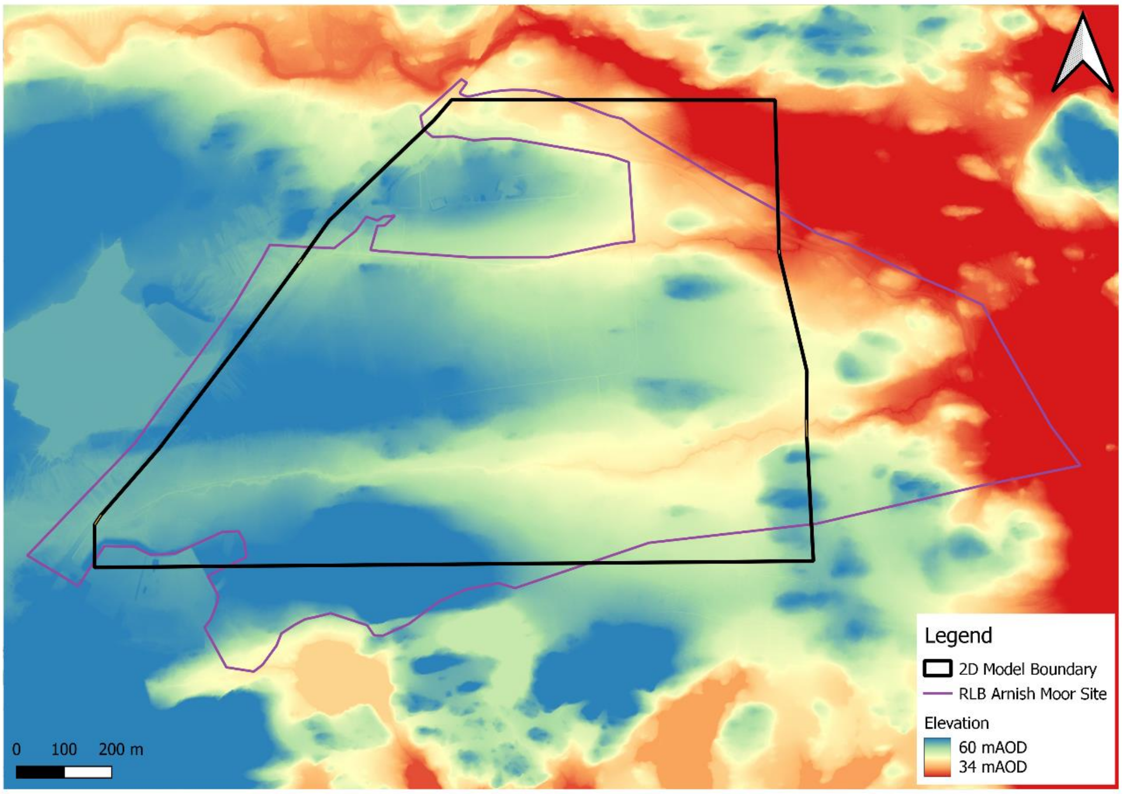
5.4.1 Model extent and underlaying DTM

The model extends from the existing A859 to the west of the subject Site, covering approximately 1000m of the watercourse to the north and 1500m of watercourse 3 along the boundary of the Site. It also extends approximately 300m downstream of the proposed development location. This was chosen as the riverbed is more than 10m below the proposed HVDC Platform level at this point, which is low enough where any attenuation caused by blockages to the culvert would not affect the development location or any of the associated laydown areas.

The 2D boundaries are based on the local topography and are set against the A859 on the western boundary as any 'glasswalling' caused by the boundary will be indictive of the natural glasswalling caused by the raised topography of the road. The boundaries are also based on minimising or removing any unjustified restriction of flood extents. In that way it enables the flood water to reach natural flood extents for all design floods return periods and not to underestimate the flood risk of the subject Site. The 2D boundaries are shown in Figure 5.3.

The underlying DTM has been based on the available 50cm grid LiDAR available of the wider Site area. A grid size of 2m was chosen for the model based on the LiDAR data. Details of the LiDAR are also shown in Figure 5.3.

Figure 5.3: Proposed Model Extent and Underlying DTM



Source: © OpenStreetMap contributors; Contains OS data © Crown copyright and database rights (2024)

5.4.2 Boundary Conditions

5.4.2.1 Upstream boundary condition- Inflow

The upstream boundary for Watercourse 1 has been placed upstream of the Site but downstream of the A859, thus omitting the impact of the road culvert on design flows. The same process has been used on the southern watercourse, with the upstream boundary starting downstream of the A859. This has been done in line with the conservative assumptions as the culvert is likely to provide some degree of attenuation to the design flows.

A Flow-Time (QT) boundary type at the upstream end has been used to represent the inflows from the watercourse. QT curves are derived from hydrological analysis of the catchment.

5.4.2.2 Downstream boundary condition- Normal Depth

The downstream boundary condition is placed approximately 300m downstream of the proposed development. Whilst this is within the site boundary, the location has been chosen to where it would not influence flood levels for the proposed development.

A Water Level (Head) versus Flow (Q), or the “normal depth”, has been used as the downstream boundary condition. The applied slope of 0.001 has been determined as the average watercourse slope near the downstream boundary.

5.4.3 Roughness values

Surface roughness was modelled using the Manning's roughness coefficient 'n'. The roughness coefficients were determined from standard tabular values based on the terrain types in the model. These were based on available satellite imagery and a site visit in 2024 (see Appendix C). Table 5.2 presents the roughness values assigned to each land use within the model.

Sensitivity analysis has been undertaken on the roughness values as presented in Section 5.4.6.

Table 5.2: Manning's n Roughness Coefficient

Material	Manning's n value
General roughness- pasture (bushy and grassy surfaces)	0.060
Roads - local field roads	0.022
Channel - natural watercourse channel	0.035
Trees - localised areas of high vegetation	0.100
Buildings - Areas of buildings and surroundings	1.000
Cultivated land - agricultural land in the Site	0.030

Source: TUFLOW hydraulic model

Adapted from literature and practice.

From the site visit (see Appendix C) it was determined that the roughness of the watercourses was beyond that of natural channel roughness. The area is overgrown with natural grasses and other vegetation along and within the two watercourses. As such, the roughness value of 0.060 was used for the general surface including the watercourses, to provide a more conservative approach to the modelling of the channel. The established channel roughness values were used in the sensitivity test in Section 5.4.6 however it was determined that this had little impact on flood extents.

5.4.4 Hydraulic structures

No hydraulic structures such as bridges, culverts, weirs, etc have been included in the hydraulic model.

There are culverts at the upstream end of the model connecting Loch a'Choilich and both unnamed watercourses. These structures have been omitted as explained in Section 5.4.2.1. As such, the model starts downstream of these locations on the eastern side of the A859, which is considered conservative.

Additionally, there are two culverts located downstream of the Proposed Development location within the Site boundary. These have not been included within the model extent as they are located approximately 10m below the ground level of the Proposed Development location and as such any blockage or attenuation caused by these structures will overflow the road and will not have any impact on the Proposed Development.

5.4.5 Other parameters

The default TUFLOW model parameters have been used in the modelling.

5.4.6 Calibration and sensitivity analysis

No historical flood events were available for this subject Site to calibrate the hydraulic model. Therefore, a sensitivity analysis was undertaken on key model parameters that could potentially affect the hydraulic modelling results at the Site as follows:

- The downstream boundary slope for normal depth has been increased from 0.001 to 0.01. This caused no significant change in the flood extent estimated by the model.
- The roughness coefficient was varied across the floodplain with values 0.035, 0.06 and 0.1 to simulate varying degrees of roughness. Reducing the roughness to 0.035 saw a minor increase in flood extent and depth in both watercourses, however this increase did not impact the site location and was located mostly upstream or at the downstream end of the model past the downstream end of the site. Increasing the roughness to 0.1 saw an increase in flood extent and depth, with some in channel depths increasing by 0.05m at the highest levels of flooding. This increase occurs along both watercourses increasing the width of flooding from the 0.065 roughness. This is not a significant increase in flood extent as the level of flooding does not reach the proposed HVDC Platform boundary. The sensitivity analysis of roughness shows that whilst the flood levels vary with changing roughness the high roughness test did not change the assessment of flood risk to the site. As such, the 0.065 central roughness value was retained for the hydraulic modelling.
- Computational grid size reduced from 2m to 1m. The reduction in grid size had no significant impact on the flood extent compared to the 2m scenario. Additionally reducing the grid size saw a reduction in flood depths of roughly 0.1m at a maximum, this being located at the downstream end of the model away from the HVDC Convertor Platform. As such, the 2m grid size has been kept moving forward to keep the more conservative flood estimate, as well as reducing the time needed to run the model.
- Blockage of any culverts downstream of the 2D boundary under The Arnish Road to the east of the site has not been assessed as part of this modelling process. This is due to the topography being approximately 10m below the ground level at the site. As such, regardless of blockage at the culvert, this will not impact the HVDC Site.

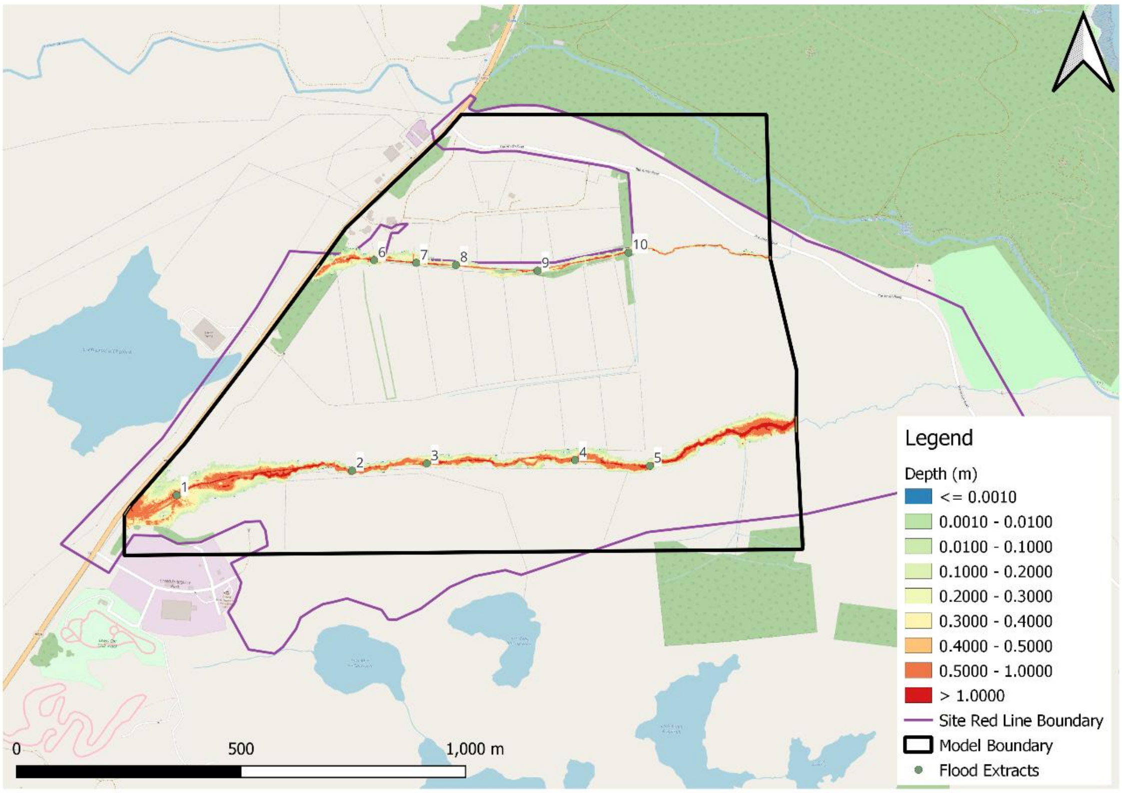
6 Modelling Results

6.1 Flood mechanism and model outputs

The hydraulic model confirmed that the flood risk and flood mechanisms from the two watercourses will be contained to the low ground away from any of the proposed works in the Site. The remaining area of the Site, i.e. the area further away from the watercourses consists of higher ground levels and is outside the predicted fluvial flood mechanism of the two unnamed watercourses.

The graphical presentation of the 0.1% AEP fluvial flood extent with an allowance for climate change is presented in Figure 6.1.

Figure 6.1: Flood Map for 0.1% AEP (1 in 1000yr) with Climate Change Allowance



Source: © OpenStreetMap contributors; Contains OS data © Crown copyright and database rights (2024). Mott MacDonald Hydraulic Calculation Results

The predicted maximum flood water levels have been extracted from the hydraulic model results at key locations (see Figure 6.1) as follows:

- 1- Immediately downstream of the culvert under the A859 for the southern watercourse
- 3- At the upstream end of the proposed HVDC Platform on Watercourse 3
- 4- At the downstream end of the proposed HVDC Platform on Watercourse 3
- 6- Downstream of the culvert under the A859 for the northern watercourse
- 9- Central to the proposed HVDC Platform Site and the location of the SUDS basin
- 10- At the downstream end of the proposed HVDC Platform on Watercourse 1

Table 6.1 summaries the maximum flood water levels at the subject Site.

Table 6.1: Predicted Flood Levels Within the Site Boundary

Design flood	Flood water levels (mAOD)					
Subject watercourse	**Point 1**	**Point 3**	**Point 4**	**Point 6**	**Point 9**	**Point 10**
1% AEP (1 in 100 year)	56.472	50.810	46.576	53.511	48.314	44.948
0.5% AEP (1 in 200 year)	56.497	50.848	46.612	53.535	48.343	44.972
0.1% AEP (1 in 1000 year)	56.551	50.928	46.691	53.602	48.420	45.031
1% AEP (1 in 100 year) including climate change allowance	56.552	50.930	46.692	53.603	48.421	45.032
0.5% AEP (1 in 200 year) including climate change allowance	56.582	50.977	46.738	53.635	48.465	45.065
0.1% AEP (1 in 1000 year) including climate change allowance	56.651	51.081	46.830	53.715	48.555	45.146

Source: TUFLOW hydraulic model

Source: Mott MacDonald Hydraulic Calculation Results

The proposed level of the HVDC Converter Station Platform, the AC Substation Platform and the proposed Laydown Areas is proposed as 55.50 mAOD. This is significantly above the flood water levels seen in Table 6.1 except at Point 1. Flood water levels at Point 1 are predicted to be above the proposed platform levels, however, Point 1 is upstream of the site and the flood extents, indicated in Figure 6.1, show natural high ground providing a flood defence function. The complete flood extents for the return periods detailed in Table 6.1 can be found in Appendix B.

6.2 Proposed development and compliance with Flood Risk Policy

6.2.1 Minimum finished floor level of platform

The hydraulic model predicts that the subject Site is partially overlapping with the floodplain of the two nearby unnamed watercourses. However, the predicted flooding is only expected to occur at the lower ground near the watercourse channels or downstream away from the HVDC Platform itself.

The HVDC Converter Station Platform part of the Proposed Development is positioned on the higher ground outside of the functional floodplain and so is predicted to be not at fluvial flood risk.

The HVDC Converter Station Platform part of the Proposed Development is predicted to be not at risk of fluvial flooding due to natural topography of the site and is sufficiently far away from the flood extent of the modelled watercourse. Therefore, the minimum finished floor level has not been proposed in relation to the fluvial flooding.

The finished floor level will be recommended in the Drainage Impact Assessment in relation to the surface water flooding.

6.2.2 Impact of development on flood levels elsewhere.

Where the active floodplain of the river is removed by a new development, there may be an impact on the flood water levels elsewhere. This is undesirable and appropriate measures must be taken to avoid this.

The HVDC Convertor Station Platform is outside of the fluvial floodplain of the unnamed watercourse and therefore presents no risk of increase in flooding elsewhere.

All drainage from impermeable areas should make use of sustainable drainage systems (SUDS) to mitigate against increase in storm runoff from the subject site.

A SUDS basin is planned through the HVDC Platform the details of which are detailed in the Drainage Impact Assessment.

6.2.3 Access / egress

The predicted flood extent is limited and fluvial flooding from the unnamed watercourse does not affect access/egress routes from the site to the trunk road to the east.

7 Conclusions and Recommendations

Fluvial flood risk from the unnamed watercourses to the north (Watercourse 1) and south (Watercourse 3) of the proposed development at Arnish Moor HVDC Convertor Site has been assessed. The watercourses run along the northern and southern boundaries of the subject Site and due to its small catchment size is not included in the SEPA Flood Maps. Therefore, 2D hydraulic modelling has been undertaken to assess the extent of flood risk.

Hydraulic analyses based on the FEH ReFH2 model have been carried out to provide an estimate of the design flood return periods. A computer hydraulic model has been developed using the TUFLOW software package, to predict peak water levels for a range of flood events. From these, flood extents and depths have been developed.

This study shows that the subject Site is partially located within the fluvial floodplain of the unnamed watercourses to the north and to the south for the 0.5% annual exceedance probability (1 in 200 year) flood event including allowance for climate change. The area with the identified flood risk is located on low ground away from the HVDC platform on both the northern and southern boundary of the site. These areas are proposed to stay unchanged.

The HVDC Converter Station Platform part of the Proposed Development is located at the middle/northern side on a higher ground and is away from the functional floodplain of the northern and southern watercourse. Access to the trunk road is also predicted not to be affected by flooding.

It is noted that the western part of the site is lower than the predicted flood level and is defended by natural ground. The ability of the natural ground to provide a water retaining function should be confirmed.

As the proposed development is proposed outside the river floodplain, the development will not adversely affect flood risk elsewhere, provided that drainage is dealt with using appropriate sustainable drainage systems to mitigate against increased runoff from the subject site.

Appendices

A. Hydrology analysis

A.1 ReFH2 Method

The Revitalised Flood Hydrograph 2 (ReFH2) model has been developed for modelling flood events. The ReFH2 model is based on robust hydrological modelling techniques and is considered to be an improvement of the existing FSR/FEH model. It enables a more direct and transparent description of flood-generating mechanisms and introduces the concept of seasonal variation in soil moisture content, design rainfall and baseflow.

The ReFH2 approach undertaken for this study uses a catchment descriptor estimate of peak flows. The peak flow estimates reported at the end of this Appendix use the FEH website catchment descriptors (CD) for the unnamed subject catchment, coupled with a default storm duration and time to peak, Tp (which themselves are based on catchment descriptor equations).

Table A.1 shows the parameters at subject catchment for the ReFH2 model using catchment descriptors.

Table A.1: Model Parameters

Parameter	Watercourse 1	Watercourse 3	Watercourse 3 Additional
Area (km2)	0.7575	1.5875	0.5250
Cini (mm)	152.898	150.584	145.483
Cmax (mm)	292.051	296.411	306.749
BL (hours)	17.056	19.566	14.228
Tp (hrs)	1.727	1.845	1.452
Storm Duration (hrs)	4.25	4.25	4.25
Timestep (hrs)	0.25	0.25	0.25

Source: ReFH2 model

A.1.1 Design Rainfall

The 2022 DDF (Depth Duration Frequency) rainfall model has been applied within the latest ReFH 2 version (namely ReFH 2.3 model) to produce the rainfall depths for each return period. The DDF input rainfall files were obtained from the FEH Web Service. The final design rainfall depth is calculated as the product of the point rainfall depths, the ARF (area reduction factor and the SCF (Seasonal Correction Factor). The ARF reduces the point rainfall estimates to a catchment average rainfall depth and is a function of catchment area. An ARF for the catchment has been automatically generated within the ReFH2 model and is shown in Table A.2.

The SCF converts an annual maximum rainfall depth to a seasonal maximum depth and is calculated based upon location, season, duration, and selected return period. ReFH2 also automatically generates the SCF (Seasonal Correction Factor) based on the chosen seasonality selected. For this study, the 75% winter profile has been selected given the rural nature of the catchments. Table A.2 shows the SCF value generated for the catchment. The design rainfall depths are presented in Table A.3.

Table A.2: Catchment ARF and SCF

Parameter	Watercourse 1	Watercourse 3	Watercourse 3 Additional
Areal reduction factor (ARF)	0.979	0.973	0.982
Seasonal correction factor (SCF)	0.815	0.816	0.817

Source: ReFH2 model

Table A.3: Design Rainfall Depths (mm)

Return Period	Watercourse 1	Watercourse 3	Watercourse 3 Additional
50% AEP (or 1 in 2yr) flood event	16.29	16.13	16.38
10% AEP (or 1 in 10yr) flood event	27.58	27.35	27.73
2% AEP (or 1 in 50yr) flood event	41.25	40.95	41.49
1% AEP (or 1 in 100yr) flood event	47.75	47.41	48.01
0.5% AEP (or 1 in 200yr) flood event	54.40	54.08	54.77
0.5% AEP +CC (or 1 in 200yr) flood event +cc	80.52	80.04	81.06
0.1% AEP (or 1 in 1000yr) flood event	70.34	69.87	70.79
0.1% AEP - CC (or 1 in 1000yr) flood event +cc	104.10	103.41	104.77

Source: ReFH2 model

A.1.2 Peak flows

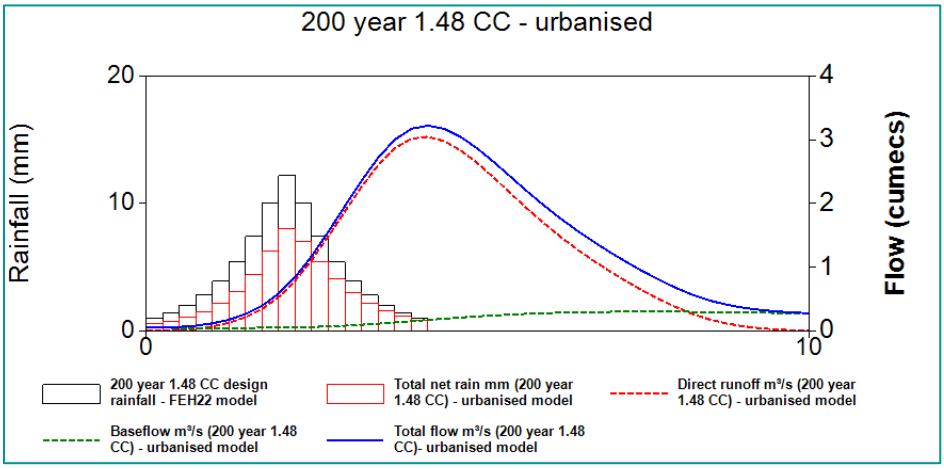
The peak flows generated in the ReFH2 method are shown in Table A.4. Design hydrographs for the critical flood events are presented in Figure A.1 to Figure A.6.

Table A.4: FEH ReFH2 flood peak flows (m3/s)

Return Period	Watercourse 1	Watercourse 3	Watercourse 3 Additional	Watercourse 3 Combined
50% AEP (or 1 in 2yr) flood event	0.59	1.14	0.42	1.55
10% AEP (or 1 in 10yr) flood event	1.00	1.93	0.72	2.63
2% AEP (or 1 in 50yr) flood event	1.52	2.95	1.10	4.02
1% AEP (or 1 in 100yr) flood event	1.79	3.45	1.29	4.71
0.5% AEP (or 1 in 200yr) flood event	2.06	3.99	1.49	5.45
0.5% AEP +CC (or 1 in 200yr) flood event +cc	3.22	6.24	2.34	8.53
0.1% AEP (or 1 in 1000yr) flood event	2.76	5.33	1.99	7.28
0.1% AEP - CC (or 1 in 1000yr) flood event +cc	4.38	8.47	3.18	11.59

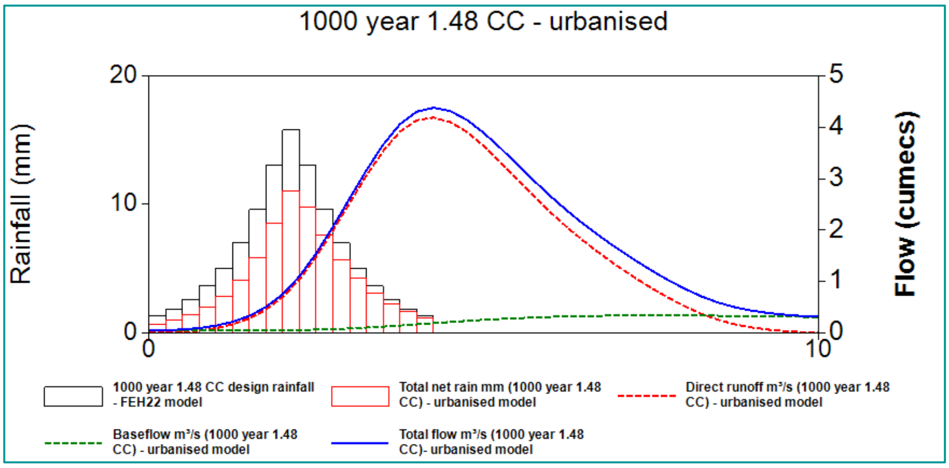
Source: ReFH2 model

Figure A.1: Watercourse 1 hydrograph for 1 in 200yr + cc design



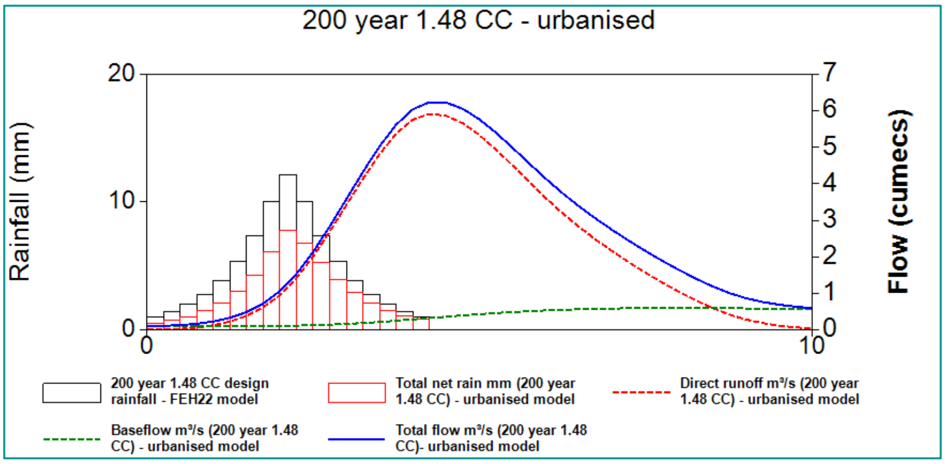
Source: ReFH2 model

Figure A.2: Watercourse 1 hydrograph for 1 in 1000yr + cc design



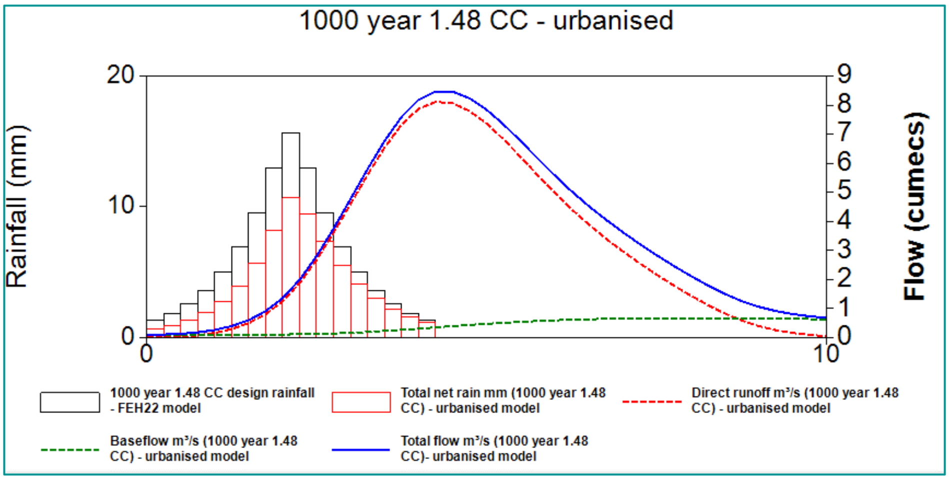
Source: ReFH2 model

Figure A.3: Watercourse 3 hydrograph for 1 in 200yr + cc design



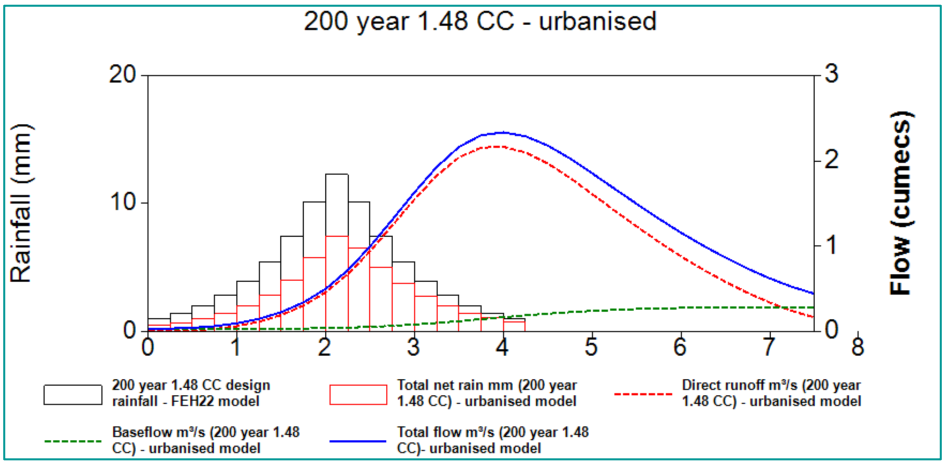
Source: ReFH2 model

Figure A.4: Watercourse 3 hydrograph for 1 in 1000yr + cc design



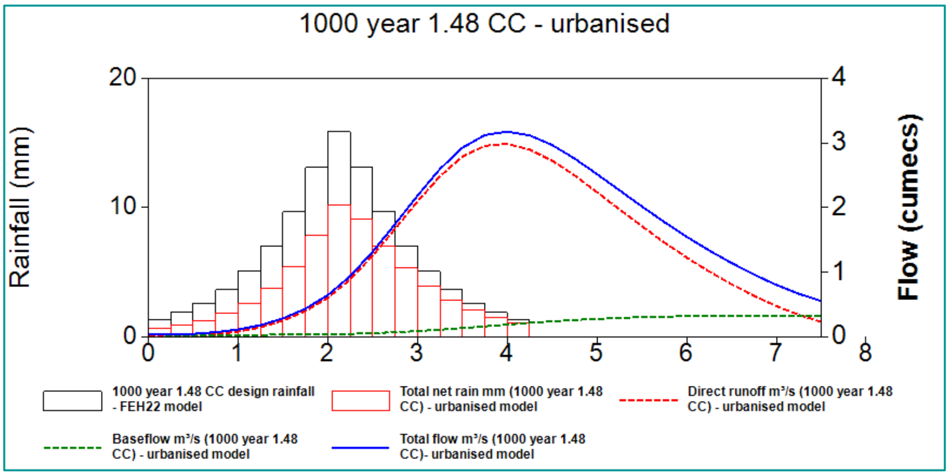
Source: ReFH2 model

Figure A.5: Watercourse 3 Additional hydrograph for 1 in 200yr + cc design



Source: ReFH2 model

Figure A.6: Watercourse 3 Additional hydrograph for 1 in 1000yr + cc design



Source: ReFH2 model

A.2 IoH124 Method

The Institute of Hydrology Report No. 124 provided a method for estimation of flood flows in the small rural catchments up to 25km^2. The method has been applied as a second independent method; however, it has been considered less reliable as it originates from 1994 and the latest methods such as REFH2 use more up to date models. It also does not provide an extension of the growth curve to the 1000-year return period and therefore, it has not been further used in the hydraulic analysis.

The input parameters are presented in Table A.5, the FSR growth curve for North Scotland has been applied.

Table A.5: Input parameters for IOH 124 Method

Parameter	Watercourse 1	Watercourse 3	Watercourse 3 Additional
Catchment area (km2)	0.7575	1.5875	0.5250
SAAR4170 (mm)	1330	1332	1342
SOIL	0.5	0.5	0.5
WRAP class	5	5	5
URBAN	0	0	0

Source: IoH124 model

The peak flows generated in the IoH124 method are shown in Table A.6. The method does not provide an extension of the growth curve to the 0.1% AEP (or 1 in 1000yr) flood event.

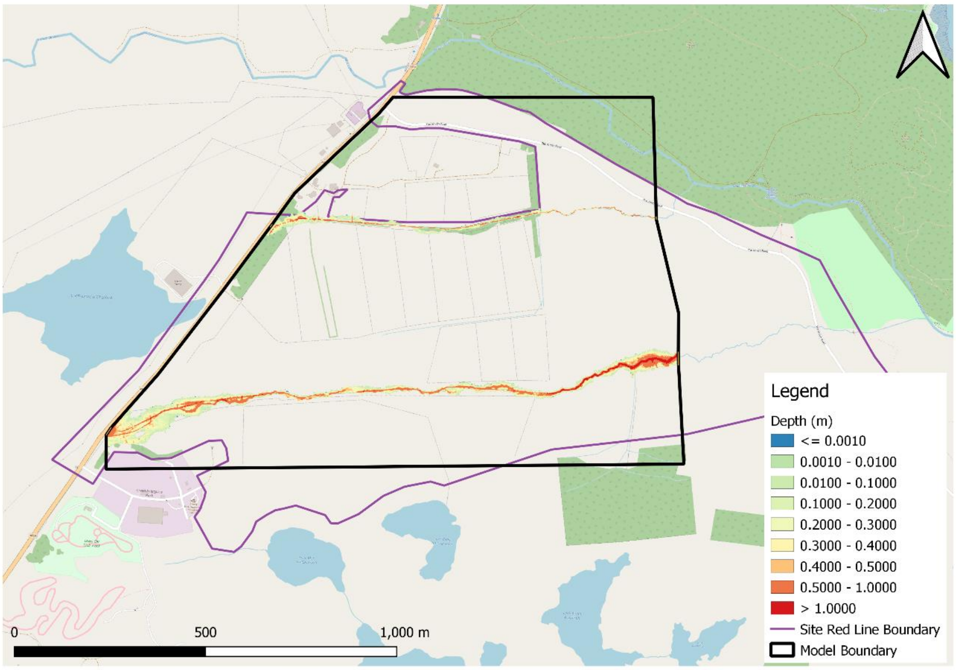
Table A.6: IoH124 flood peak flows (m3/s)

Return Period	Watercourse 1	Watercourse 3	Watercourse 3 Additional	Watercourse 3 Combined
50% AEP (or 1 in 2yr) flood event	0.77	1.48	0.56	2.04
10% AEP (or 1 in 10yr) flood event	1.22	2.37	0.89	3.26
2% AEP (or 1 in 50yr) flood event	1.80	3.47	1.31	4.78
1% AEP (or 1 in 100yr) flood event	2.10	4.06	1.53	5.60
0.5% AEP (or 1 in 200yr) flood event	2.45	4.74	1.79	6.53

Source: IoH124 model

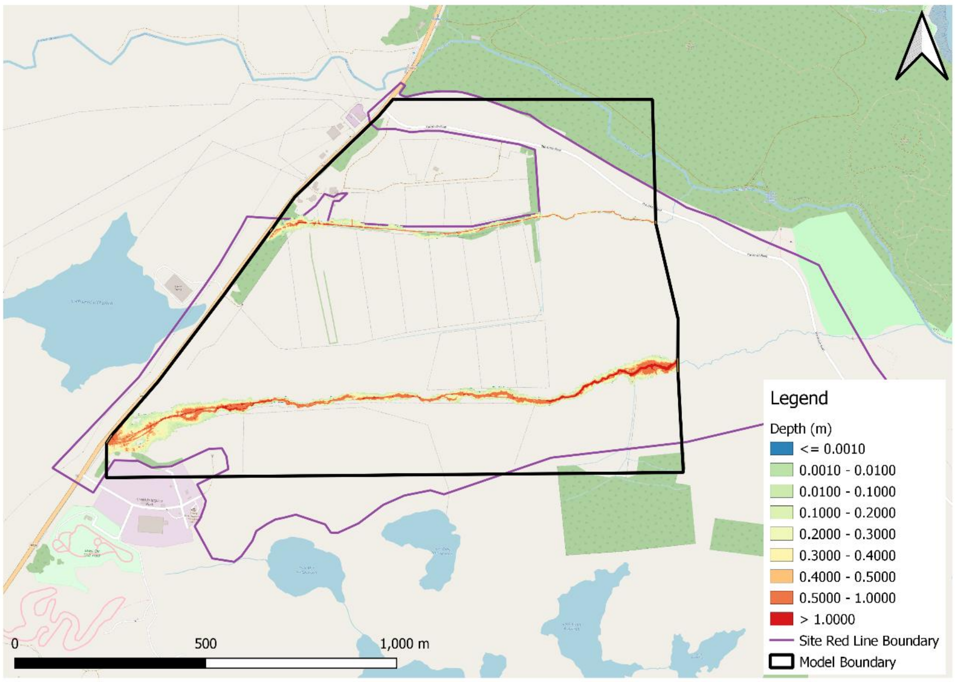
B. Flood Maps

Figure B.1: 1% AEP Fluvial Flood Extent



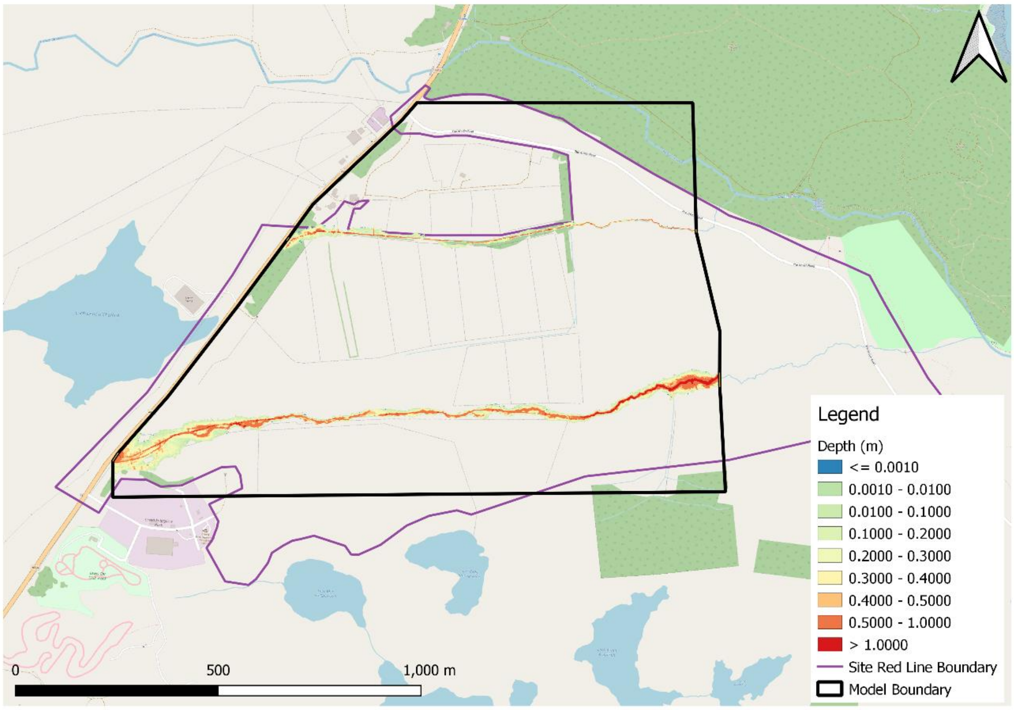
Source: © OpenStreetMap contributors; Contains OS data © Crown copyright and database rights (2024).

Figure B.2: 1% AEP+cc Fluvial Flood Extent



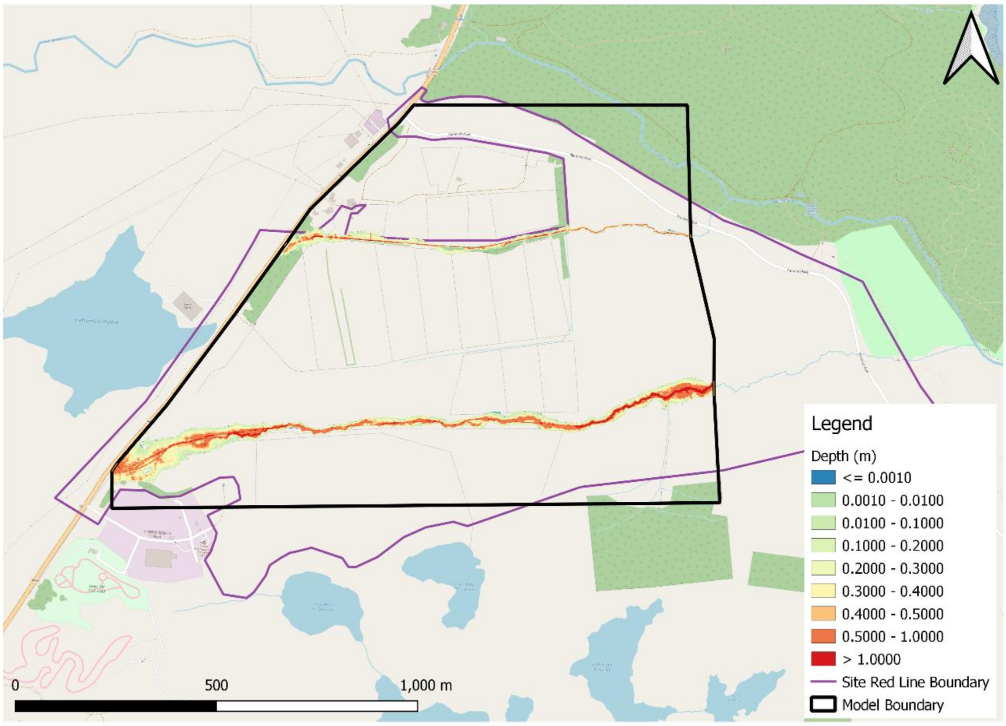
Source: © OpenStreetMap contributors; Contains OS data © Crown copyright and database rights (2024).

Figure B.3: 0.5% AEP Fluvial Flood Extent



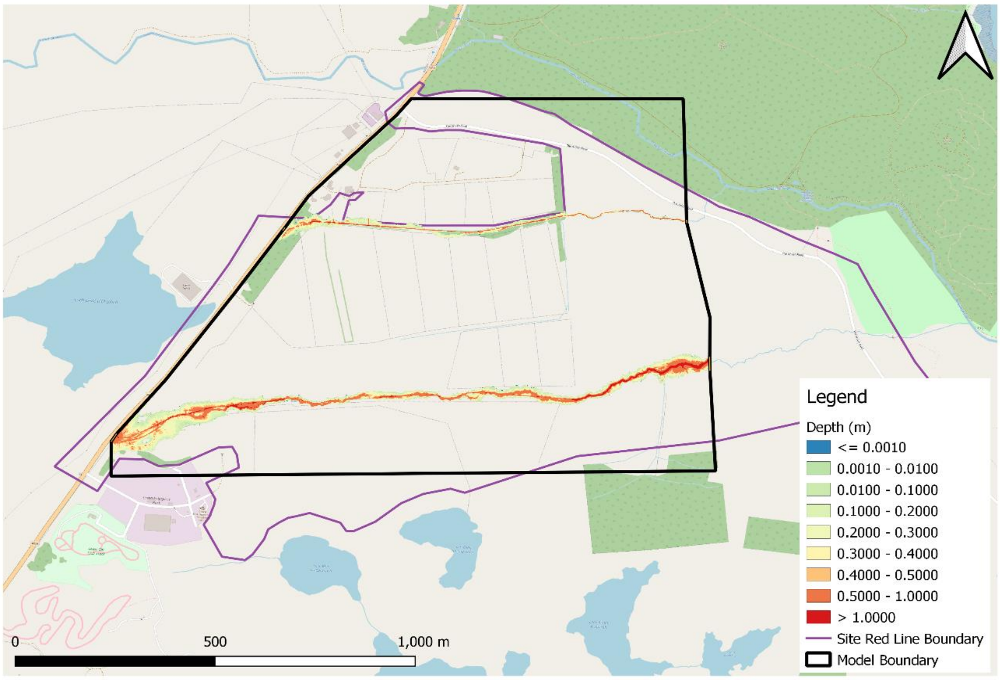
Source: © OpenStreetMap contributors; Contains OS data © Crown copyright and database rights (2024).

Figure B.4: 0.5% AEP+cc Fluvial Flood Extent



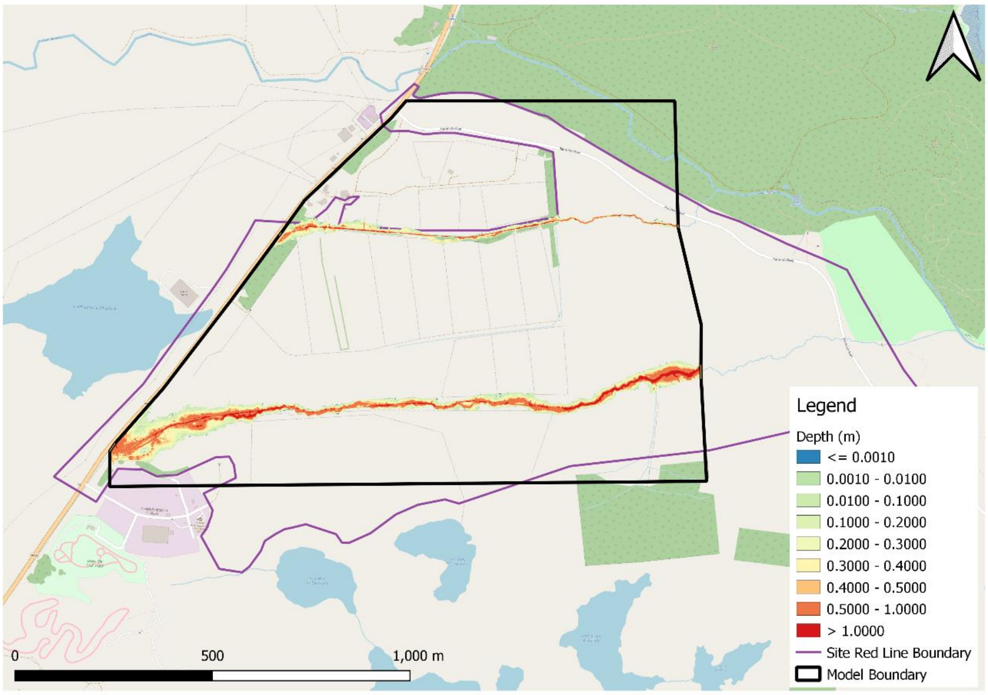
Source: © OpenStreetMap contributors; Contains OS data © Crown copyright and database rights (2024).

Figure B.5: 0.1% AEP Fluvial Flood Extent



Source: © OpenStreetMap contributors; Contains OS data © Crown copyright and database rights (2024).

Figure B.6: 0.1% AEP+cc Fluvial Flood Extent



Source: © OpenStreetMap contributors; Contains OS data © Crown copyright and database rights (2024).

C. Site Visit

Figure C.1: Watercourse 1

Source: Mott MacDonald Site Visit (2024)

Figure C.2: Site Terrain

Source: Mott MacDonald Site Visit (2024)

Figure C.3: Site Visit

Source: Mott MacDonald Site Visit (2024)

Figure C.4: Watercourse 3

Source: Mott MacDonald Site Visit (2024)