LT407 Banniskirk 400kV Substation

Flood Risk Assessment

Prepared for
J Murphy & Sons Ltd

Scottish & Southern Electricity Network (SSEN)

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Contents

Table of Figures

Schedule of Tables

Appendices

Appendix A – Additional Information

Appendix B – Structure Register

1. Introduction

Tony Gee and Partners (LLP) have been appointed by Scottish & Southern Electricity (SSEN) to produce a Flood Risk Assessment (FRA) to inform the design and planning application for the proposed development 400kV Banniskirk Substation located in the north of Scotland, adjacent to the A9 trunk road, north of Spittal. The proposed substation is to facilitate connections for new and renewable onshore and offshore electrical generation.

The report is intended to supersede the Flood Risk Assessment produced by Jacobs on 4th December 2023.

This FRA has been undertaken to provide information on the assessment of all sources of flood risk relevant to the proposed development.

The purpose of this FRA is to:

- investigate existing (baseline) flood risks;
- identify potential flood risk impacts associated with the proposed development; and
- provide details of appropriate flood mitigation / flood management measures where appropriate.

1.1. Design Standards

Flood Protection Standards are based on those prescribed by the SSEN Drainage Specification SP-NET-CIV-502 and THC. For operational areas the level of flood protection is the 0.5% AEP (200- year) event plus allowance for climate change, whilst for critical equipment the level of protection is the 0.1% AEP (1000-year) event, plus allowance for climate change.

Critical equipment, as defined by SSEN, is that which the plant would fail to fulfil its basic function if flooded, whilst operational areas are defined as those within the substation compound that are necessary for staff to access to maintain critical equipment.

THC has stated that at a minimum standard, the onsite drainage infrastructure should be designed to manage a 3.33% (30-year) plus climate change allowance storm event without flooding and the 0.5% AEP (200-year) plus climate change event should be manged within the site without increasing flood risk elsewhere. Flood Protection Standards were confirmed by The Highland Council Flood Risk Management Team on 11 October 2023 via email communications.

1.2. Context

Based on the SEPA Flood Risk and Land Use Vulnerability Guidance (SEPA, 10 July 2018), the proposed development is classified as 'essential infrastructure' and should generally be permitted providing it can be demonstrated that the proposed development will be designed and constructed to be operational during flood events and not impede flood flows or increase flooding downstream.

The proposed site being considered for development extends over previously undeveloped agricultural land. A desk-based investigation of the SEPA Flood Mapping has been undertaken and fluvial and surface water flood extents for the 0.5% AEP (200-year) event are reproduced in Figure 1. The site extents are denoted by the red line boundary annotation within Figure 1.

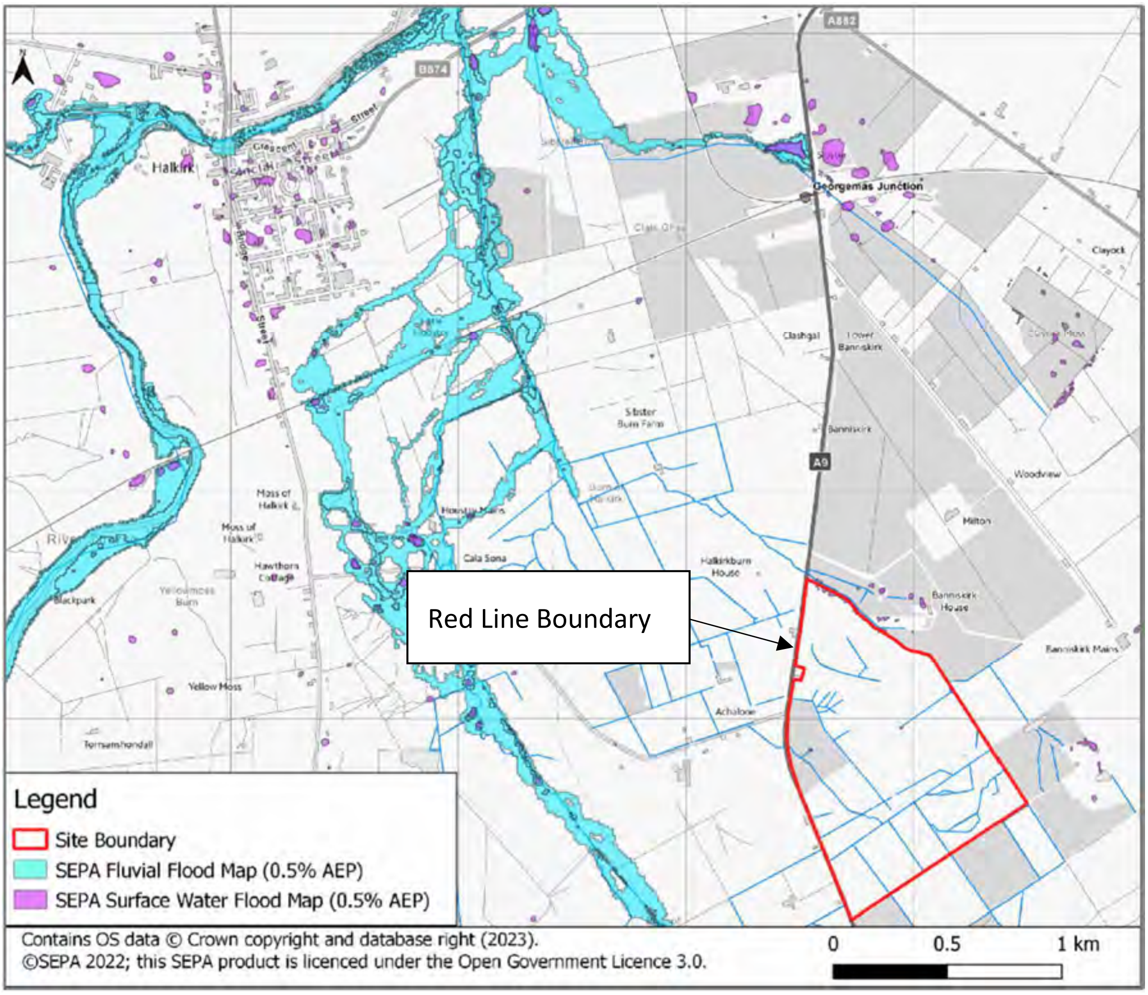

Figure 1: Location Plan Showing Indicative Flood Extents as Based on SEPA Flood Map Data.

At the limit of the 0.5% AEP (200-year) fluvial flood extent on the Burn of Halkirk, shown by the SEPA Flood Mapping, the contributing catchment area is <3km² and hence flooding along this reach of the watercourse is not included by SEPA in the production of their Flood Maps. The lower reach of the Burn of Halkirk is included and it is shown that upstream of the railway, the indicative flood extent along the Burn of Halkirk, extends over the left and right bank floodplain (i.e., combined flood inundation extent) for approximately 65 m, although this varies according to local topography. The flood extents shown by the SEPA Flood Maps are indicative and do not fully take account of structures such as culverts and bridges that can influence local flooding (SEPA, 2022).

Also shown by the SEPA Flood Mapping are areas of isolated surface water flooding, though these are slight in terms of their extent, particularly within the proposed site boundary. In some locations such as at Banniskirk Quarry (outwith the site boundary), the surface water flooding shown, appears to be associated with localised topographical depressions, i.e., settling ponds for example. Along the left bank of the Burn of Halkirk (along the eastern site boundary), the surface water flooding shown, is also considered to be associated with localised topographic depressions, during the hydrology walkover survey, the ground here was observed to be heavily poached by livestock.

The proposed development has the potential to alter existing hydrological regimes and flood mechanisms, which may result in adverse impacts. Where adverse effects are identified in this assessment, recommendations are made, where practical and appropriate, for how these can be mitigated.

1.3. Flood Risk Legislation, Policy & Guidance

The FRA has been developed with reference to the following legislation, policy and guidance:

Flood Risk Management (Scotland) Act 2009

The Flood Risk Management (Scotland) Act 2009 sets in place a statutory framework for delivering a sustainable and risk-based approach to the management of flooding.

The Act places a duty on responsible authorities (Scottish Ministers, SEPA, Scottish Water and local authorities) to manage and reduce flood risk and promote sustainable flood risk management.

Scottish Government National Planning Framework 4

National Planning Framework 4 (NPF4) requires planning authorities to strengthen resilience to flood risk by promoting avoidance as a first principle and reducing the vulnerability of existing and future development to flooding (Scottish Government, 2023).

Whilst NPF4 promotes avoidance of development in flood risk areas, Policy 22a states that development proposals in a flood risk area may be supported if they are for essential infrastructure where the location is required for operational reasons, provided it is designed and constructed to remain operational during times of flood and not increase flood risk elsewhere.

SEPA Technical Flood Risk Guidance for Stakeholders

The SEPA Technical Flood Risk Guidance for Stakeholders document provides an overview of the flood risk assessment process; primarily appropriate methodologies and techniques to be adopted to ensure flood risk matters have been addressed in a manner consistent with NPF4 and the Flood Risk Management (Scotland) Act 2009. This guidance recommends that an assessment for future climate change should be carried out, to [50]SEPA's river flood maps do not include modelling of flooding from watercourses with catchment areas less than 3km^2. take a precautionary and sustainable approach to flood risk assessment as per SEPA recommendations set out in ‘Climate change allowances for flood risk assessment in land use planning’.

The Highland and Argyll Council Local Flood Risk Management Plan (2016-2022)

The Highland and Argyll Local Flood Risk Management Plan (LPD01) identifies a list of constraints to development in the Highlands, one of which is proposed development in areas at ‘medium’ to ‘high’ risk of flooding. Flood risk and drainage impacts are highlighted as material considerations for any new application and new developments are required to follow guidance on flood risk and drainage presented in The Flood Risk and Drainage Impact Assessment Supplementary Guidance.

The Highland and Argyll Council Flood Risk and Drainage Impact Supplementary Guidance

The Highland and Argyll Council Flood Risk and Drainage Impact Supplementary Guidance stipulates additional regional FRA requirements including consultation with organisations such as SEPA, The Highland Councils Flood Team and Scottish Water to establish the flood history of the site. The guidance emphasises that developments proposed within or bordering ‘medium’ to ‘high’ flood risk areas will need to demonstrate compliance with the Scottish Government’s flood risk framework. This includes the criteria that all new developments should be free from unacceptable flood risk for all flood events up to and including the 0.5% AEP (200-year), plus an allowance for climate change. For potentially vulnerable developments such as critical infrastructure, this becomes the 0.1% AEP (1000-year) event.

Where flood management measures are required, natural techniques (e.g., restoration of floodplains, wetlands and water bodies) should be incorporated into the design or sufficient justification provided as to why they are not included. All proposed new developments are also required to be drained by Sustainable Drainage Systems (SuDS) to attenuate flows and reduce pollution to receiving watercourses.

1.4. Flood Risk Assessment Approach

Flood risk assessment should be proportionate to the development proposal and design stage. At the time of preparing this FRA, no detailed design has been produced and hence, the FRA presented herein is a **Level 2 Flood Risk Assessment** based on desk study, site walkover and consultation with the Highland Council Flood Team and Scottish Water for known incidences of historic flooding and guidance with respect to flood protection and hence design standards.

Where the FRA has identified potential flood risk impacts, flood mitigation measures have been considered, and recommendations based on engineering judgement are made on appropriate development design and possible mitigation measures.

1.5. Design Principles and Standards

The assessment has considered a range of design principles and standards in conjunction with the proposed permanent development site layout i.e., the location of operational areas and critical equipment. The climate change allowance to be considered within the assessment is to be 42% as per the SEPA guidance (SEPA, 2023).

Table 1 provides a list of flood risk design principles and standards considered during the assessment of the proposed development.

Table 1: Proposed Development Flood Protection Design Principles and Standards.

Development	Flood Protection Standards	Description
Proposed Development		
AC & DC Platform	0.1% AEP (1000-year return period) Rainfall Event plus 42% (allowance for climate change).	Critical Equipment.
Access Roads	0.5% AEP (200-year return period) Rainfall Event plus 42% (allowance for climate change).	Operational Area.
Depot and External Storage	0.5% AEP (200-year return period) Rainfall Event plus 42% (allowance for climate change).	Operational Area.

Development	Flood Protection Standards	Description
Associated Elements		
Watercourse Crossings	The design flood event is the 0.5% AEP (200-year return period) fluvial event plus 42% (allowance for climate change) plus an appropriate flood freeboard. Where modifying or replacing existing hydraulic structures which are associated with a public road; freeboard to bridge and/or culvert soffits shall meet the requirements of DMRB CD 529 (Highways England, 2021).	Where the proposed development intends to replace existing structures, or construct new structures, soffit levels are set above the design flood event level plus appropriate freeboard. In line with DMRB, all new (or replaced) mainline and access road culverts and bridges are designed to freely pass the 0.5% AEP (200-year) design flood event (with appropriate freeboard.
SuDS Features	0.5% AEP (200-year) Functional Floodplain	Avoid the placement of SuDS in the functional floodplain and provide mitigation for increase in flood risk caused by any loss of floodplain capacity where practicable.
	3.33% AEP (30-year) flood event plus 42% (allowance for climate change).	SuDS features not to be inundated with floodwater during the fluvial event
	0.5% AEP (200-year) rainfall flood event, plus 42% (allowance for climate change) and appropriate freeboard.	SuDS features to treat and attenuate the peak flow from the proposed permanent development
	Where infiltration to ground is possible, equivalent greenfield rates for all events up to and including the 0.5% (1 in 200-year event). Where infiltration to ground is not feasible, mean annual peak rate of runoff for	SuDS features to discharge into the nearest watercourse at a controlled rate, taken here as QBAR.

Development	Flood Protection Standards	Description
	the greenfield site (i.e., $QBAR_{rural}$), or 2 l/s/ha, whichever is greater	
Pre-earthwork Drainage (PED)	5% AEP (20-year return period) Rainfall Event.	Taken as 5% AEP (20-year return period) Rainfall Event as per that for the temporary welfare, laydown and parking areas.

1.6. Sources of Flooding

The assessment of flood risk has considered all sources of flooding, specifically:

- Surface Water (Pluvial) Flooding
- Fluvial Flood Risk
- Groundwater Flooding
- Flooding from Sewers and Water Mains
- Flooding from Land Drainage and Artificial Drainage
- Flooding from the Failure of Water Retaining Infrastructure
- Coastal/Tidal Flooding
- Construction Risks

1.7. Flood History

The Highland Council and Scottish Water were consulted regarding historical flood records at or in close proximity to the proposed development (Scottish Water operate a WWTP located on the Burn of Halkirk). Additionally, an internet search for anecdotal flood information from news articles etc. was undertaken.

Information on incidences of flooding at the proposed site are limited to one record. On 23 October 2006 the driveway to Banniskirk Mains was reported to have been flooded. Based on the accompanying note this is assumed to be caused by surface water flooding exacerbated by blockages in the surface water drainage system (rather than a fluvial event associated with flows in excess of the channel capacity).

More recently, during the groundwater monitoring on the 08 November 2023, the ground was reported as being waterlogged and a local landowner (Banniskirk Farm) showed evidence of flood inundation of a farm barn. During the hydrology walkover survey undertaken on 15 and 16 November, flood wrack marks were observed, indicating a recent water level in the Burn of Halkirk of 0.85m above bed level.

Table 2: Historic Flood Events.

Data Source	Date	Location	Source	Cause and further details
The Highland Council Biennial Report No. 6, November 2007.	23/10/2006	Banniskirk Mains, Halkirk	Surface water	Driveway flooded, please check drains and ditches".
Raeburn Drilling & Geotechnical Limited.	08/11/2023	Farm Banniskirk	Surface Water	A local landowner showed evidence of flood inundation of a farm barn

2. Surface Water (Pluvial) Flooding

Surface water (or pluvial) flooding is defined here as rainfall-generated overland flow before the runoff enters a watercourse, drainage system or sewer or, when the infiltration capacity of the ground surface is exceeded during intense rainfall events.

2.1. Baseline Risks

The site proposed for development is primarily rural, undeveloped, agricultural land. The underlying ground condition over the area, i.e., localised pockets of clay and hence poor infiltration and high groundwater levels is likely to generate increased runoff during a high intensity rainfall event, relative to a more well drained soil profile.

There are also areas of localised depressions, locations such as at Banniskirk Quarry and along the left bank of the Burn of Halkirk and within the site boundary at NGR ND 15555 56858. Surface water flooding within the proposed red line boundary, as indicated by the SEPA Flood Mapping, is slight in terms of extent and for the 0.1% AEP (1000-year) ‘low’ likelihood event the indicative flood depth is <0.3 m. Areas at risk of surface water flooding as identified by the SEPA Surface Water Flood Mapping for the ‘high’, ‘medium’ and ‘low’ flooding likelihoods are shown in Figure 2.

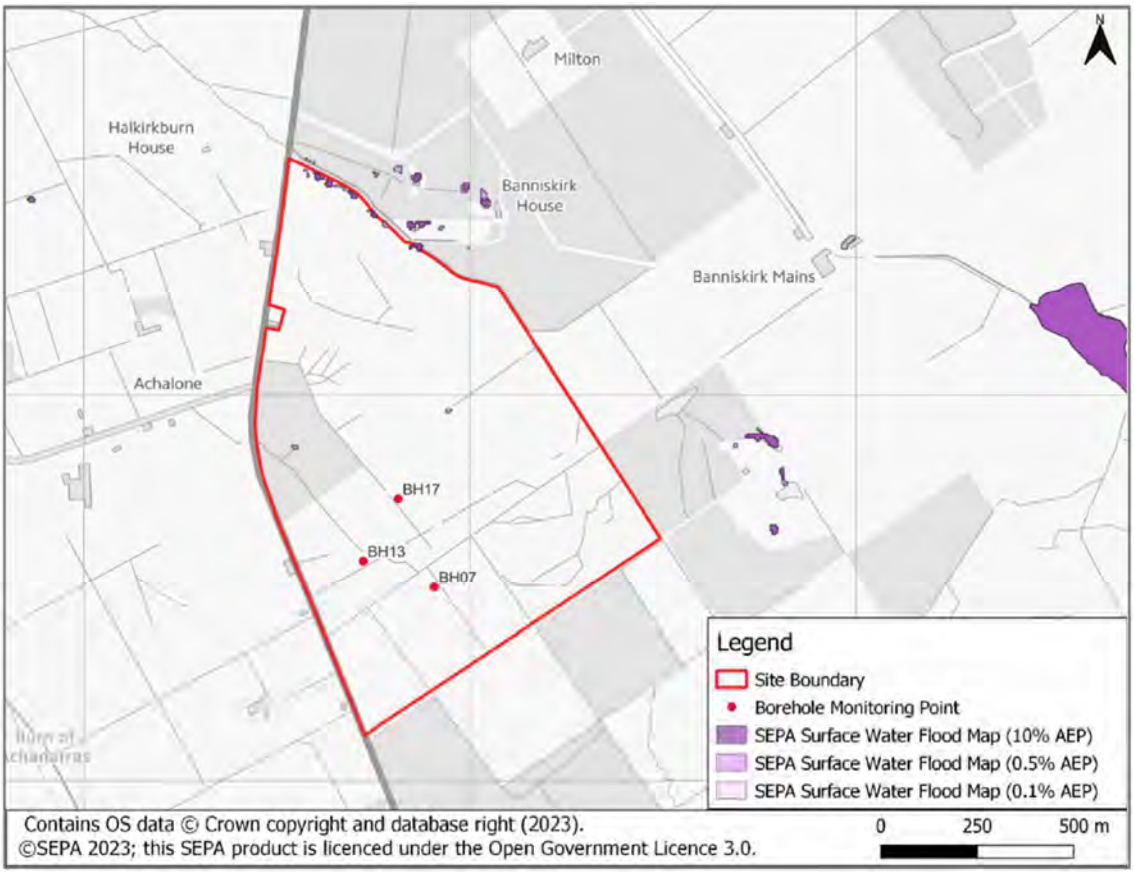

Figure 2: Location Plan Showing Indicative Surface Water Flood Extents as Based on SEPA Flood Map Data.

Based on the SEPA Flood Mapping, there would appear to be a low risk of surface water flooding within the area of the proposed development. Historical incidences of surface water flooding have been reported at Banniskirk Mains (refer to Table 2), located over 700 m north-east of the proposed development. However, no record of flooding at the proposed site was identified, in part, likely due to the undeveloped rural location of the site. It is understood that the settlement of Halkirk, located downstream of the development, is frequently affected by surface water flooding (SEPA, 2021) although this has no direct influence on surface water flood risk at the proposed site. Groundwater monitoring undertaken on the 08 November 2023, identified groundwater above ground level at borehole monitoring points, 07, 13 and 17, all located within the western area of the site, drained by the Unnamed Tributary 01. The maximum depth above ground was recorded as 0.10 m at borehole 17.

It was communicated to Jacobs that during the groundwater monitoring on the 08 November 2023, the network of field drains that cross the site contained water, with the ground reported as being waterlogged and evidence that a large volume of water up to 1-1 ½ foot high had flowed through the site, as observed from wrack marks and the flattening of grass. A local landowner showed evidence of flood inundation of a farm barn.

2.2. Potential Impacts

The proposed development has the potential to impact existing surface water flood risk by:

- constructing new features including the AC and DC Platforms, depot and road network over existing overland flow paths, which could impede the movement of water causing local changes to catchment drainage patterns and consequently flood risk;
- increasing runoff rates from areas impacted by the proposed development during construction, with potential for compaction of ground, changes in gradients and changes in vegetation levels;
- increasing runoff rates during the permanent development through the creation of new impermeable areas into natural drainage catchments; and
- surface water flooding caused by inappropriately sized drainage systems surcharging during both the construction phase and permanent development.

2.3. Mitigation

The surface water drainage strategy described in the Drainage Impact Assessment (DIA) report (BANN4-LT407-JMS-DRAI-XX-RPT-C-0004), only captures the runoff from the hard standing areas within the proposed development area, e.g. the substation roads, buildings, transformer bunds, concrete refuelling areas, and discharges. The remaining platform area is to be constructed from granular fill as per SSEN specification. The granular fill is to allow water to permeate through and runoff/infiltrate the formation layer, which will be graded towards the existing catchments to mimic existing runoff regimes.

The surface water drainage strategy has hence adopted the 0.5% AEP (200-year) design storm event for sizing of the proposed attenuation SuDS measures which are discussed in detail in the DIA.

The drainage strategy for the proposed development is based upon utilising the free draining AC and DC Platforms as the first level of storage to manage the risk of surface water flooding within the site. To illustrate the strategy here, only the AC Platform is considered. The platform has been assessed to attenuate the rainfall within the platform extent, this assessment was completed by Jacobs before Tony Gee were engaged. The area of the permeable AC Platform is 194,018 m^2 and at 1.0 m depth has a volume of 194,018 m^3. At half storage the volume provided by the free draining platform is hence 97, 009 m^3. The volume of the platform that is taken up by building, equipment and road foundations etc. (including areas for cable ducts) is 47,505 m^3 which represents just 24% of the total platform volume. In other words, 146,513 m^3 or 76% is assumed as available storage.

Although this assessment has been completed, it is not anticipated that the platform will retain the runoff as the platform is granular and there is no measure to capture this flow. Therefore, there is a negligible risk of surface water flooding of critical equipment within the platform extents.

2.3.1. Sustainable Drainage Systems (SuDS)

Discharges from the AC and DC Platforms and runoff from other hardstanding surfaces outwith the AC and DC Platforms will be conveyed and treated by newly implemented SuDS measures, which comprise of filter drains, swales and attenuation basins in sequence, prior to discharging to the respective watercourse via an appropriately sized outfall at a rate no greater than the estimated greenfield runoff rate for the respective drainage catchment, adopted as QBAR.

The proposed SuDS measures are designed to treat and attenuate runoff from the permanent development of 0.5% AEP (200-year) and no flooding of critical equipment of up to the 0.1% AEP (1000-year) rainfall event, including an allowance for climate change.

3. Fluvial Flood Risk

A walkover survey, to observe and record the surface water network draining the site, was undertaken by Jacobs on the 15th and 16th of November 2023. The observations documented by Jacobs were later confirmed by a site walkover undertaken by Tony Gee and Murphys on the 31st of January 2024. The walkover survey identified key hydraulic structures and catchment features which are documented in the subsequent paragraphs.

The watercourse network is described in detail in the DIA (BANN4-LT407-JMS-DRAI-XX-RPT-C-0003), but there is a snip of the watercourse catchments (as shown in the DIA) in Figure 3 for context.

Fluvial flooding is considered here as flooding originating from watercourses in proximity to the proposed development.

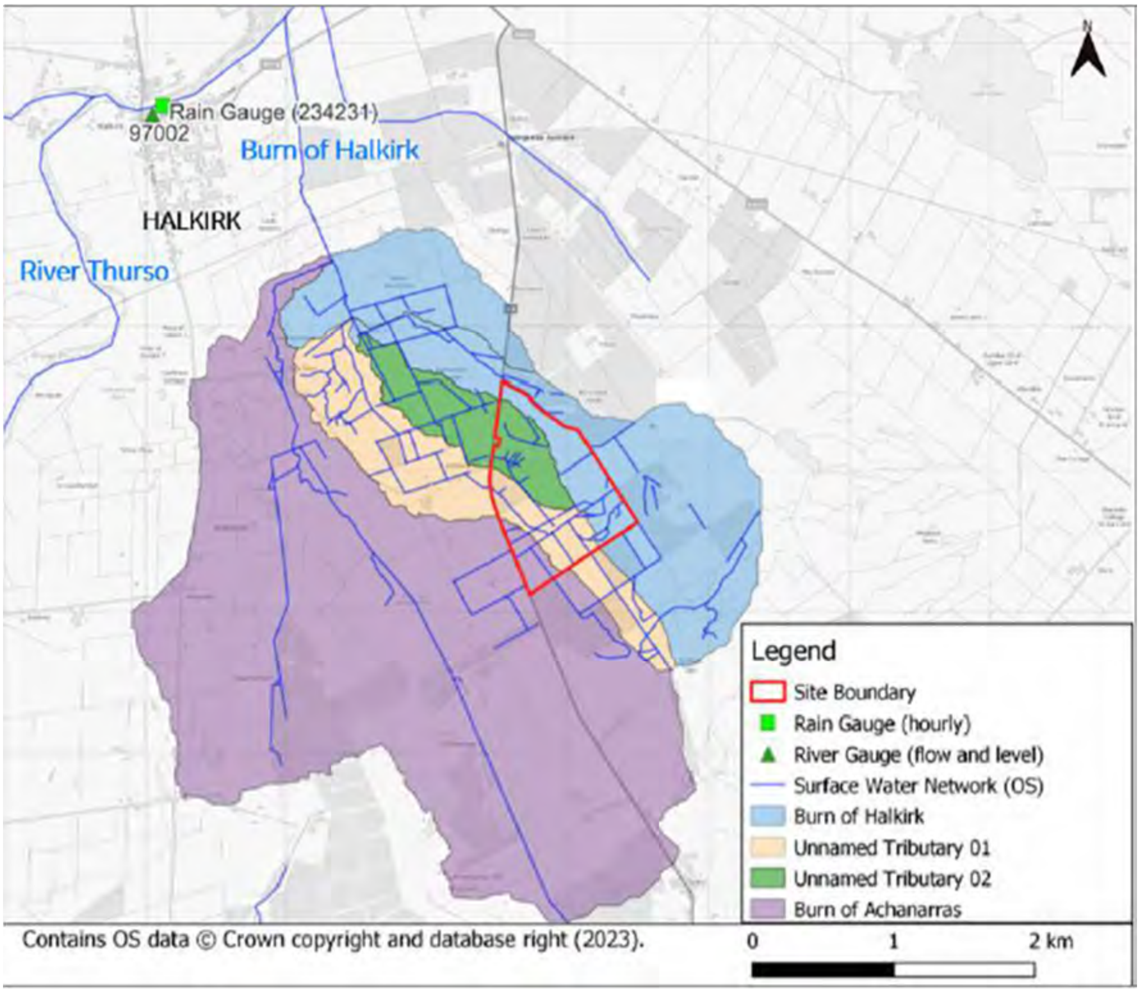

Figure 3: Location plan showing surface water network, contributing catchments and local hydrometric monitoring points

Fluvial flood risk has been assessed based on a desktop review of the SEPA Flood Mapping and by undertaking assessment of channel capacity and hydraulic structure capacities against estimated peak flood flows at various locations along the Burn of Halkirk and Unnamed Tributary 01, shown in Figure 3. Unnamed Tributary 02 is considered to pose less of a flood risk to the development, which is also shown in Figure 3. At its crossing of the A9, Unnamed Tributary 02 drains an area of just 0.23 km². Under the permanent development, approximately 38% of the catchment headwaters will be lost from the construction of the AC Platform.

In the absence of any topographical survey, channel capacity calculations are based on the watercourse geometry as informed from either the Cyberhawk high resolution DTM and/or the Phase II 1m LiDAR data. Channel measurements were obtained at the adopted sections during the hydrology site walkover survey and used to sense check the cross-sectional profiles derived from the DTM data.

3.1. Baseline Risks

The SEPA Flood Mapping shows flooding along the Burn of Halkirk for the 10% AEP (10-year) probability fluvial event, refer to Figure 4 for context. This has been confirmed by undertaking assessment of channel capacity some 15 m upstream of the railway against the estimated design flows presented in Table 6. Estimated channel capacity is reported in Table 5 based on cross-sectional profiles derived from the available DTM data and also, where obtainable, by measurements of the channel taken at the corresponding locations of the DTM derived cross-sections. The locations of the cross sections were confirmed in the field by use of a GPS device.

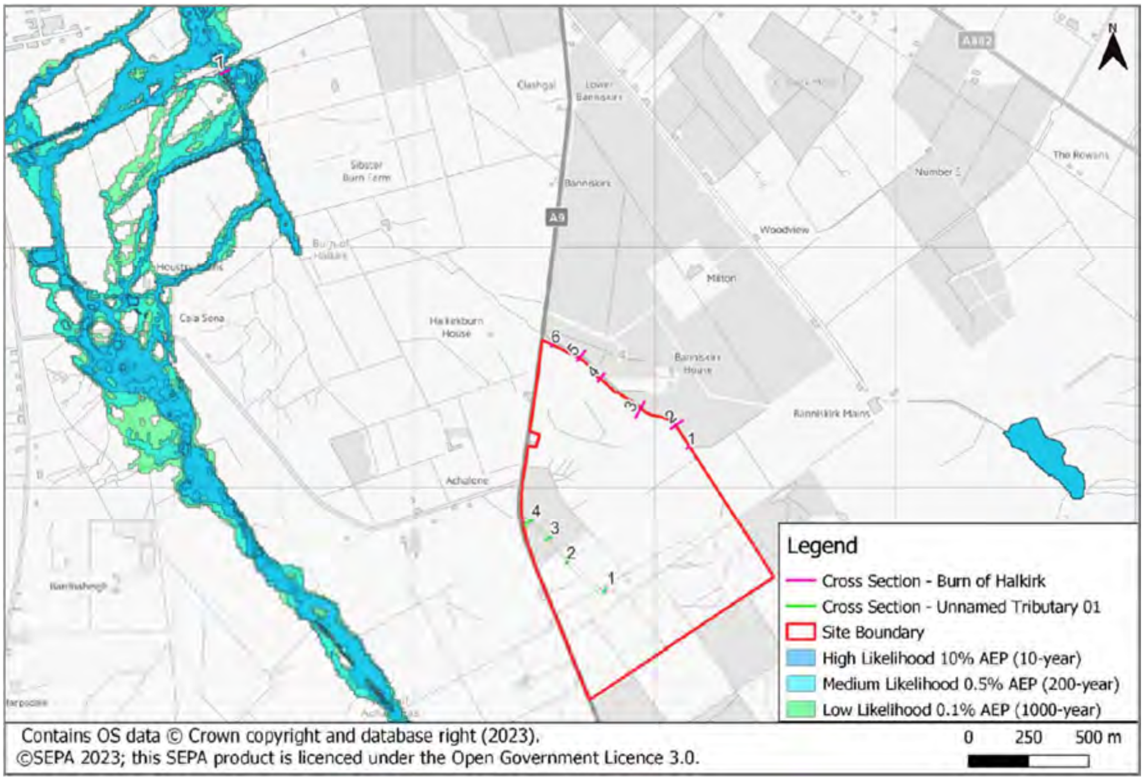

Figure 4: Location Plan Showing Indicative Fluvial Flood Extents as Based on SEPA Flood Map Data.

3.2. Design Peak Flood Flows

Estimated design peak flood flows have been derived within ReFH2.3 based on the inputs and parameters presented in

Table 3. The adopted design flows are shown in Table 4.

Table 3: ReFH2 Inputs and Model Parameters.

Site Code	Area	DPLBAR (km)	Storm Duration (hours)	Method	TPural (hours)	Cmax (mm)	Primp (%)	BL (hours)	BR
BoH_01	1.92	1.7	3.75	CD	1.98	300.8	70	21.8	0.949
TRIB_01	0.48	0.67	2.75	CD	1.44	300.8	70	17.1	0.961
TRIB_02	0.24	0.56	2.15	CD	1.26	300.8	70	15.5	0.967
BoA_01	0.38	0.59	2.75	CD	1.38	300.8	70	16.6	0.960
Methods: OPT Optimisation, BR Baseflow recession fitting, CD Catchment descriptors, DT Data transfer									

Table 4: Design Peak Flood Flows (m^3/s).

Site Code		**BoH_01**	**TRIB_01**	**TRIB_02**	**BoA_01**
Location		**A9**	**A9**	**A9**	**A9**
AEP (%)	**Return period (years)**	**Design peak Flow (m^3/s)**			
50	**2**	1.08	0.32	0.16	0.25
20	**5**	1.5	0.45	0.23	0.36
10	**10**	1.85	0.56	0.29	0.45
5	**20**	2.26	0.68	0.36	0.55
3.33	**30**	2.54	0.77	0.41	0.62
3.33 + CC	**30 + CC**	3.69	1.12	0.59	0.91
2	**50**	2.93	0.89	0.47	0.72
1.33	**75**	3.28	1.00	0.53	0.81
1	**100**	3.54	1.08	0.57	0.88
0.5	**200**	4.20	1.29	0.68	1.05
+ CC	**200 + CC**	6.25	1.92	1.01	1.55
0.1	**1000**	5.90	1.84	0.98	1.49
CC	**1000 + CC**	8.93	2.77	1.47	2.24

3.3. Channel Capacity Calculations

Table 5 presents the calculated channel capacity based on channel cross-sectional profiles obtained from the available DTM data and as measured during the hydrology site walkover survey. Channel gradient has been inferred from the DTM data. The assessment has adopted a Manning's roughness value of 0.035 and as a sensitivity test, has assessed capacity based on varying the Manning's roughness value by ±20%. The locations of the cross-sections are shown in Figure 4 for the Burn of Halkirk and Unnamed Tributary 01

Values highlighted in green indicate that the calculated channel capacity is greater than the estimated 0.5% AEP (200-year) plus climate change design flow. Values highlighted red indicate that calculated capacity is less than the 0.5% AEP (200-year) design flow. Values highlighted amber indicate that the calculated capacity is greater than the 0.5% AEP (200-year) design flow but less than the estimated 0.5% AEP (200- year) plus climate change design flow.

Cross-sections are referenced 1 - 7 from upstream to downstream along the Burn of Halkirk (BoH). Cross sections 1 – 6 are located along the eastern site boundary while cross section number seven is located just upstream of the railway, refer to Figure 4 for context. Along the Unnamed Tributary 01 (UT01), cross sections are referenced from 1 - 4, from upstream to downstream, refer to Figure 4 for context.

Table 5: Calculated Channel Capacity.

Cross-Section Reference (XS)	**Location**	**Calculated Capacity (m^3/s) DTM Data**			**Calculated Capacity (m^3/s) Measured Data**		
		n (0.035)	n (-20%)	n (+20%)	n (0.035)	n (-20%)	n (+20%)
1	BoH @ 316146.3, 957172.9	8.9	11.1	7.4	10.6	13.3	8.9
2	BoH @ 316090.0, 957261.5	10.8	13.5	9.0	15.8	19.8	13.2
3	BoH @ 315945.5, 957332.5	29.1	36.3	24.2	24.7	30.9	20.6
4	BoH @ 315781.7, 957463.0	15.7	19.7	13.1	13.5	16.8	11.2
5	BoH @ 315692.0, 957546.4	18.6	23.2	15.5	-	-	-
6	BoH @ 315578.1, 957605.6	4.3	5.3	3.5	5.9	7.4	4.9

Cross-Section Reference (XS)	Location	Calculated Capacity (m^3/s) DTM Data			Calculated Capacity (m^3/s) Measured Data		
		n (0.035)	n (-20%)	n (+20%)	n (0.035)	n (-20%)	n (+20%)
7	BoH @ 314208.5, 958730.2	4.4	5.3	3.5	-	-	-
1	UT01 @ 315792.7, 956574.6	2.8	3.5	2.4	5.3	6.6	4.4
2	UT01 @ 315636.5, 956689.5	3.2	4.0	2.7	7.4	9.3	6.2
3	UT01 @ 315557.9, 956787.2	2.7	3.4	2.3	4.8	6.0	4.0
4	UT01 @ 315472.2, 956855.2	3.4	4.2	2.8	12.0	15.0	10.0

The catchment area draining to the Railway culvert is calculated as 14.6 km² and by scaling of the reported flows for the Burn of Halkirk, as estimated at the A9, by the ratio of catchment areas; it is found from Table 4 and Table 5, that channel capacity upstream of the railway is less than the estimated 50% AEP (2-year) event. It should be noted that this is based on assessment of a single cross-section with a minimum bank level taken as 0.53 m, as inferred from the Scottish Public Sector 1 m LiDAR (Phase II) dataset.

The channel gradient of the Burn of Halkirk increases with upstream distance as can be seen in the calculated slope at the sections where assessment was undertaken. Channel geometry including slope are presented under 'Additional Information'.

Based on channel capacity as assessed at the various locations along the Burn of Halkirk, it is shown that the channel generally has capacity to convey the estimated 0.5% AEP (200-year) plus climate change allowance event (6.25 m^3/s). The exception being at cross section number six which is located immediately upstream of the A9 Trunk Road. At this location, capacity (based on a Manning's roughness of 0.035 and measurements obtained on site) is calculated as being approximately the 0.1% AEP (1000-year) event but less than the 0.5% AEP (200-year) plus climate change allowance event.

The calculated water level at Burn of Halkirk cross section number six under the 0.5% AEP (200-year) plus climate change allowance event is 64.70 mAOD (or 64.78 mAOD based on the DTM based cross-sectional profile) and is shown against the adopted section for context. It should be noted that ground elevation on the left bank continues to rise towards the development and whilst bank level is exceeded, the development would not necessarily be inundated. The finished levels of the AC and DC Platforms are 81.5 mAOD and 83.5 mAOD, respectively and no critical operational areas or noncritical operational areas are located in this area of the site.

Based on interrogation of the ground topography, flood water that spills over the left bank would be conveyed north-west towards the A9 and with increasing water level would inundate and be stored over the right bank floodplain before inundating the site. The elevation of the A9 carriageway at the nearest location is ~65.2 mAOD, i.e., located above the calculated 0.5% AEP (200-year) plus climate change water level of 64.70 mAOD.

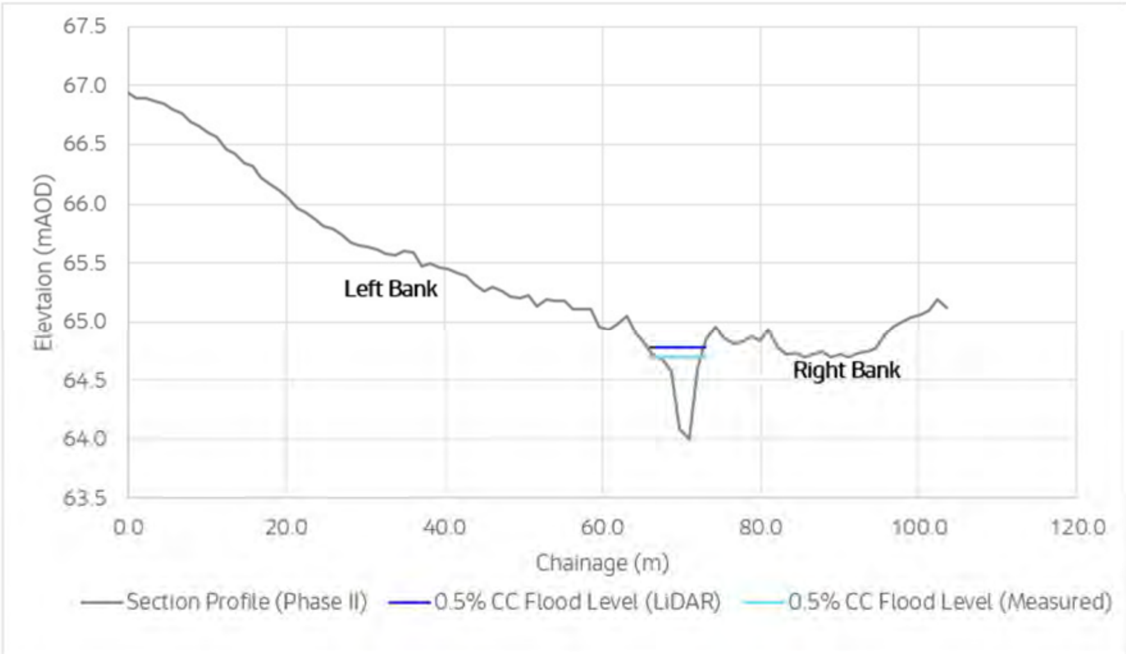

Figure 5: Calculated 0.5% AEP + CC Water Level at Burn of Halkirk Cross-Section 06.

At the locations where channel capacity was assessed along the Unnamed Tributary 01, it is shown that the channel again has capacity to convey the estimated 0.5% AEP (200-year) plus climate change allowance (1.92 m^3/s) event. The minimum capacity is calculated at cross section number three and cross section number one which is 4.8 m^3/s and 5.3 m^3/s, respectively.

The assessment undertaken at cross section number one is discussed as it is located approximately 80 m from the DC Platform. Cross-section one also represents the location of a required watercourse crossing associated with the access road to the DC Platform, refer to Figure 4 for context. The calculated water level at Unnamed Tributary 01, cross section number one, under the 0.5% AEP (200- year) plus climate change allowance event is 82.31 mAOD (or 82.67 mAOD based on the DTM based cross-sectional profile) and is shown against the adopted section for context.

It should be noted that the discrepancy in calculated water level is partly the result of the bank height as measured on site. The minimum bank height as inferred from the DTM data is 0.73 m whilst the minimum bank height as measured in the field was 1.1m. Hence, under assessment of the measured cross sections, channel bed level is adjusted based on the assumption that bank level as inferred from the DTM data is correct. This does not impact upon the comparability of the reported channel capacities as the starting bed level between two comparisons could as well be an arbitrary value.

The finished level of the DC Platform is 83.5 mAOD, i.e., located above the calculated 0.5% AEP (200-year) plus climate change water level. Taking the most critical assessed water level, based on a +20% increase in the adopted Manning's roughness value and assuming the cross-sectional properties as inferred from the DTM data gives a 0.5% AEP (200-year) plus climate change water level of 82.72 mAOD, again below the DC Platform level of 83.5 mAOD.

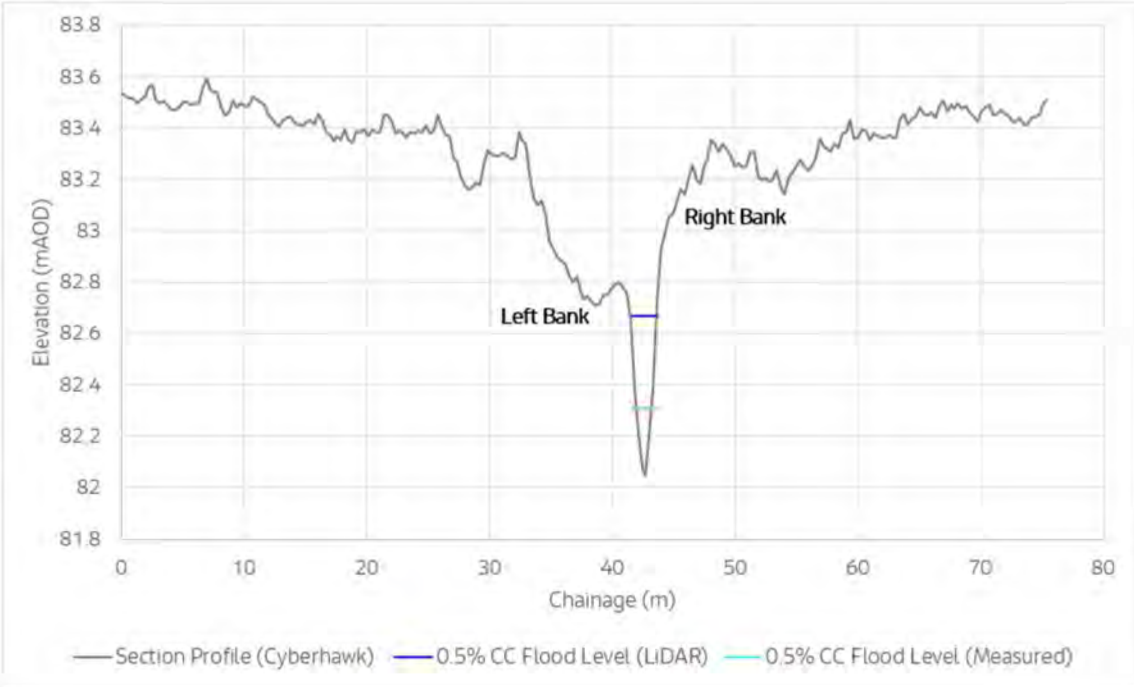

Figure 6: Calculated 0.5% AEP + CC Water Level at Unnamed Tributary 01 Cross-Section 01.

3.4. Hydraulic Structure Capacity Calculations

Culverts and other in-channel structures can result in throttling of flow resulting in reduced conveyance. Blockages, resulting from trapped debris or sedimentation, can further lead to reduced conveyance, which in turn, could exacerbate flood levels. The Burn of Halkirk is culverted at various locations along its course as are Unnamed Tributary 01 and Unnamed Tributary 02. A structure register is included in Appendix B 'Structure register' which provides details of all structures observed and recorded during the hydrology walkover survey which took place on the 15th and 16th of November 2023.

It would be too onerous to assess all observed structure capacities and unlikely that the data available would be sufficient to do so or yield any true benefit to understanding the existing fluvial flood risk. For example, no topographical survey data is available for the site and instead, structure capacities are assessed based on channel and structure geometry as measured in the field and using the available DTM data.

Hydraulic structures that are considered important in terms of influencing flood risk have been assessed in accordance with the CIRIA Culvert, Screen and Outfall Manual (C786) and the assessments detailed in the subsequent paragraphs.

3.4.1. Burn of Halkirk

The Burn of Halkirk receives flow from two main branches one which is culverted under the Quarry access road via a 450mm pre-cast concrete pipe and the other out-falling from the diverted channel and pond outflow via a 600mm pre-cast concrete culvert. Calculated capacities are ~0.2 m^3/s and ~0.4 m^3/s, respectively. The catchment area draining to the inlet of the 450 mm culvert under the Quarry access road, is calculated as 0.35 km^2 and hence through scaling of the reported flows for the Burn of Halkirk by the ratio of catchment areas; it is found that the 450 mm pipe has capacity to pass the estimated 50% AEP (2-year) fluvial event but less than the estimated 20% AEP (5-year) fluvial event. The catchment area draining to the inlet of the 600 mm culvert is calculated as 1.22 km² and hence the calculated capacity is less than the estimated 50% AEP (2-year) fluvial event.

Flows in excess of the calculated capacity would first flood upstream of the culvert(s). At the location of the branch carried under the Quarry access road, capacity to soffit level (88.47 mAOD) is calculated as approximately 0.2 m³/s and to road level (89.17 mAOD) capacity is calculated as 0.45 m³/s. The estimated 3.33% AEP (30-year) design flow upstream of the Quarry access road is 0.47 m³/s suggesting that flows in excess of 0.45 m³/s (approximately the 30-year return period) could potentially overtop the road.

The access road drains north-east towards the Quarry entrance. Flood water that overtopped the road would be conveyed initially towards the Quarry before entering a channel located at NGR ND 16564 56684 where it would flood the area of wetland between the pond and Quarry site, refer to Figure 7 for context.

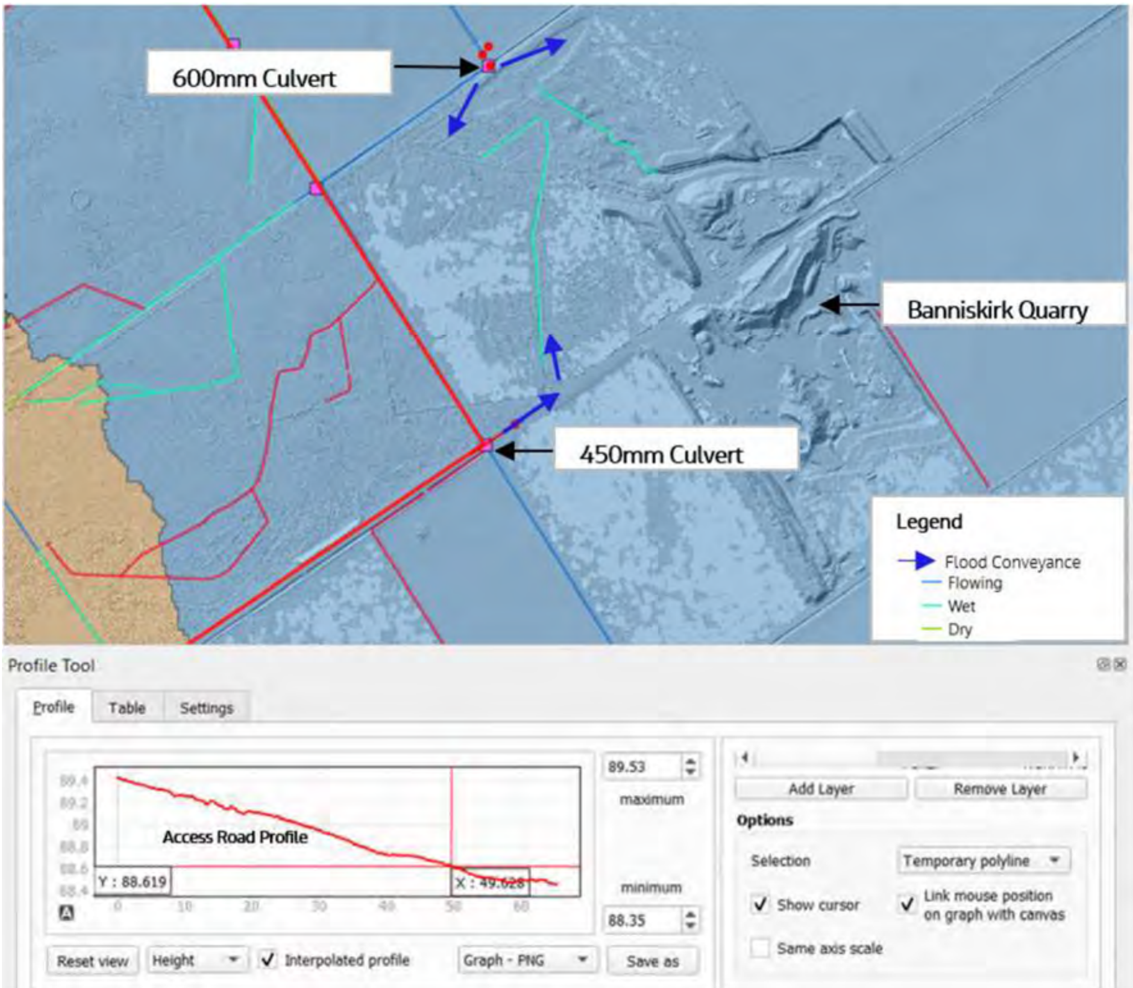

Figure 7: Location Plan Showing Channels and Structures Discussed and Anticipated Flow Paths.

At the branch downstream of the diversion channel and pond, i.e., the 600 mm culvert, capacity to soffit level (82.32 mAOD) is calculated as 0.4 m³/s and to the top of the embankment (83.0 mAOD), capacity is calculated as 0.84 m³/s. The estimated 20% AEP (5-year) design flow at the location upstream of the culvert is 0.95 m³/s. Hence, flows in excess of 0.84 m³/s (less than the estimated 20-year return period event) could potentially overtop the embankment and contribute overtopping flow into the downstream channel.

It Is important to state that calculations have been undertaken in a spreadsheet environment and do not account for flood water laterally spilling over the floodplain upstream of the culvert inlet. Rather the calculations assume a ‘glass walled’ scenario and whilst appropriate for calculating structure capacity, the calculated water level associated with a flow rate of 0.84 m^3/s will be conservative. The capacity of the receiving channel downstream of the culvert has been assessed using the tailwater cross section obtained on site.

The receiving channel is found to have sufficient capacity (12.8 m^3/s based on the most critical assessment, adopting a Manning’s roughness value of +20%) to convey the estimated 0.5% AEP (200-year) plus climate change allowance design flow as well as the 0.1% AEP (1000-year) plus climate change design flow. As mentioned, it is considered that during flood events that exceed culvert capacity, flood water would at least partly be conveyed to the area of wetland between the pond and Quarry site, thereby restricting the flow passed downstream. Refer back to Figure 7 for context.

Elsewhere along the course of the Burn of Halkirk, capacity is calculated as being less than the estimated 20% AEP (5-year) fluvial flow at most structures assessed and no greater than the 5% AEP (20-year) fluvial event.

Hence, whilst the channel is assessed as having sufficient capacity, the culverts which convey the watercourse do not. The location of the culvert structures on the Burn of Halkirk that have been assessed are shown in Figure 8.

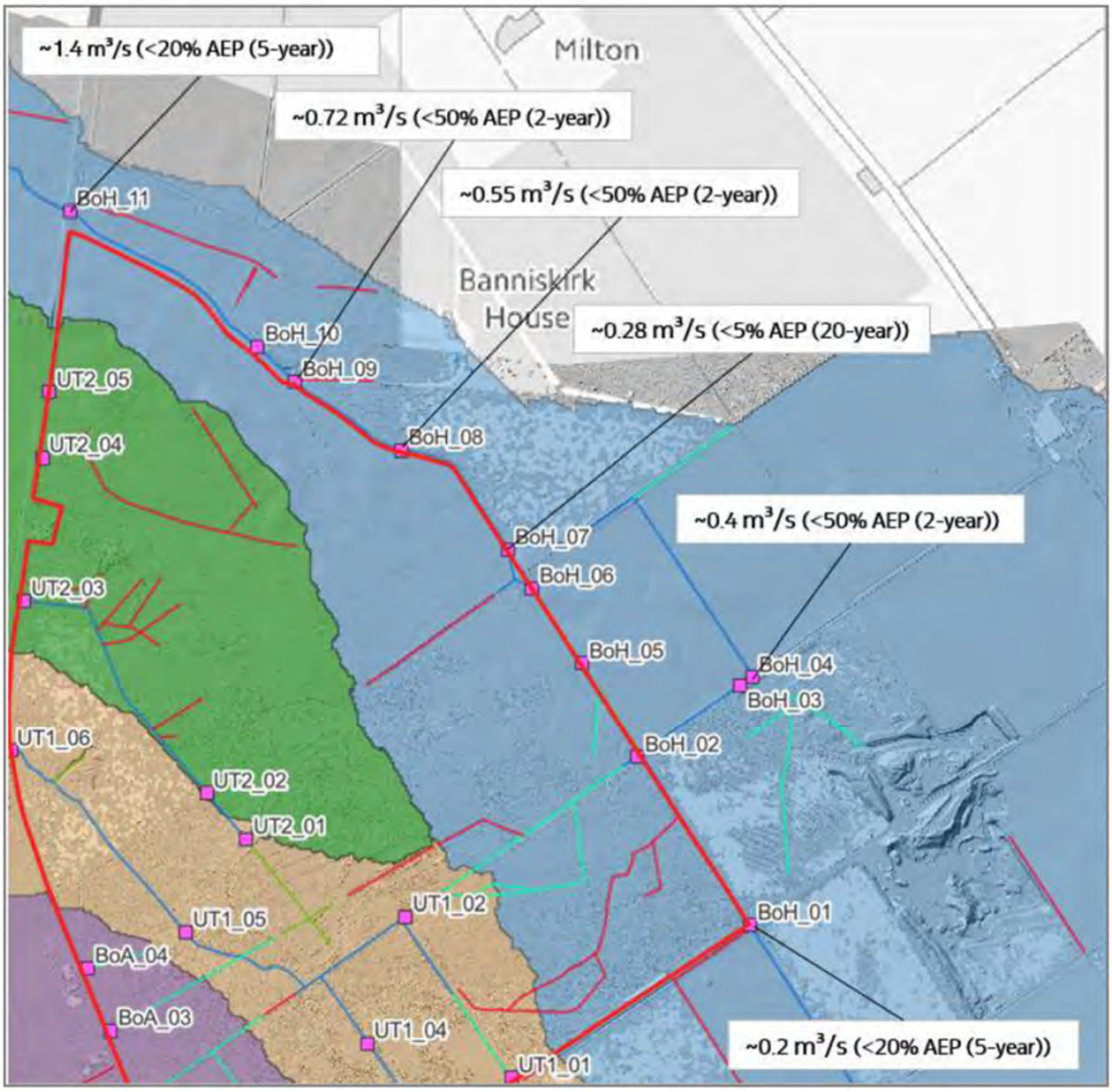

Figure 8: Location Plan Showing Calculated Structure Capacity Along Burn of Halkirk.

3.4.2. Unnamed Tributary 01

The Unnamed Tributary 01 receives flow from two main branches one which drains from Spittal Hill and is culverted under the Quarry access road via two 250mm corrugated PVC pipe and the other out-falling from an unidentified upstream source via a 250mm steel pipe. The combined calculated capacity of the two 250mm corrugated PVC pipes is 0.11 m^3/s. The catchment area draining to the inlet of the two 250mm pipes is calculated as 0.14 km^2 and hence through scaling of the reported flows for Unnamed Tributary 01 by the ratio of catchment areas; it is found that the two 250 mm pipes have capacity to pass the estimated 50% AEP (2-year) fluvial event but less than the estimated 20% AEP (5-year) fluvial event. Capacity to headwall level (93.75 mAOD) is calculated as 0.22 m^3/s (approximately the estimated 3.33% AEP (30-year) fluvial flow of 0.23 m^3/s).

As mentioned, no obvious upstream source was identified at channel two and hence there is no means to calculate channel gradient. Assuming the same gradient as for the assessment of the two 250mm culverts carrying channel one under the Quarry access, capacity of the single 250mm pipe is hence 0.055 m^3/s. Based on the calculated area draining to the 250mm pipe (calculated as 0.02 km^2), the capacity is sufficient to convey flows up to approximately the estimated 0.5% AEP (200-year) fluvial flow of 0.056 m^3/s. It is thought that the single 250m pipe is draining the access road runoff and hence the gradient would be shallower and reported capacity less.

Taking channel one as example, there is potential for the access road to be overtopped during fluvial events greater than the 3.33% AEP (30-year) event. There is a high point along the access road in this location and surface water runoff and out-of-bank flows can be expected to shed from the road into this lower lying area. Once the road is overwhelmed flood water will be conveyed into the southern area of the site where it is conveyed by either of channel one or channel two. The capacity of channel one and channel two have been assessed, based on the tailwater cross sections obtained during the hydrology walkover survey, to have sufficient capacity to convey flows up to and beyond the estimated 0.1% AEP (1000-year) plus climate change fluvial flow. As shown in Table 6, the receiving channel i.e., at cross section one, downstream of the confluence of channel one and channel two, capacity is again calculated to be greater than the estimated 0.1% AEP (1000-year) plus climate change fluvial flow.

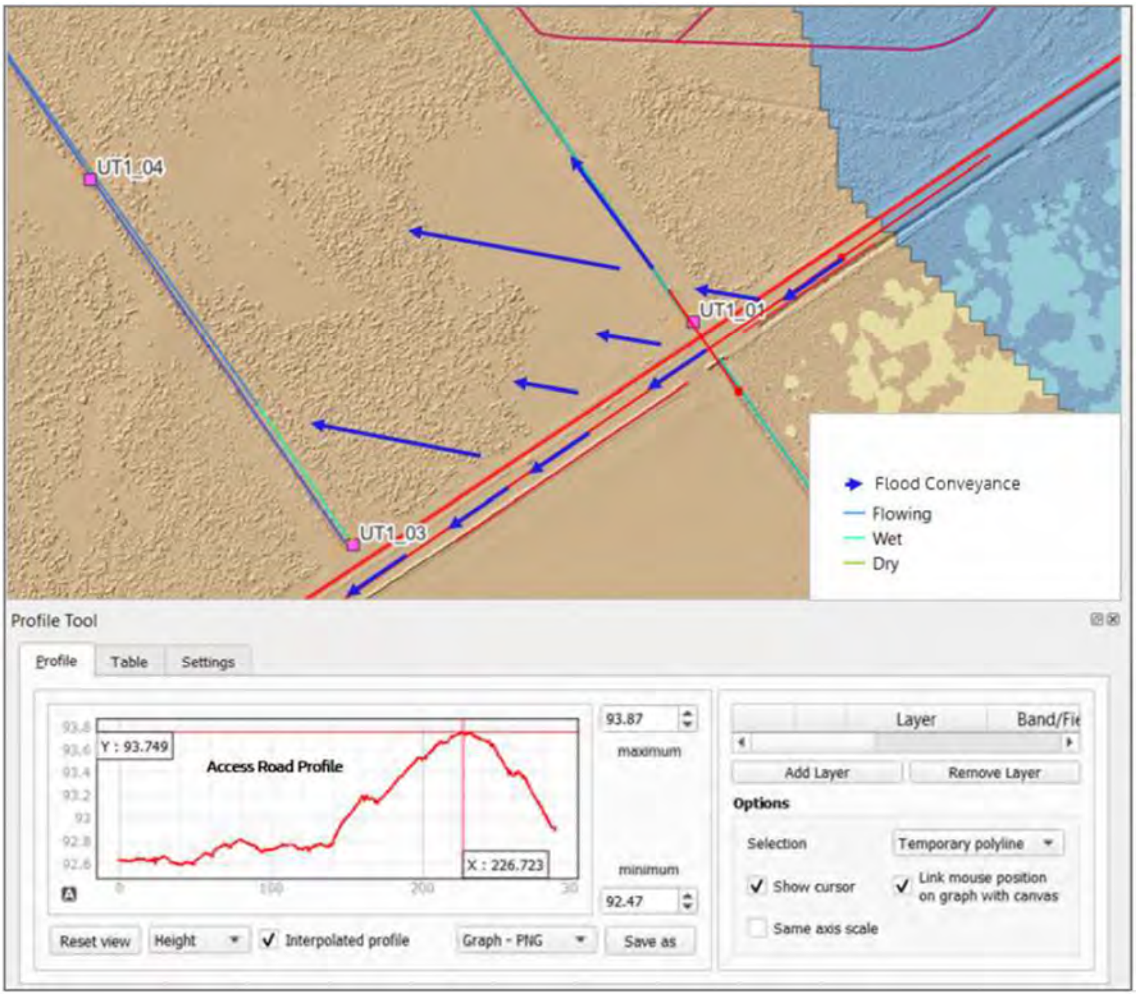

Figure 9: Location Plan Showing Channels and Structures Discussed and Anticipated Flow Paths.

Capacity at the 500 mm pre-cast concrete culvert downstream of the confluence and at the 500 mm pre-cast concrete culvert carrying the Unnamed Tributary 01 under the A9 is calculated as ~0.2 m^3/s which is less than the estimated 50% AEP (2-year) return period fluvial flow as reported in Table 5. Hence there is potential for the Unnamed Tributary to be throttled at these locations and for the watercourse to back-up, potentially resulting in out of bank flows.

3.4.3. Unnamed Tributary 02

Unnamed Tributary 02 emerges from a 300 mm corrugated PVC pipe culvert located at ND 15782 56750. The capacity of the pipe and the capacity of a further 300 mm corrugated PVC pipe located some 85 m downstream, is calculated as just 0.055 m^3/s. Based on a catchment area of 0.016 km^2 as calculated for the headwaters draining to the second 300 mm pipe, the culverts have sufficient capacity to pass the estimated 0.5% AEP (200-year) fluvial flow but not the 0.5% AEP (200-year) plus climate change allowance nor the 0.1% AEP (1000-year) fluvial flow. Capacity of the receiving channel as calculated from the adopted tailwater cross section is 1.2 m^3/s which is significantly greater than the estimated 0.5% AEP (200-year) plus climate change allowance fluvial flow. The Unnamed Tributary 02 is conveyed under the A9 via a further 300 mm corrugated PVC pipe. Its capacity is also calculated as approximately 0.05 m^3/s, which based on the catchment area draining to the culvert inlet at this location (0.11 km^2), is less than the estimated 50% AEP (2-year) fluvial flow.

3.4.4. Burn of Achanarras

The branch of the Burn of Achanarras that crosses the site, drains from Spittal Hill and is culverted under the Quarry access road via two 250mm clay pipes and out-falling to a heavily vegetated ditch. The pipes were observed to be of corrugated PVC at the upstream inlet. The combined calculated capacity of the two 250mm pipes is 0.07 m^3/s. The catchment area draining to the inlet of the two 250mm pipes is calculated as 0.12 km^2 and hence through scaling of the reported flows in Table 5, capacity is calculated as being less than the estimated 50% AEP (2-year) fluvial flow. At the 300 mm pre-cast concrete culvert at the A9, capacity is not assessed as the downstream outlet is uncertain. Given the barrel size, it is most probable the culvert has limited capacity.

3.5. Summary of Baseline Fluvial Flood Risk

From a fluvial flood risk perspective, the site is considered to be at risk of flooding during flood events less than the 3.33% (30-year) event. This is not to say that the proposed development would be impacted from fluvial flooding but rather, based on the assessment of upstream culvert capacity, the Quarry access road may be overtopped during the 3.33% AEP event at NGR ND 16166 56403 from the Unnamed Tributary 01 and at ND 16498 56628 from the Burn of Halkirk. Whilst flood water spilling from the Burn of Halkirk would be expected to initially flow towards the Quarry entrance and then be conveyed to the area of wetland via the channel at ND 16570 56681; flood water spiling from Unnamed Tributary 01 is expected to shed away from the Quarry entrance and flow south-west along the access road and potentially into the southern portion of the site.

It is important to note here, that the capacity of the two channels which drain the catchment of Unnamed Tributary 01 have more than sufficient capacity to convey flows up to and beyond the estimated 0.1% AEP (1000-year) plus climate change fluvial flow. Any flood water conveyed into the site would follow the natural fall of ground, which from Figure 9, it is shown that flood water would be expected to be conveyed into either of the two channels and conveyed through the site via the surface water network.

At the 600 mm diameter culvert (BoH_04) that conveys the combined outfall from the pond and diverted branch of the Burn of Halkirk, flow entering the watercourse and therefrom passed downstream is restricted by that which can be conveyed by the culvert barrel, calculated as 0.4 m^3/s (less than the estimated 50% AEP (2-year) fluvial flow). Capacity to the top of the embankment (83.0 mAOD) is calculated as 0.84 m^3/s, less than the estimated 20-year return period however this is likely to be a highly conservative estimate of the calculated head water level, given the calculations have been undertaken in a spreadsheet environment and assume a 'glass walled' scenario.

Where hydraulic structures have been assessed, the calculated capacities are found to be significantly less than the estimated design flow (i.e., the 0.5% AEP (200-year) plus climate change allowance fluvial flow). Hence there is potential for the watercourses which drain the site to be throttled at these locations and for the watercourse to back-up, potentially resulting in out of bank flows. The assessment is not based upon topographical survey but instead, structure capacities are assessed based on channel and structure geometry as measured in the field and using the available DTM data. However, the assessment does provide an indicative understanding that whilst the channel is assessed as generally having sufficient capacity to convey the design flood event without flooding, the existing culverts do not.

3.6. Potential Impacts

The AC and DC footprints sever the main existing flow paths of the Unnamed Tributary 01 and Unnamed Tributary 02 (refer to Figure 10 for context), thereby reducing the extent of the existing surface water network. During the hydrology walkover survey, the flow condition of the surface water network was recorded with regard to whether it was visibly flowing, wet or dry and whether the surface water was a formal watercourse or rather a manmade channel or ditch. Where surface waters are recorded as not observed ('Not Obsvd.'), this does not necessarily mean the feature does not exist but rather this feature was not observed or was not visited during the walkover survey. Figure 10 shows the proposed permanent development overlain with all watercourses and ditches.

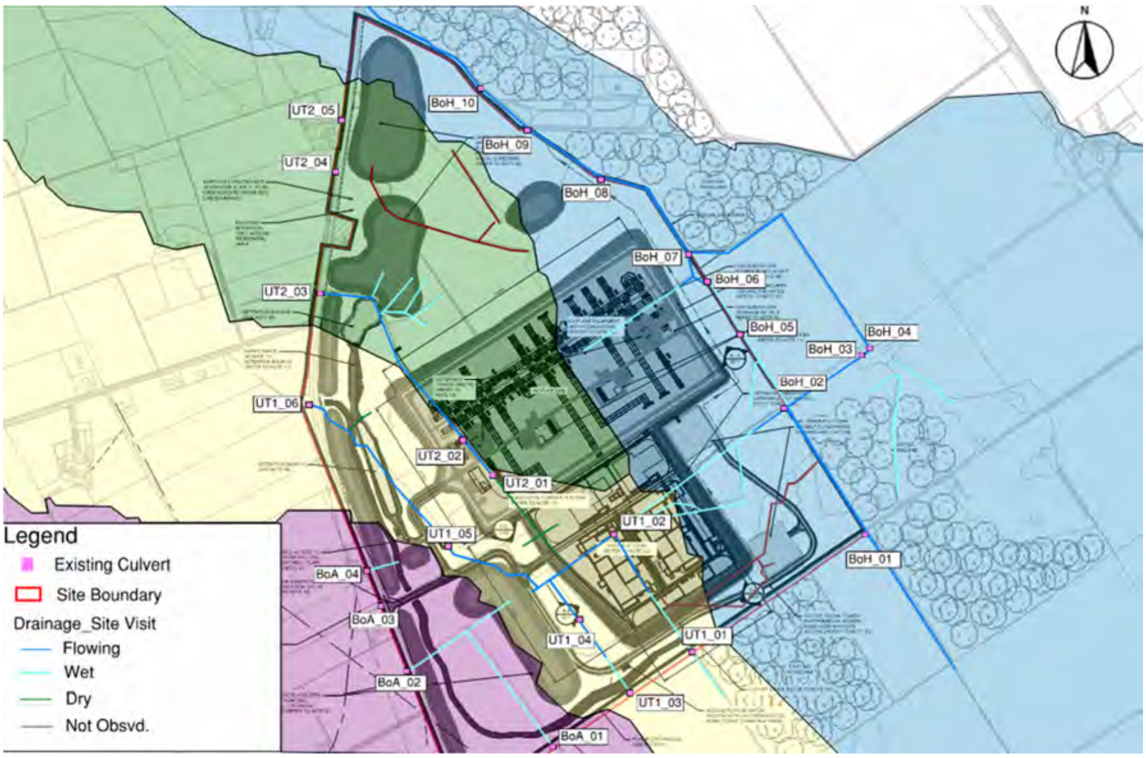

Figure 10: Location Plan Showing the Proposed Permanent Development Overlain with all Watercourses.

The Unnamed Tributary 01 is a minor but notable watercourse particularly downstream of the two branches (channel one and channel two) converging. Where measured during the walkover survey, the average minimum bank height was recorded as ~1.2 m and the average channel and bank width (bank to bank) recorded as 0.8 m and 3.5 m, respectively.

Under the permanent development, approximately 38% of the catchment headwaters and an approximate 300 m length of the upper reach of Unnamed Tributary 02 will be lost through the construction of the AC Platform.

The proposed access roads will necessitate watercourse crossings of the Unnamed Tributary 01, the branch of the Burn of Achannaras that enters from the Quarry access and potentially at locations throughout the wider catchments and catchment of Unnamed Tributary 02.

In summary, the proposed development has the potential to impact existing fluvial flood risk by:

- severing existing overland flow paths by the footprint of the AC and DC Platforms and by the network of access roads.
- potentially locating development infrastructure including SuDS features within the functional floodplain.
- fluvial flooding caused by inappropriately sized watercourse crossings (culverts) or from blockages occurring in newly constructed watercourse crossings.
- fluvial flooding caused by inappropriately designed channel diversions in terms of cross-section, planform and slope such that appropriate hydraulic conveyance (i.e., the 0.5% AEP (200-year) plus climate change allowance design event) is not achieved.

3.7. Mitigation

NPF4 promotes avoidance of development in flood risk areas, where avoidance is not possible i.e., where the location is required for operational reasons such as the proposed site; the development should be designed to remain operational during times of flood.

With regards to flood risk and hydrology, SEPA has stated in their Pre-Application Advice Service Response that the site layout should be designed to minimise watercourse crossings and avoid other direct impacts on water features. Where watercourse crossings are proposed, they should be designed to convey the 0.5% AEP (200-year) fluvial flood event including an appropriate allowance for climate change.

These requirements have been considered during collaborative discussions between Jacobs and SSEN to arrive at what is initially considered to be an acceptable and feasible site layout in terms of environmental protection and engineering feasibility.

In preparing the site layout, consideration has been given to the necessary watercourse diversions and with regard to minimising newly constructed watercourse crossings. Where watercourse crossings are proposed, the required culvert size reported here is in accordance with the CIRIA C786 Culvert, Screen and Outfall Manual (CIRIA C786, 2019) and meets the SEPA requirements to convey the 0.5% AEP (200-year) fluvial flood event including an allowance for climate change and provision of appropriate freeboard.

In accordance with the SEPA Planning Background Paper: Water Environment (SEPA, 2023), buffer strips between the proposed development and the boundary of watercourses including the proposed diverted watercourses have been provided for, proportional to the bank width and whether the surface water constitutes a ditch or watercourse. A minimum buffer of 10 m around each watercourse and ditch has, where possible, been achieved.

The proposed permanent development is overlain with the watercourse reaches that will be impacted by the development in Figure 11. Ditches and drainage channels impacted by the proposed development are discussed in the subsequent section 'Flooding from Land Drainage and Artificial Drainage'. A 10 m buffer strip is drawn around the existing watercourse alignment to indicate where the proposed development will encroach within 10 m of an existing watercourse alignment.

Figure 11: Location Plan Showing the Proposed Permanent Development Overlain with Impacted Watercourses

It is shown by Figure 11 that along the course of the Burn of Halkirk, the proposed development lies outwith the 10 m buffer strip. With the exception of planting mitigation and a natural regeneration area, no works are proposed within approximately 30 m of the Burn of Halkirk. The proposed planting mitigation and other landscaping considerations are being progressed by consultants ERM. It is understood that proposals for planting may consist of tree belts, hedgerows or a combination of hedgerows and trees.

As previously stated, the AC and DC footprints sever the existing flow paths of the Unnamed Tributary 01 and Unnamed Tributary 02. It will be necessary to divert the watercourses to maintain hydrological connectivity with their upstream catchment.

Unnamed Tributary 01 and Unnamed Tributary 02 are further impacted by the proposed access roads and will require appropriately sized crossings. The watercourses are also impacted by proposals for potential mounded areas, as shown in Figure 11. Mitigation of these impacts are discussed in the subsequent paragraphs.

Watercourse Diversions

For the Unnamed Tributary 01, it will be necessary to divert the watercourse around the footprint of the DC Platform and associated earthwork cuttings. Figure 12 shows the existing water course alignment and the proposed diverted reach. A 10 m buffer strip, either side of the diverted channel, is maintained between the DC Platform and Depot. The proposed length of the diversion is approximately 400 m.

Figure 12: Location Plan Showing the Proposed Permanent Development Overlain with Watercourse Diversion Proposals.

Watercourse diversions (and culverting for land gain) are engineering activities which require a licence under the Water Environment (Controlled Activities) (Scotland) Regulations 2011. It is beyond the scope of this FRA to provide any detailed design of an appropriate diversion channel in terms of planform, cross section, or gradient. Based on the assessment of channel capacity, the existing channel which carries surface water flows across the site was found to have sufficient capacity to convey the estimated 0.1% AEP (1000-year) plus climate change allowance fluvial flow. It would be sensible to ensure there is no abrupt change in channel profile in terms of both planform and gradient to that which the diversion will connect.

Diversion of the Unnamed Tributary 02 is complicated by the location of the catchment headwaters in relation to the proposed AC Platform. There are existing drainage paths as shown by the dashed blue line and these could be reprofiled to ensure surface water runoff is collected in the channels and conveyed away from the proposed development by its existing downstream reach.

Watercourse Crossings

The network of access roads will necessitate the implementation of newly constructed watercourse crossings. As shown in Figure 13, based on the current road layout, it considered that up to nine crossings will potentially be required.

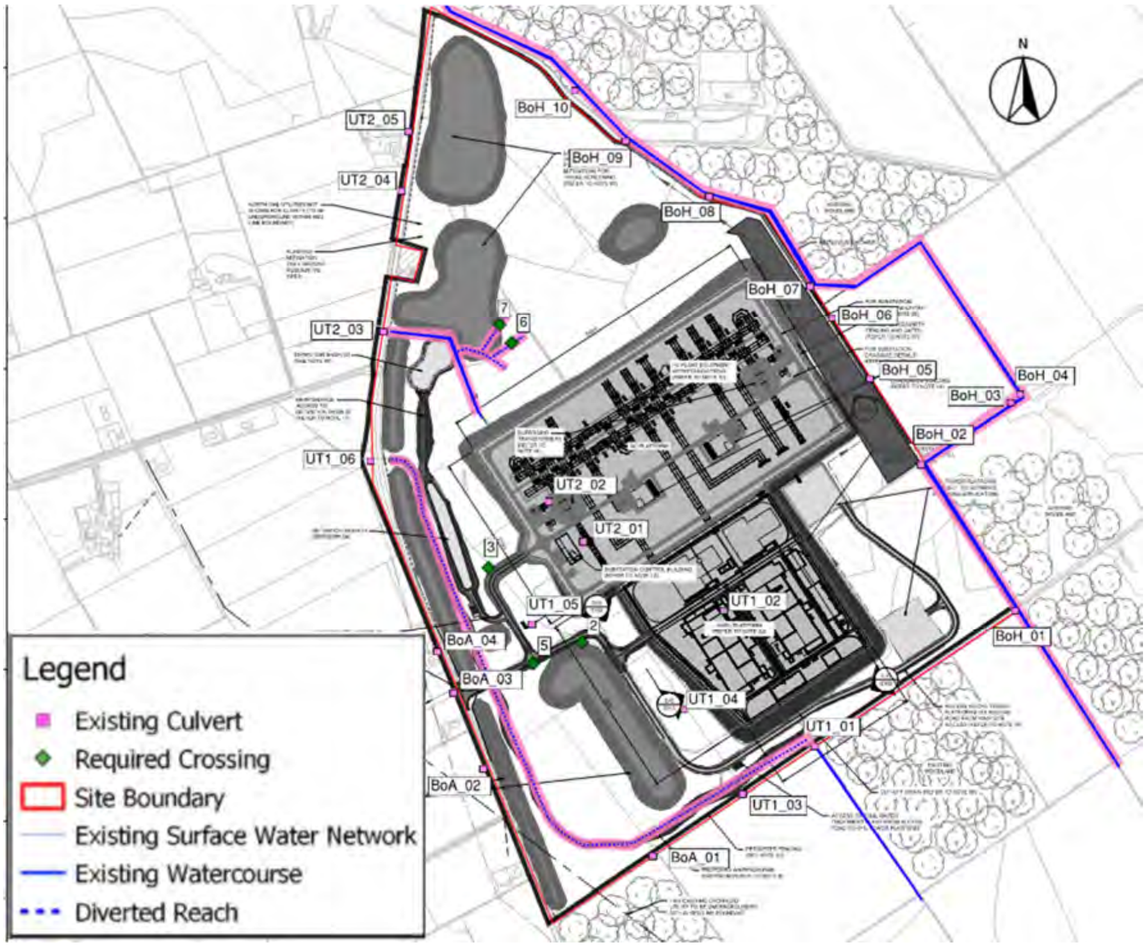

Figure 13: Location Plan Showing the Proposed Permanent Development Overlain with Watercourse Diversion Proposals and Required (and existing) Watercourse Crossings.

The Water Environment (Controlled Activities) (Scotland) Regulations 2011 (CAR) define culverting of a watercourse as a controlled activity. As such, authorisation must be obtained from SEPA for all culverting works.

Where watercourse crossings are proposed, they should be designed to convey the 0.5% AEP (200-year) fluvial flood event including an appropriate allowance for climate change and provision of appropriate freeboard.

There are three crossings required on the Unnamed Tributary 01, two within the Burn of Achanarras catchment and four within the catchment of Unnamed Tributary 02. A subset of the crossing locations has been considered and assessment undertaken.

The proposed sizing is in accordance with the CIRIA C786 (CIRIA C786, 2019) Culvert, Screen and Outfall Manual and meets the SEPA requirements to convey the 0.5% AEP (200-year) fluvial flood event including an allowance for climate change and provision of appropriate freeboard. The assessment does not consider requirements such as any embedment depth nor restrictions on culvert size imposed by channel width for example.

SEPA requirements are for small crossings to be oversized bottomless (box) culverts and larger crossings to be single span bridges, sized accordingly. These requirements will need to be taken into account in the final sizing of watercourse crossings during detailed design.

The assessment presented here, aims purely to provide an indicative size based on channel slope as inferred from the DTM data and the estimated design flows reported in Table 5.

At Unnamed Tributary 01 crossing number two, the catchment area draining to the proposed inlet is 0. 42 km^2 and the estimated 0.5% AEP (200-year) plus climate change allowance fluvial flow estimated as 1.66 m^3/s. It is calculated based on an adopted slope of 0.027 or 1 in 38 and Manning's roughness value of 0.015 representing the culvert, that the minimum required size of box culvert to freely pass the estimated design flow whilst maintaining an acceptable freeboard is 1.5 (h) x 1.5 (w).

At Unnamed Tributary 01 crossing number three, the catchment area draining to the proposed inlet is 0. 44 km^2 and hence the estimated 0.5% AEP (200-year) plus climate change allowance fluvial flow estimated as 1.77 m^3/s. Based on an adopted slope of 0.014 or 1 in 71, it is calculated that the minimum required size of box culvert to freely pass the estimated design flow whilst maintaining an acceptable freeboard is again 1.5 (h) x 1.5 (w).

At Unnamed Tributary 02 crossing number six, the catchment area draining to the proposed inlet is taken conservatively as 0.045 km^2 and the estimated 0.5% AEP (200-year) plus climate change allowance fluvial flow estimated as 0.192 m^3/s. It is calculated based on an adopted slope of 0.024 or 1 in 43 and Manning's roughness value of 0.015 representing the culvert, that the minimum required size of box culvert to freely pass the estimated design flow whilst maintaining an acceptable freeboard is 0.5 m (h) x 1.0 m (w).

Table 6: Indicative Culvert Sizes at Required Watercourse Crossings.

Crossing	Size (m) [HxW]	Calculated 0.5% CC Freeboard (m)	Required Freeboard (m)
Unnamed Tributary 01 – Crossing 02	1.0 x 1.0	-0.10	0.3
	1.0 x 1.2	0.02	0.3
	1.0 x 1.5	0.14	0.3
	1.2 x 1.2	0.22	0.4
	1.2 x 1.5	0.34	0.4
	1.5 x 1.5	0.64	0.5
Unnamed Tributary 01 – Crossing 03	1.0 x 1.0	-0.18	0.3
	1.0 x 1.2	-0.07	0.3
	1.0 x 1.5	0.09	0.3

Crossing	Size (m) [HxW]	Calculated 0.5% CC Freeboard (m)	Required Freeboard (m)
	1.2 x 1.2	0.13	0.4
	1.2 x 1.5	0.29	0.4
	1.5 x 1.5	0.59	0.5
Unnamed Tributary 02 – Crossing 06	0.5 x 1.0	0.23	0.2
	0.6 x 1.2	0.33	0.2
	0.8 x 1.5	0.53	0.3
	1.0 x 1.2	0.73	0.2

Along the Unnamed Tributary 01, the minimum size of culvert required to maintain the prescribed freeboard was found to be 1.5 m (h) x 1.5 m (w). This required width is greater than the measured average channel width (0.8 m) during the hydrology walkover survey. It would be necessary to ensure the width of any culvert is as per the width of the natural channel at ‘normal’ flow levels.

At Unnamed Tributary 02, catchment area was taken conservatively to produce a conservative flow estimate. The minimum size of culvert required to maintain the prescribed freeboard was found to be 0.5 m (h) x 1.0 m (w).

It is considered that given channel widths, whilst oversized bottomless (box) culverts will likely be suitable for the Unnamed Tributary 02 and crossings associated with the branch of the Burn of Achanarras, single span bridges may be required over the Unnamed Tributary 01.

The final proposed culvert / bridge sizes should be based on detailed topographic survey and should include for the requirements of SEPA regarding embedment depth etc., as well as ensuring that the proposed size can convey the 0.5% AEP (200-year) fluvial flood event including an appropriate allowance for climate change. Based on the assessment of existing culvert capacity, presented in 3.4, it would be of benefit removing those undersized culverts that are currently insitu such as the 500 mm pre-cast concrete culvert at NGR ND 15698 56618.

Elsewhere, where culverts are found to be undersized to convey the estimated design flow(s), such as at the culverts under the A9; to increase the capacity would serve to potentially increase downstream flood risk through increased pass forward flow rates. This would not be acceptable unless supported by detailed hydraulic modelling of the impacts upon downstream flood risk.

4. Flooding from Land Drainage and Artificial Drainage

Flooding from land drainage and artificial drainage is defined here as flooding resulting from the failure of land drainage infrastructure such as drains, channels and outflow pipes, which is most commonly the result of obstructions and / or blockages.

4.1. Baseline Risks

The wider area proposed for development is crossed by a historic system of field drains which are piped or culverted along their course. During the hydrology walkover survey, several of these manmade channels were observed to be wet whilst others observed as dry. The channels are thought to drain the land and divert water across catchments. It was observed that a 150 mm pipe (refer to structure register in Additional Information) was most likely diverting water from the Unnamed Tributary 01 catchment to the Burn of Halkirk. The pipes or structures which drain the network of field drains are typically small orifice pipes which are likely to become overwhelmed and hence can result in surface water flooding.

4.2. Potential Impacts

The proposed development will necessitate building upon the network of field drains as shown in Figure 14. Ditches will be infilled during formation of the platform layers, the strategy for maintaining the hydrological connectivity of channels one and two of Unnamed Tributary 01 are already discussed in Section 3.7. To the west of these a flow path (ditch) to the Burn of Halkirk will be severed. Elsewhere, the loss of land drainage is considered less of an impact as many of the ditches were observed as dry drainage ditches or partially wet and are not considered to be natural drainage pathways but rather a means of draining the site in its existing condition to allow for grazing of livestock. Under the permanent development, surface water runoff will be managed by the surface water strategy proposed for the site and hence will not require the same network of artificial land drainage.

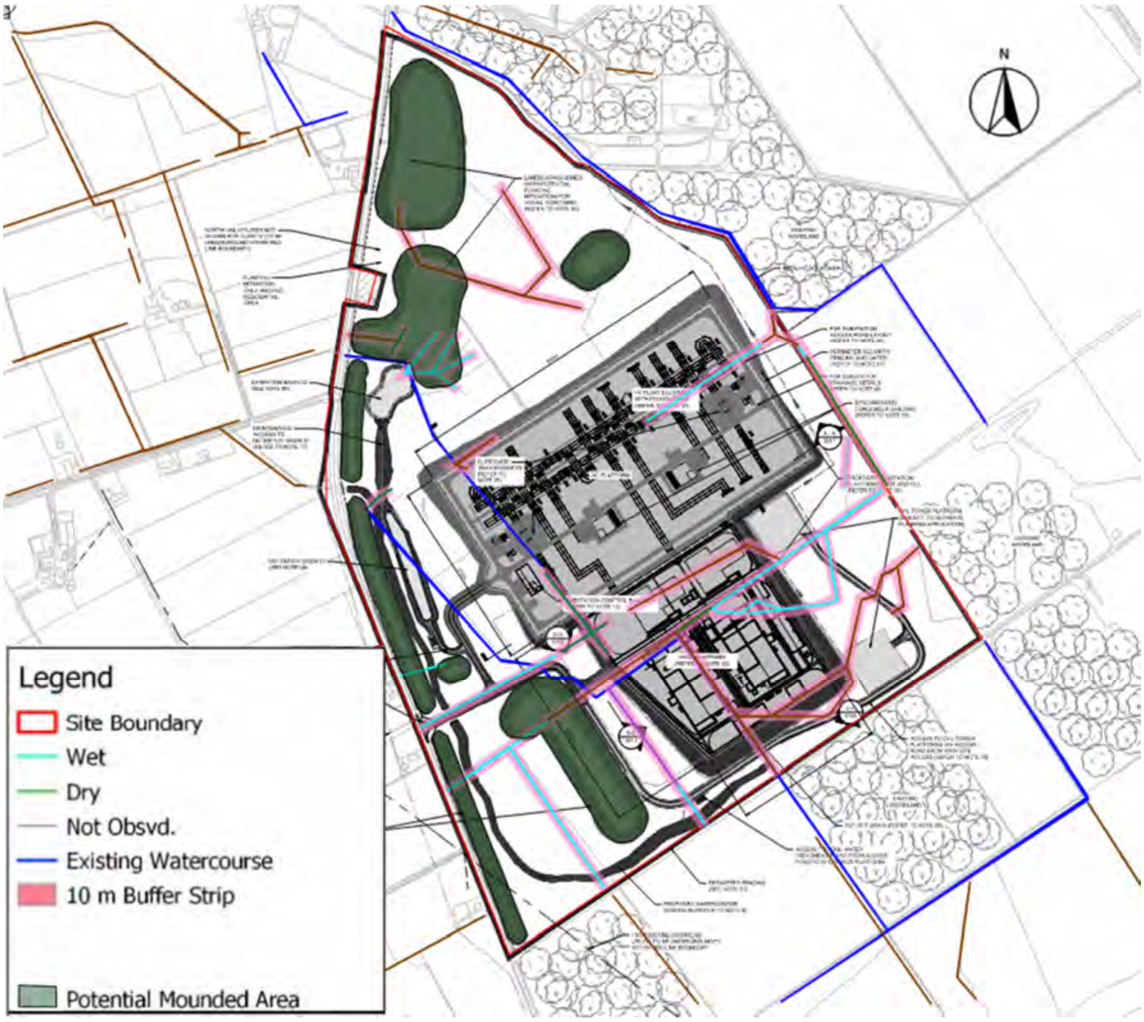

Figure 14: Location Plan Showing the Proposed Permanent Development Overlain with Impacted Land Drainage (Field Drains).

4.3. Mitigation

Where possible, the existing network of drainage ditches should be maintained for assisting in shedding water from the site. However as highlighted, the existing network of drains outfall to pipes or culverts that have been determined to be undersized for conveying flood flows and hence if left insitu could result in the ditches becoming overwhelmed leading to a risk of surface water flooding. It is recommended to remove culverts / pipes where no longer required during site works. It is further recommended that the commencement of retained drainage ditches ensure a 10 m buffer between the channel and proposed development as indicated in Figure 15.

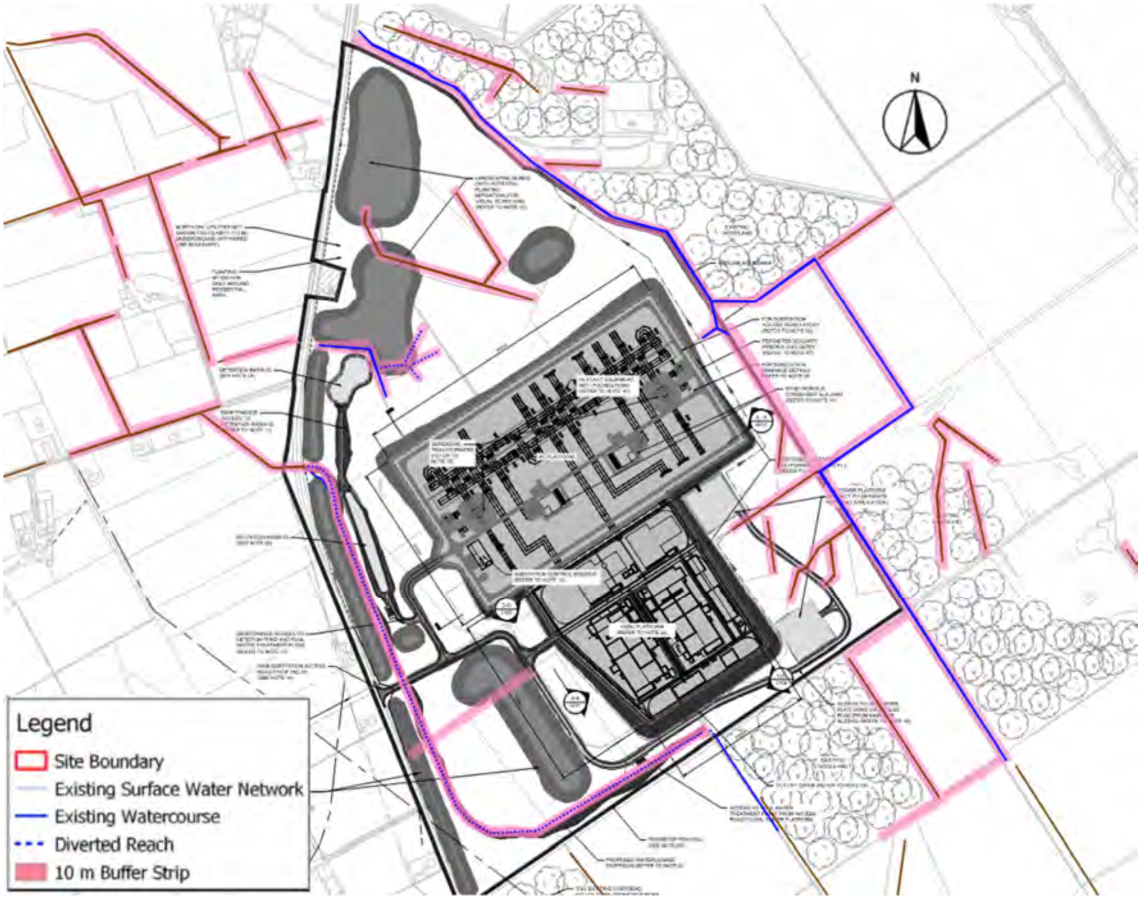

Figure 15: Location Plan Showing the Proposed Permanent Development Overlain with Drainage

5. Groundwater Flooding

Groundwater flooding occurs where water levels beneath the ground rise above the ground surface. In some instances, groundwater can emerge at surface level following heavy rainfall events and contribute to existing flooding from other sources. Alternatively, a greater risk can be presented if construction works or permanent development, intersect areas with shallow groundwater levels or create pathways for deeper confined artesian pressures, which can be released at ground level and cause widespread flooding.

The proposed development area is underlain by the Caithness groundwater body, a moderately productive aquifer formed within Middle Old Red Sandstone (Undifferentiated). The Old Red Sandstone (North) Aquifer is sedimentary and dominantly noncalcareous. In this location, it is classified as having low productivity, likely due to the presence of lower permeability siltstones and mudstones which separate fine grained sandstone beds and act as a barrier to groundwater flow. In Caithness, Ó Dochartaigh et.al (Ó Dochartaigh, 2015) states that groundwater flow is “concentrated along bedding planes and which tend to form only moderately productive aquifers”. Local to the site, the bedrock comprises the Spittal Flagstone Formation. Ó Dochartaigh et.al quotes a hydraulic conductivity of between 1.16 x 10^{-7} m/sec and 2.31 x 10^{-5} m/sec for the Old Red Sandstone Aquifer. Given the siltstone content at the proposed development, the hydraulic conductivity in this area is likely on the lower end of the range. The overlying superficial deposits comprise glacial till and are not considered a significant aquifer.

To develop a conceptual understanding of groundwater flooding associated with the proposed development, groundwater level data within the site boundary has been reviewed. Groundwater levels were obtained from Ground Investigations (GIs) undertaken by Raeburn Drilling & Geotechnical Limited[61].

5.1.1. Baseline Risks

Baseline conditions were determined through a desk-based assessment and review of GI data. This included a review area focused on areas of the proposed development that would involve excavations below existing ground level to form the AC and DC platforms.

The review focused on groundwater elevation data from November 2023, considering that groundwater levels would be expected to now be rising following the summer recession period. Data were available for 17 groundwater monitoring boreholes located across the proposed development. These are monitoring groundwater levels either in the siltstone or water bearing lenses of the Glacial Till/weathered siltstone.

Groundwater levels within the superficial deposits were between 2.27 mBGL and 0.1 m above ground level (average 82.87 mAOD). Groundwater levels within the siltstone bedrock were between 1.42 mBGL and 0.04 m above ground level (90.22 mAOD to 73.94 mAOD).

Given that the piezometric water level within the bedrock is higher than the base of the superficial deposits, the Spittal flagstone is a confined aquifer in this area. The shallow groundwater table in the superficial deposits is likely perched within the clay with limited vertical migration into the siltstone. In some cases, there were artesian conditions, such as at BH07 (water level +0.04 m above ground), BH17 (+0.1 m above ground) and BH13 (water at the surface).

The monitoring data indicates groundwater flow is to the northeast, generally following topography. The available data indicate that where excavations are required there is potential for intercepting groundwater, which could exacerbate flooding, such as fluvial flooding in the areas adjacent to watercourses or surface water flooding over the wider area. Dewatering measures may be required, subject to the depth of the excavation.

In areas underlain by glacial till deposits, groundwater may also emerge at surface level because of rising groundwater levels in the superficial deposits. The low permeability horizons (sandstone and siltstone with subsidiary mudstone (IGNE, 2023)) within the Spittal Flagstone Formation may lead to variable connectivity and therefore variable groundwater yields across the aquifer. The depth to bedrock is shallow and potential artesian conditions have been observed, hence there is potential for groundwater flood risk from the bedrock aquifer below.

It should be noted that the groundwater monitoring data used to inform this baseline assessment has been collected over finite periods and hence, they do not necessarily indicate the maximum groundwater levels that may develop. Groundwater levels would usually be expected to increase through the winter, typically peaking early in the new year (e.g. February to March). Consequently, there may be potential for groundwater-related flooding beyond the current conceptual understanding of groundwater flood risk. Currently, according to SEPA Groundwater Flood mapping (SEPA, 2023) the proposed development is not indicated as having likelihood of groundwater flooding.

There are no designated sites within the boundary of the proposed development (Scottish Government, 2023) or any known sites with a dependence on groundwater. Nevertheless, based on the observed hydrogeological conditions outlined above there is potential for groundwater emergence in topographically lower areas where the low permeability superficial deposits are thin or absent. However, there is no strong evidence that this is currently occurring to any significant degree.

Due to the shallow observed groundwater levels, any excavations are likely to encounter groundwater and groundwater inflow to excavations can be expected where these penetrate below the low permeability superficial deposits, or those deposits are thin or absent.

Groundwater elevation shows that the bedrock groundwater is unlikely to be in continuity with surface water courses or the mapped marshland. Geological mapping shows that these water features are likely to be situated on glacial till and therefore perched on these low permeability deposits. The burn receives waters from the drains and any surface water run-off. The groundwater within the superficial deposits is likely in continuity with surface water features but only in so much as once the till is fully saturated, run-off is directed to the drains and burns. Groundwater flow within the till to the bed of the drains and burns is likely to be very limited due to the low permeability of these deposits.

Given the shallow groundwater levels and identified perched groundwater within the glacial till, the proposed development would likely become flooded if water was discharged to ground as the geology would not be able to readily absorb the water; the ground is likely fully saturated already, hence the agricultural drains to relieve the farmland.

5.1.2. Potential Impacts

There are several ways that the proposed development may influence groundwater flooding during both the construction phase and permanent development. These include the potential for dewatering due to proposed cuttings or aspects of infrastructure which may impede or alter local hydrological regimes and groundwater flows. Dewatering solutions will be proposed within the water management plan (BANN4-LT407-JMS-DRAI-XX-PLN-C-0101).

The basis of the assessment has been to identify areas of excavations. These comprise excavations to form the AC Platform and DC Platform. Geological and hydrogeological information derived from available GI and the recent monitoring is provided in Table 7. Groundwater level and depth to bedrock data have been interpreted to evaluate indicative groundwater and bedrock levels as far as possible across the footprint of the proposed development.

Table 7: GI and Groundwater Monitoring Information (November 2023).

Borehole ID	Ground Elevation (mAOD)	Depth (m)	Bedrock / Superficial Installation	Response Zone	Water Level (mbgl)	Water Level (mAOD)	Notes
BH01	90.19	14.9	Bedrock	2.5 - 10	0.58	89.61	50mm Standpipe – slotted casing in Siltstone
BH02	91.02	14.6	Bedrock	1.1 – 14	0.8	90.22	50mm Standpipe – slotted casing in sandstone and siltstone
BH03	89.65	15	Bedrock	5.0 – 14	0.55	89.1	50mm Standpipe – slotted casing in Siltstone
BH04	88.76	15.35	Bedrock	3.2 – 14	0.70	88.06	50mm Standpipe – slotted casing in Siltstone
BH05	88.49	15	Superficial Deposits	1.2 – 3.1	0.40	88.09	50mm Standpipe – slotted casing in till (very soft to stiff slightly gravelly slightly sandy clay)
BH06	87.85	14.8	Superficial Deposits	1.2 – 2.8	0.33	87.52	50mm Standpipe – slotted casing in till (stiff brownish grey slightly gravelly sandy clay)
BH07	85.52	15.1	Bedrock	1.8 - 14	+0.04	86.09	50mm Standpipe – slotted casing in Siltstone. Water strike at 1.3mBGL which dropped to 1.5mBGL after 10 minutes.

Borehole ID	Ground Elevation (mAOD)	Depth (m)	Bedrock / Superficial Installation	Response Zone	Water Level (mbgl)	Water Level (mAOD)	Notes
BH09	86.79	15.15	Bedrock	2.7 – 10	0.7	86.09	50mm Standpipe – slotted casing in Siltstone
BH10	87	10.05	Superficial Deposits	1 – 2.5	2.27	84.73	50mm Standpipe – slotted casing in Sand and Weathered siltstone
BH11	86.43	9.9	Bedrock	3.5 – 9	0.77	85.66	50mm Standpipe – slotted casing in Siltstone
BH13	81.93	10.05	Superficial Deposits	1 – 2.2	0	81.93	50mm Standpipe – slotted casing in Till. Water struck at 1.2mBGL stayed at 1.2mBGL after 10 minutes.
BH15	85.16	10	Bedrock	4.5 – 9	1.42	83.74	50mm Standpipe – slotted casing in Siltstone
BH16	83.79	6.7	Bedrock	2.5 – 6	-	-	50mm Standpipe – slotted casing in Siltstone
BH17	83.2	7.65	Superficial Deposits	1.0 – 2.0	+0.1	83.3	50mm Standpipe – slotted casing in Till.
BH18	80.68	6	Bedrock	2.0 – 6	0.5	80.18	50mm Standpipe – slotted casing in Siltstone
BH20	79.27	7.05	Bedrock	2.5 – 7.05	0.5	78.77	50mm Standpipe – slotted casing in Siltstone

Borehole ID	Ground Elevation (mAOD)	Depth (m)	Bedrock / Superficial Installation	Response Zone	Water Level (mbgl)	Water Level (mAOD)	Notes
BH21	78.40	7.3	Bedrock	1.5 – 7.3	0.53	77.87	50mm Standpipe – slotted casing in Siltstone
BH24	73.67	7.95	Superficial Deposits	1 – 2.5	2	71.67	50mm Standpipe – slotted casing in Made ground (described as gravel)
BH26	75.13	7.1	Bedrock	2.0 – 6.0	1.9	73.94	50mm Standpipe – slotted casing in Siltstone

The proposed DC Platform will be excavated into the north-west side of Spittal Hill and is expected to generate groundwater dewatering. The AC Platform will require some limited excavation at its south-east side but the degree of dewatering is expected to be very limited. A dewatering assessment has therefore been conducted for the DC Platform.

The deepest excavation is based on the lowest proposed platform finished level, 83.5 mAOD (Option G DC Platform) with an additional 1 m of excavation allowed below this finished level. The bulk of the excavated area lies between 85 and 90 mAOD. The highest recorded ground elevation in the proposed development area is 91.02 mAOD, recorded at BH02 at the south-east side of the platform. The width of the proposed excavation is 320 m. The anticipated maximum depth of excavation, at the south-east side of the DC Platform, will be approximately 7.5 m.

A high-level assessment of anticipated dewatering at the DC Platform has been performed with the expectation that at least 7 m of groundwater drawdown will be necessary, assuming a water table at 0.5 mBGL, with no consideration for the thin superficial layer. (The water table has been observed to be 0.5 mBGL at ground elevations of around 90 mAOD.)

The radius of influence was calculated using the empirical formula of Sichardt (CIRIA, 2016). When groundwater is intercepted, due to acknowledged limitations in the Sichardt method, a minimum radius of influence of 30 m has been set (Cashman and Preene, 2021).

The hydraulic conductivities have been taken from the Ó Dochartaigh et al (B É Ó Dochartaigh, 2015) in the absence of in-situ test data. The proposed development is predominantly underlain by siltstone. A hydraulic conductivity of 1.16 x 10-7 m/sec has been conservatively used in this instance. While this is at the lower end of the range quoted in the BGS report, literature values quoted for the hydraulic conductivity of siltstones can be as little as 1.00 x 10-11 m/sec (Domenico & Schwartz, 1990) and is considered to be a conservative choice here.

The radius of Influence was calculated to be relatively small around the excavation, therefore the default minimum of 30 m has been assumed for calculation purposes.

Using the Thiem - Dupuit equation for steady-state confined flow, the dewatering volume was estimated to be 0.4 l/s. The equation is as follows:

$$Q = \frac{2\pi k D(H - h_w)}{\ln[{}^{R_o}/_{r_e}]}$$

k is the hydraulic conductivity (m/sec)

D is the thickness of the confined aquifer (m)

H is the initial piezometric level in the aquifer (mBGL)

h_w is the lowered water level in equivalent well (mBGL)

r_e is the equivalent radius of well (m)

R_o is the radius of influence (m)

This assumes an excavation into flat ground at equal depth across the excavation. However, considering this excavation is into a hill side, with the depth of excavation decreasing progressively down slope, the actual dewatering rate would be expected to be less than this. It is considered reasonable to assume a rate of approximately half the theoretical calculated value, approximately 0.2 l/s (17 m^3/day).

5.2. Mitigation

The investigation boreholes indicate the piezometric water level in the bedrock rises above the base of the glacial till, indicating a level of confined pressure is developed within the siltstone bedrock from the overlying cohesive deposits.

Excavations into the superficial deposits and bedrock will intercept the water table and dewatering will be necessary. The ground is susceptible to water logging, which is likely to explain why there are boggy, peaty areas and agricultural drains in the area.

There is no existing risk of groundwater flooding in this area based on the SEPA Groundwater Flood mapping, indicating that there has been no significant historical issue with groundwater flooding. However, there is potential for groundwater emergence in topographically lower areas where the low permeability superficial deposits are thin or absent. Any excavations are likely to encounter groundwater and groundwater inflow to excavations can be expected where these penetrate below the low permeability superficial deposits. Therefore, the main groundwater flooding risk as a result of the proposed development will be related to the discharge of the dewatering activities that will be required for proposed excavations. Discharge to ground would be inappropriate due to the poorly draining conditions of the soils and superficial. Groundwater dewatering should be directed towards a receiving water course with the capacity to accept around 0.2 l/s of long-term dewatering discharge.

6. Flooding from Sewers and Water Mains

Flooding from Sewers and Water Mains is defined here as flooding which occurs due to exceedance of the capacity of man-made drainage systems. Scottish Water were consulted to understand whether they maintain any public sewer at the proposed site. Scottish Water (SW) responded to confirm SW has no public sewer assets in the vicinity of the proposed development. As there are no existing public sewers in the vicinity of the proposed site, surface water discharges will be managed on-site. The proposed development would therefore not result in additional flow being discharged and consequently the FRA has not considered this source of flooding further.

7. Flooding from the Failure of Water Retaining Infrastructure

Flooding from the Failure of Water Retaining Infrastructure is defined here as flooding due to the collapse and/or failure of man-made water-retaining infrastructure such as a dam, water supply reservoirs, flood defences and water treatment tanks or pumping station. It is considered to be a residual flood risk and whilst it is not possible to attach a probability of collapse and/or failure, as it will be dependent on the combined effects of a number of factors, the probability of such an event is considered low. Hence, no detailed assessment has been undertaken but rather an assessment was undertaken to identify the location of water retaining infrastructure and assess the potential for the proposed development to be affected by or to affect the residual risks associated with infrastructure failure.

7.1. Reservoirs

The proposed development is located approximately 12.5 km downstream of Loch More Reservoir and within approximately 7 km of Loch Calder Reservoir. The River Thurso flows into Loch More Reservoir and outfalls at the downstream end, to continue north east towards Halkirk. The SEPA Reservoir inundation maps show that, in the event of existing reservoir failure at either Loch Calder or Loch More Reservoirs, the proposed site would not be at risk of flooding as shown in Figure 16, reproduced from the SEPA Reservoir Inundation Mapping.

As part of statutory obligations under the Reservoirs (Scotland) Act 2011 (Scottish Parliament, 2011), the continued maintenance of Loch Calder Reservoir by Scottish Water and the continued maintenance of Loch More Reservoir by Thurso River Limited, will manage the risk to the wider public and downstream areas. As such failure is considered unlikely, and hence it is considered there is little or no risk of flooding to the proposed development from this source.

Figure 16: SEPA Reservoir Inundation Map.

7.2. River Thurso Flood Protection Scheme

The Highland Council are currently developing a Flood Protection Study for the River Thurso. The River Thurso Flood Protection Study is being progressed by AECOM and currently the study is investigating potential solutions through stakeholder engagement and public consultations. Details of the proposed development are hence unknown at present.

There is an extensive history of flooding in the town of Thurso. The most recent occurrence being on 11 August 2023 when the town was hit by a flash flood leading to various local businesses being affected (The Highland Council, 2023). Other notable flood events include December 2014; October 2006; January 2005; and October 2004.

The largest recent fluvial event was recorded on 26 October 2006 when extensive flooding occurred to residential and non-residential properties, a power station, roads and car parks. This was caused by drainage systems being unable to cope with volume of surface water runoff and the Wolf Burn bursting its banks (SEPA, 2023). The proposed development is located approximately 3.5 km upstream of the River Thurso and Burn of Halkirk confluence. At the confluence, bed level of the Burn of Halkirk, as inferred from 1 m LiDAR data, is 24 mAOD whilst at the proposed development bed level is 64 mAOD representing a rise of 40 m over 3.5 km.

Hence it is considered unlikely that the proposed development would be directly impacted in the event of failure of the proposed River Thurso Flood Protection Scheme nor that the proposed development would impact upon the scheme.

Maintenance of the proposed flood protection scheme would manage the risk of failure. The impact of the proposed development on the function of the proposed flood alleviation scheme is considered negligible.

8. Coastal/Tidal Flooding

Coastal flooding is defined here as that originating from the sea where water levels exceed the normal tidal range and flood onto the low-lying areas that define the coastline. Tidal flood events are generally the result of raised sea levels occurring when large storm surges interact with high astronomical tide levels. The proposed development is located over 10 km from the coast and the confluence of the Burn of Halkirk with the River Thurso is located over 10 km upstream of the Normal Tidal Level (NTL) of the River Thurso. Hence, coastal and tidal flooding is not considered further in this FRA.

9. Construction Phase Flood Risk

Detailed construction plans, other than the location of a preferred compound area for laydown and welfare facilities were not available at the time of preparing this FRA. It would be expected that the appointed contractor would develop these at a later stage.

The assessment of flood risk is therefore limited to an overview of potential flood risks during the construction phase, to set out high-level requirements with respect to managing flood risk. It is the contractor's responsibility to assess the flood risk to work areas, to assess the flood risk resulting both to and from temporary works, and to provide appropriate mitigation measures where necessary.

9.1. Potential Impacts

Temporary construction works can in themselves be at risk of flooding and have the potential to impact flood risks both to the immediate work areas and to receptors beyond the work site.

The proposed construction works have the potential to impact existing flood risk by:

- Excavation works associated with the DC Platform cuttings resulting in the pooling of surface water runoff, or through the emergence of groundwater. Works associated with the AC Platform filling could result in the diversion of overland flow routes, a reduction in floodplain storage, impacts on floodplain conveyance, and increased volumes of surface water runoff.
- Temporary pre-Earthwork Drainage (PED) drainage could increase both the rate and volume of surface water runoff and has the potential to transfer sediment to the receiving watercourse.
- Temporary work located within or adjacent to watercourses could affect the frequency, depth, extent and duration of fluvial flooding.
- The location of the site compound and the storage of construction materials and equipment on-site could potentially reduce floodplain storage and divert flood flow routes. Heavy plant could also damage existing land drains, and could also compact ground, which could increase surface water runoff.

9.2. Mitigation

The area proposed for a temporary laydown and welfare area is shown in Figure 17 by the hatched area highlighted pink. Also shown are the watercourses or ditches impacted by the proposed laydown area and a 10 m buffer strip drawn around each surface water. The construction water management plan (BANN4-LT407-JMS-DRAI-XX-PLN-C-0101) proposes enabling works and a strategy to manage the construction water runoff.

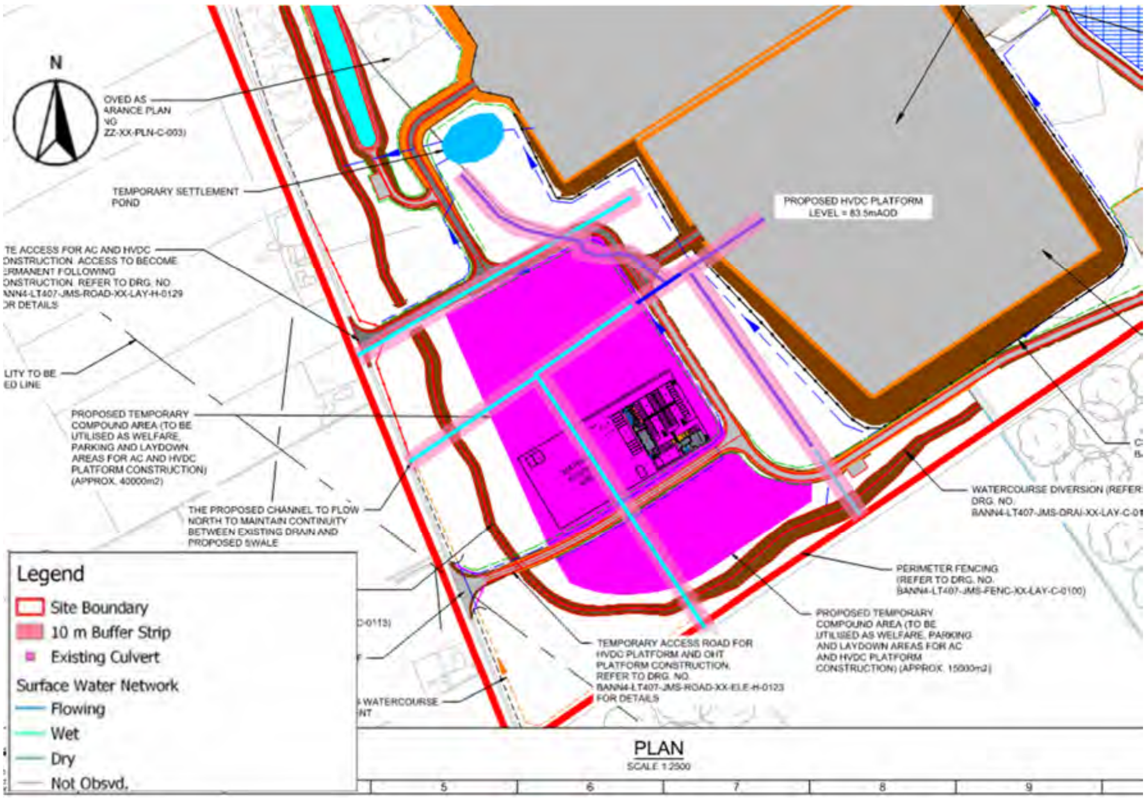

Figure 17: Location Plan Showing the Proposed Area for the Temporary Laydown and Welfare and the Watercourses or Ditches Impacted.

The contractor should ensure that temporary construction works are protected from flooding during the construction phase and that the temporary works do not increase the risk of flooding outwith the site. To this end, plant and other equipment should be kept outwith the buffer zones where possible shown in Figure 17.

The contractor should avoid any temporary works within the functional floodplain. Based on the assessment undertaken and presented herein, the works are not assessed to lie within the 0.5% AEP (200-year) plus climate change flood extent however the limitations of the assessment must be understood.

Where it is not practical to avoid temporary works in areas at risk of flooding, be this surface water flooding, the contractor should consider the depth of flooding, potential overland flows and local site conditions to place more vulnerable works in lower risk areas.

The contractor will be expected to follow the following general guidance concerning the management of flood risk during the construction period of the proposed development including:

- Preparing a Flood Response Plan.
- Signing up to the Floodline, Scotland's flood warning service provided by SEPA, and also be responsible for monitoring forecasts and weather conditions on-site.
- Consulting with SEPA when working within a river or within 50m of bank top is proposed and ensure the activities are licensed under the Water Environment (Controlled Activities) Regulations (CAR), if applicable.
- Monitoring water levels when working within or near rivers.

- Preparing emergency evacuation plans for each construction area given issue of a Flood Warning or following rapid rises in river level or continuous heavy rainfall, identifying safe access and egress routes and refuge points.
- Providing standby pumping equipment to remove any surface water runoff that enters the working area.
- Contacting SEPA during a flooding event greater in magnitude than the temporary works are designed to, particularly where receptors could be at increased risk of flooding.
- Temporary Work Guidance
- The contractor is also expected to adhere to the following guidance regarding to temporary works and flood risk: Temporary Earthworks
- Review local groundwater data prior to extensive excavations.
- Where dewatering of excavations is undertaken, discharge overland or to a watercourse (with appropriate treatment where necessary) at the relevant greenfield runoff rate.
- Undertake initial desk-based services searches before digging on-site. The contractor should also undertake appropriate survey (CAT scans, GPR survey, etc.) on-site to verify the location or presence of underground services before digging.
- Avoid trafficking areas with known vulnerable services. Assess ground loading in these areas and provide additional cover protection if necessary. Plan abnormal load routes.
- Locate stockpiles outside of areas susceptible to prominent surface water flows. Where this is not possible, stockpiles should be constructed with regular spaces between heaps (with each stockpile not exceeding 25m in length) to preserve existing low points and flow paths, and to prevent surface water backing up behind the structure and being re-directed elsewhere.
- Store excavated materials outside of the floodplain. Excavated material should only be placed in 'at risk areas' when required for use.
- Construct haul roads and access roads as close to ground level as possible when crossing the floodplain.
- Construct ditches along access road / temporary diversion edges to collect run off and direct to treatment facilities.

9.2.1. Temporary Drainage

- Assess requirements for discharge rate control as part of the construction works.
- Runoff that is expected to contain sediment should be directed towards a suitably sized temporary settlement pond before being discharged to watercourse.

Works within or adjacent to watercourses

- Design temporary river works, which involve the diversion of a watercourse (e.g. fluming or overpumping), to convey the design flood event to be agreed with SEPA. A lower standard may be acceptable if the works would be in place for a shorter period than the overall construction phase.
- Where temporary access crossings include the use of culvert, design to convey the peak flow during the design flood event, to be agreed with SEPA. Multiple pipes should not be used, where reasonably practicable, to reduce the risk of blockage.

- Where temporary access crossings include the use of bridges, design the soffit above the peak water level during the design flood event plus 600mm freeboard to be agreed with SEPA. Bridge piers should not be located within the watercourse.

General site activities

- Minimise trafficking and loading of unprotected site areas. Consider protecting large site areas subject to heavy traffic loads, and methods to alleviate soil compaction post works, as soil compaction may lead to an increased runoff rate.
- Avoid trafficking areas with known vulnerable services. Assess ground loading in these areas and provide additional cover protection if necessary. Plan abnormal load routes.
- Store construction materials outside of the floodplain. Construction material should only be placed in 'at risk areas' when required for use.
- Raise site facilities outwith the functional floodplain. Where not suitable, raise above the peak water level for the chosen design flood event to be agreed with SEPA. Facilities could be elevated on stilts where practicable, or in some cases, located on the higher areas of the compound.

10. Conclusion

The existing underlying ground condition over the site, i.e., poor infiltration and high groundwater levels result in surface water flooding during intense rainfall events caused by the minimal infiltration capacity of the underlying ground. This was observed on site during both the GI works and hydrology walkover survey.

The surface water drainage strategy only captures the runoff from the hard standing areas within the proposed development area, e.g. the substation roads, buildings, transformer bunds, concrete refuelling areas, and discharges. The remaining platform area is to be constructed from granular fill as per SSEN specification. The granular fill is to allow water to permeate through and runoff/infiltrate the formation layer, which will be graded towards the existing catchments to mimic existing runoff regimes. The surface water drainage strategy presented in the DIA report (BANN4-LT407-JMS-DRAI-XX-RPT-C-0004) has hence adopted the 0.5% AEP (200-year) design storm event for sizing of the proposed attenuation SuDS measures which are discussed in detail in the DIA.

The platform has been assessed to attenuate the rainfall within the platform extent, this assessment was completed by Jacobs before Tony Gee were engaged. The assessment found that for the conceptual design, the platform is acceptable for storing the surface water runoff from the proposed development within the site up to the design 0.1% AEP (1000- year) plus climate change allowance storm event.

From a fluvial flood risk perspective, whilst the site is considered to be at risk of flooding during flood events less than the 3.33% (30-year) event, as previously reported, it is not considered the proposed development would be impacted from fluvial flooding but rather the Quarry access road may be overtopped during the 3.33% AEP event. Where assessed, the channels draining the site generally have sufficient capacity to convey the design flood event without flooding, however the existing culverts do not.

Where hydraulic structures have been assessed, the calculated capacities are found to be significantly less than the estimated design flow (i.e., the 0.5% AEP (200-year) plus climate change allowance fluvial flow). Hence there is potential for the watercourses which drain the site to be throttled at these locations and for the watercourse to back-up, potentially resulting in out of bank flows. To increase the capacity would serve to potentially increase downstream flood risk through increased pass forward flow rates. This would not be acceptable unless supported by detailed hydraulic modelling of the impacts upon downstream flood risk. Recommendations have been made in respect to flood risk and are discussed under Section 11.

The development is compliant with the legislation, policies and guidance as highlighted in section 1.3.

11. Recommendations

Recommendations are made with respect to developing the drainage strategy and flood risk assessment during detailed design.

- Obtain detailed topographic survey of the site including topographic survey of watercourses and hydraulic structures to allow a more detailed assessment to be undertaken.
- Network Modelling of the AC and DC Platforms in a common and consistent approach to provide a more representative assessment of the attenuation storage volumes required.
- Develop detailed proposals for the design of watercourse diversions including a hydraulic assessment to determine channel profile in terms of both planform and gradient to convey the estimated design flood.
- Develop detailed proposals for proposed watercourse crossings. This should for the requirements of SEPA regarding embedment depth etc. and be based upon detailed topographic survey.
- Whilst the site is generally assessed as being at low risk of fluvial flooding, detailed design should be supported by hydraulic modelling to quantify the impacts upon flood risk to the proposed development and upon downstream flood risk.

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Appendix A – Additional Information

Results of Water Level Monitoring in Standpipes

Monitoring Point	Easting	Northing	Depth to Groundwater Meters below ground level (m b.g.l)		
			Min	Max	Mean
BH01	315952.5	956337.6	0.58	0.80	0.69
BH02	316124.1	956443.3	0.80	1.24	1.02
BH03	316282.2	956556.7	0.56	1.15	0.86
BH04	316202.0	956607.0	0.70	1.20	0.95
BH05	316103.6	956534.9	0.40	0.69	0.55
BH06	316016.4	956486.9	0.33	1.27	0.8
BH07	315909.3	956503.2	0.04	0.74	0.39
BH08	316158.9	956659.3	-	-	-
BH09	316284.0	956746.5	0.51	1.00	0.76
BH10	316132.4	956734.3	0.19	2.27	1.23
BH11	316026.6	956662.9	0.77	1.32	1.05
BH12	315940.6	956608.9	-	-	-
BH13	315725.2	956570.8	0.19	-	0.19
BH14	315933.4	956709.7	-	-	-
BH15	316135.9	956842.8	1.42	1.94	1.69
BH16	315957.3	956824.2	0.10	0.10	0.10
BH17	315815.9	956731.5	0.10	0.54	0.32
BH18	315813.5	956847.3	0.80	-	0.8
BH19	315947.6	956936.1	-	-	-
BH19A	315957.9	956943.0	-	-	-
BH20	316134.5	957057.4	0.50	0.78	0.64
BH21	315989.2	957059.6	0.33	0.49	0.41
BH22	315832.3	956957.1	-	-	-
BH23	315689.2	956873.5	-	-	-

Monitoring Point	**Easting**	**Northing**	**Depth to Groundwater Meters below ground level (m b.g.l)**		
			Min	Max	Mean
BH24	315535.3	956897.2	1.97	8.70	5.34
BH25	315764.0	957052.3	-	-	-
BH26	316057.6	957243.8	1.19	-	1.19

Channel Geometry and Assessed Capacity

							MIN	MEAN	MAX					n (-20%)	n (+20%)
Location	**XS Ref**	**DTM Data**	**Channel Slope**	**1 in:**	**n**	**Bottom Width (B)**	**Bank height (Y)**	**Bank height (Y)**	**Bank height (Y)**	**Z (m)**	**Top Width (W)**	**Z_{bo} Channel bed level (mOD)**	**Calculated Capacity (m^3/s)**	**Calculated Capacity (m^3/s)**	**Calculated Capacity (m^3/s)**
BoH@ 316146.3, 957172.9	1	Cyberhawk	0.016	62	0.035	0.93	0.99	1.04	1.09	2.8	6.54	75.9	8.9	11.1	7.4
BoH @ 316090.0, 957261.5	2	Cyberhawk	0.020	50	0.035	0.61	1.14	1.20	1.25	2.75	6.12	74.2	10.8	13.5	9.0
BoH @ 315945.5, 957332.5	3	Cyberhawk	0.015	65	0.035	1.15	1.71	1.85	1.99	4.01	9.17	70.8	29.1	36.3	24.2
BoH @ 315781.7, 957463.0	4	Cyberhawk	0.017	58	0.035	0.97	1.15	1.16	1.17	4.05	9.08	67.6	15.7	19.7	13.1
BoH @ 315692.0, 957546.4	5	Phase II	0.011	92	0.035	1.31	1.32	1.34	1.36	4.58	10.50	65.4	18.6	23.3	15.5
BoH @ 315578.1, 957605.6	6	Phase II	0.011	92	0.035	1.15	0.68	0.81	0.95	2.86	6.87	64.0	4.3	5.3	3.5
~15 m US of Railway	7	Phase II	0.008	130	0.035	2.20	0.53	0.60	0.66	4.96	12.10	32.4	4.4	5.5	3.7
UT01 @ 315792.7, 956574.6		Cyberhawk	0.024	42	0.035	0.31	0.73	0.81	0.88	1.42	3.14	82.0	2.84	3.55	2.36
UT02 @ 315636.5, 956689.5		Cyberhawk	0.021	48	0.035	0.35	0.73	0.75	0.76	1.73	3.81	77.3	3.20	4.01	2.67
UT03 @ 315557.9, 956787.2		Cyberhawk	0.026	38	0.035	0.30	0.64	0.65	0.66	1.64	3.59	74.7	2.71	3.39	2.26
UT04 @ 315472.2, 956855.2		Cyberhawk	0.019	53	0.035	0.28	0.62	0.69	0.75	3.68	5.63	71.8	3.36	4.20	2.80

							MIN	MEAN	MAX					n (-20%)	n (+20%)
Location	**XS Ref**	**DTM Data**	**Channel Slope**	**1 in:**	**n**	**Bottom Width (B)**	**Bank height (Y)**	**Bank height (Y)**	**Bank height (Y)**	**y (m)**	**Top Width (W)**	**Z_{bo} Channel bed level (mOD)**	**Calculated Capacity (m^3/s)**	**Calculated Capacity (m^3/s)**	**Calculated Capacity (m^3/s)**
BoH@ 316146.3, 957172.9	1	Measured	0.016	62	0.035	1.45	1.35			1.28	4.00	75.5	10.6	13.3	8.9
BoH @ 316090.0, 957261.5	2	Measured	0.020	50	0.035	1.50	1.40			1.85	5.20	73.9	15.8	19.8	13.2
BoH @ 315945.5, 957332.5	3	Measured	0.015	65	0.035	1.00	2.00			2.60	6.20	70.5	24.7	30.9	20.6
BoH @ 315781.7, 957463.0	4	Measured	0.017	58	0.035	2.10	1.30			1.20	1.20	67.4	13.5	16.8	11.2
BoH @ 315578.1, 957605.6	6	Measured	0.011	92	0.035	1.70	1.00			1.10	3.90	63.7	5.9	7.4	4.9
UT01 @ 315792.7, 956574.6		Measured	0.024	42	0.035	1.00	1.10			0.70	2.40	81.7	5.31	6.63	4.42
UT02 @ 315636.5, 956689.5		Measured	0.021	48	0.035	0.65	1.30			1.33	3.30	76.7	7.4	9.26	6.17
UT03 @ 315557.9, 956787.2		Measured	0.026	38	0.035	0.80	0.80			1.38	3.60	74.5	4.77	5.96	3.98
UT04 @ 315472.2, 956855.2		Measured	0.019	53	0.035	1.50	1.50			1.93	4.50	70.9	12.0	15.0	10.0

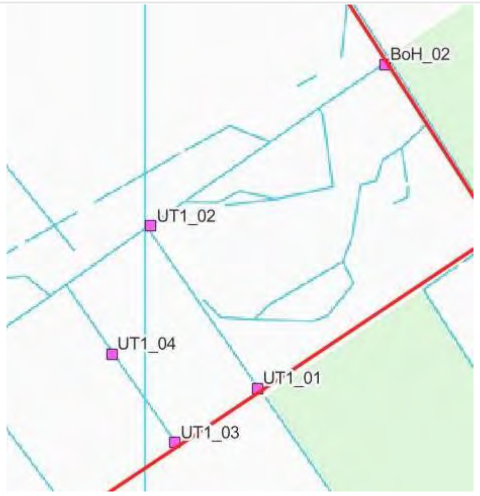
Appendix B – Structure Register

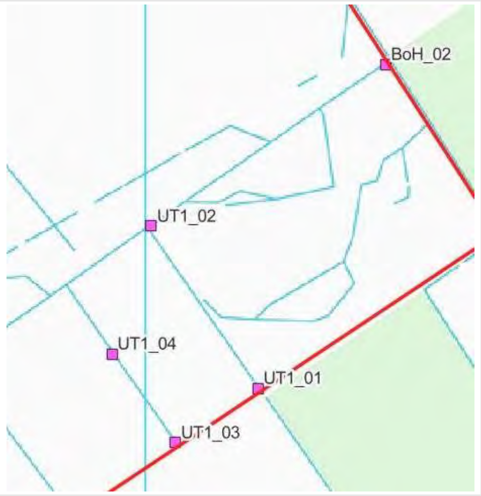
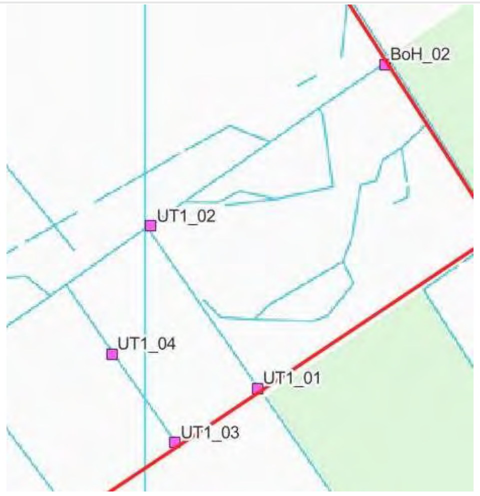
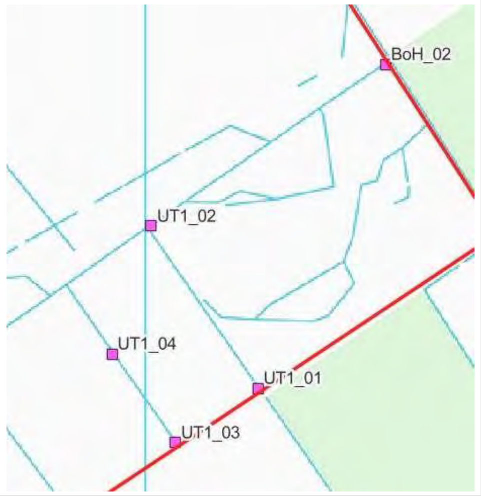
400kV Banniskirk Substation and HVDC Converter Station – Structure Register

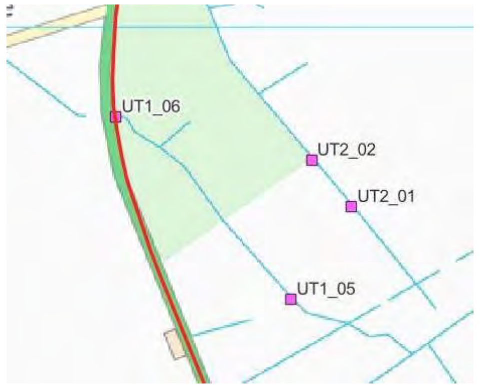
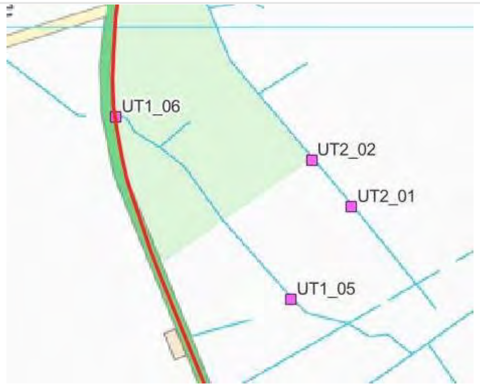
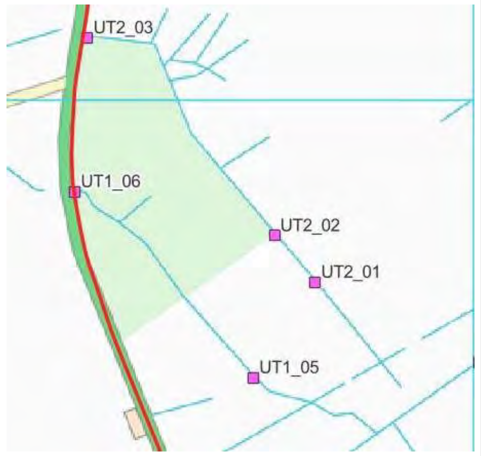
ID	Watercourse	Easting	Northing	Location	Photo Upstream Elevation	Photo Downstream Elevation	Structure Details
BoH_01	Burn of Halkirk	316498	956628				450 mm pre-cast concrete pipe culvert. Culvert under Quarry access road.
BoH_02	Burn of Halkirk	316338	956866				150 mm corrugated PVC pipe. Conveys flow from drainage ditch (thought to divert water from the Unnamed Tributary 01 catchment) to the diverted channel of Burn of Halkirk.
BoH_03	Burn of Halkirk	316483	956969				450 mm pre-cast concrete pipe culvert. Culvert located on diverted channel, just before the 600mm culvert (shown below).

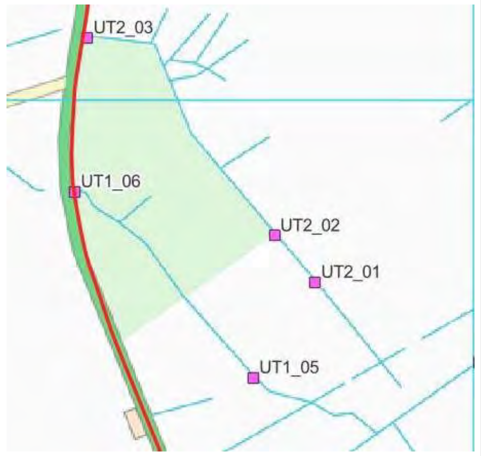
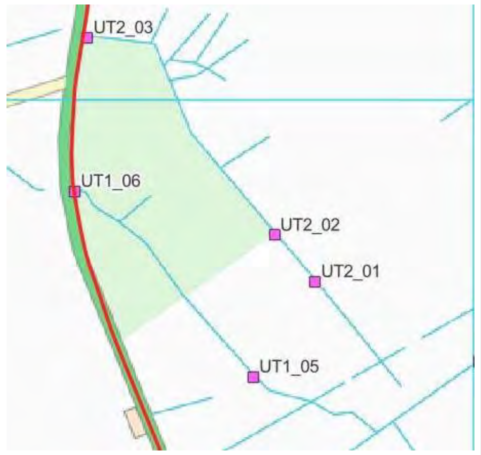
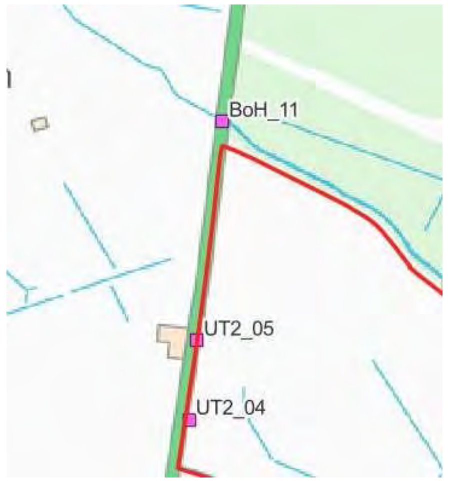
BoH_04	Burn of Halkirk	316500	956981				600 mm pre-cast concrete pipe culvert. Culvert conveys the outflow from the pond and diverted channel.
BoH_05	Burn of Halkirk	316259	957000				300 mm steel pipe culvert. Culvert located downstream of channel diversion. Barrel observed to be heavily blocked and the channel upstream and downstream observed to be dry.
BoH_06	Burn of Halkirk	316189	957106				600mm high by 450mm wide masonry/stone-built box. Culverted located downstream of diverted channel, upstream of confluence of branches.

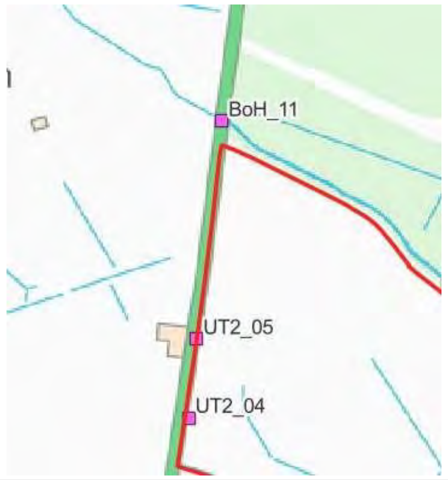
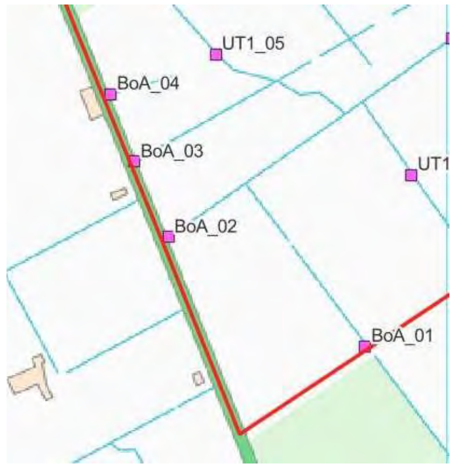
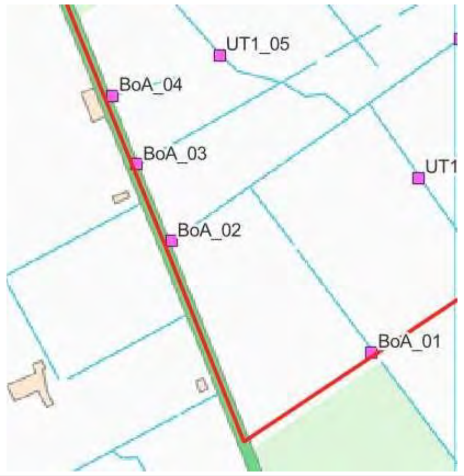
BoH_07	Burn of Halkirk	316154	957161				Masonry / stone-built box 500mm high by 550mm wide. Culvert outfalls to the main stem of the Burn of Halkirk.
BoH_08	Burn of Halkirk	316005	957300				Masonry / stone-built box culvert 800mm wide by 600mm high with sheet metal top. Culvert provides access to forestry/woodland.
BoH_09	Burn of Halkirk	315850	957399				Masonry/stone-built box culvert, 1000m wide by 750mm high. Structure is skewed. Culvert carries the Burn of Halkirk under the access track to Banniskirk House.

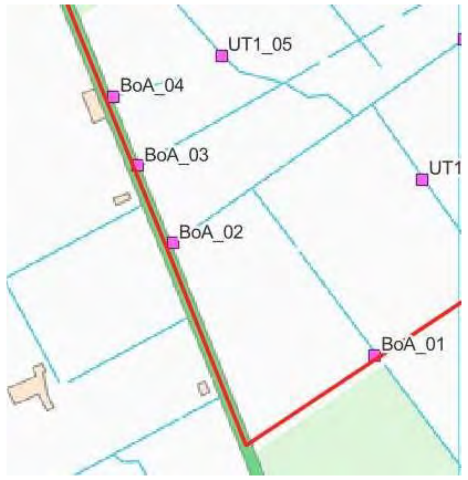
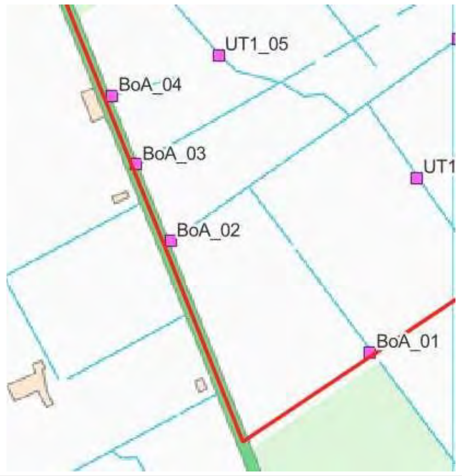
BoH_10	Burn of Halkirk	315790	957458				600mm circular corrugated PVC pipe, 6m in length. The culvert conveys the Burn of Halkirk under an access track to a paddock.
BoH_11	Burn of Halkirk	315533	957641				Two x 750mm circular pre-cast concrete culverts in parallel. The culverts convey the Burn of Halkirk under the A9. Additionally, surface water runoff from the road drainage is conveyed by the culverts.
UT1_01	Unnamed Tributary 01	316159	956412				Two x 250mm corrugated PVC pipes. Carry the Unnamed Tributary 01 under the Quarry access road and outfall to what is referenced as channel one.

UT1_02	Unnamed Tributary 01	316009	956640				150 mm corrugated PVC pipe. Conveys flow from the Unnamed Tributary 01 catchment via a drainage ditch to the diverted channel of Burn of Halkirk.
UT1_03	Unnamed Tributary 01	316044	956336				250mm steel pipe. Outfalls to channel two although no obvious upstream source could be identified.
UT1_04	Unnamed Tributary 01	315951	956459				300mm corrugated PVC pipe.

UT1_05	Unnamed Tributary 01	315698	956618				500mm pre-cast concrete pipe.
UT1_06	Unnamed Tributary 01	315450	956876				500mm pre-cast concrete pipe at A9.
UT2_01	Unnamed Tributary 02	315782	956750				300mm corrugated PVC pipe culvert. Upstream of the culvert, no obvious flow was observed within the channel. Downstream of the culvert, the channel was observed to contain little flow and was heavily vegetated.

UT2_02	Unnamed Tributary 02	315726	956815				300mm Corrugated PVC Pipe.
UT2_03	Unnamed Tributary 02	315467	957088				300mm Corrugated PVC Pipe at A9.
UT2_04	Unnamed Tributary 02	315496	957291				Masonry/stone-built culvert built into the wall. Where measured this was observed as 250mm wide by 600mm high.

UT2_05	Unnamed Tributary 02	315504	957384				Masonry/stone-built culvert built into the wall. Where measured this was observed as 250mm wide by 600mm high.
BoA_01	Burn of Achanarras	315894	956235				Two x 250mm clay pipes (corrugated PVC pipes at upstream inlet).
BoA_02	Burn of Achanarras	315640	956376				300mm pre-cast concrete pipe culvert at A9.

BoA_03	Burn of Achanarras	315590	956478				150mm clay pipe at A9.
BoA_04	Burn of Achanarras	315559	956567				150mm concrete pipe. Barrel observed to be ~ 50% blocked.