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For the attention of Lucy Moroney, Senior Planner

Our Ref:HAF-JBAU-00-00-RP-HM-0003-Flood_Risk_Letter.docx

25 November 2021

Dear Madam,

Haughhead Farm: Updated Flood Risk Assessment

Thank you for the opportunity to provide updated flood risk information for this site. We understand that this is in relation to the Armour Burn and the redevelopment of the Haughhead Farm site. In particular, we understand that Scottish Borders Council (SBC) has requested[1] that the following requirements be addressed:

"A. The Finished Floor Levels of the Farmhouse and Steading must be at least 1m above ground level.

Reason: The FRA for the 2015 application recommended a FFL of 0.9m above ground level; climate change allowances for rainfall and river flow have increased since then to 35% (as per SEPA's 2019 guidance "Climate change allowances for flood risk assessment in land use planning") and we have to take these increases into account.

B. Post- development flow path drawings need to be submitted and show that the potential flood risk to the proposed buildings, associated with the flow paths, has been mitigated.

Reason: The culverts on the access road (B709 South Of Tweed Bridge To U83-1 At Haughhead) and within the site are under capacity and flow paths within the site need to be managed to reduce flood risk to the buildings on site.

C. Flood resilience measures are installed in the solum of both buildings. Reason: to prevent the solum flooding. "

We respond to each of these requirements in the following sections[2].

1 FINISHED FLOOR LEVELS

It is understood that SBC requires the new development to be protected from a 0.5% Annual Probability (AP, 200 year) event plus allowances for climate change and freeboard. At the time of the earlier JBA study, the climate change uplift required was 20% on flow. Recent SEPA guidance now recommends a climate change uplift of 35% on rainfall for small catchments in eastern Scotland. The peak flows were therefore updated with the new

1 Email from Raffaela Diesel, Scottish Borders Council, dated 19 October 2021.

2 This work was undertaken by Emma Blades, Technical Assistant and reviewed by David Cameron, Technical Director.

climate change uplift and the existing model run with this new information in order to generate updated flood levels. This is described as follows.

1.1 Design peak flows

Catchment descriptors for the Armour Burn (Figure 1) and updated FEH Rainfall Runoff peak flows can be found in and . The resulting 0.5% AP (200 year) event with 35% uplift on rainfall was estimated to be 3.7 m³/s. (Note that a comparison with ReFH2 was not part of the current commission).

Table 1 Catchment Descriptors

Catchment Descriptor	Armour Burn
AREA (km²)	0.83
ALTBAR (m above sea level)	319
BFIHOST	0.604
DPLBAR (km)	1.03
FARL	1
FPEXT	0.003
FPDBAR	0.033
SAAR (mm)	916
SAAR4170 (mm)	927
SPRHOST (%)	31.35
URBEXT1990	0.0000
URBEXT2000	0.0000

Table 2 Design Peak Flows: Armour Burn

Return period (years)	Annual Probability (AP)	FEH Rainfall Runoff Method Flow (m³/s)
2	50	0.6
5	20	1.0
10	10	1.2
25	4	1.5
50	2	1.8
75	1.33	1.9
100	1	2.1
200	0.5	2.3
200(+20% CC on flow)	0.5	2.8
200(+35% CC on rainfall)	**0.5**	**3.7**
500	0.2	3.2
1000	0.1	4.0

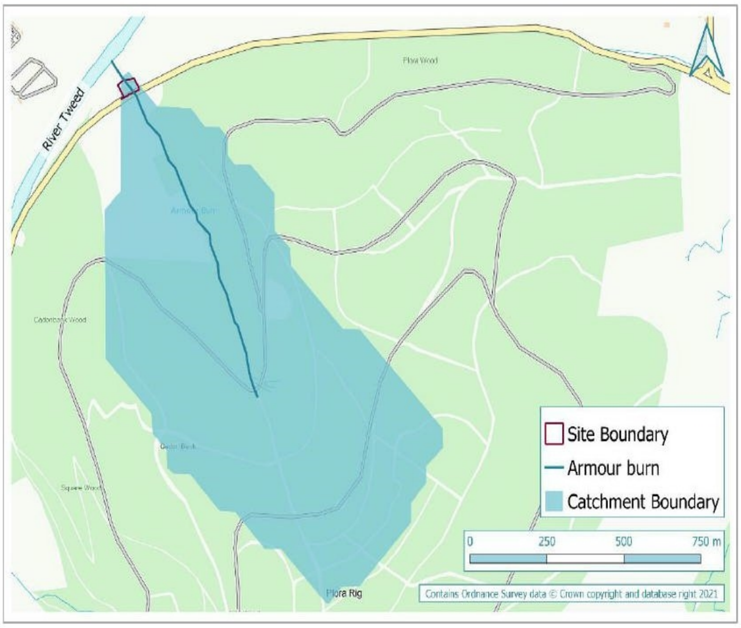

Figure 1 Armour Burn Catchment

1.2 Hydraulic Modelling - HEC-RAS

Flood risk was assessed using the same 1D hydraulic model as per the previous study. Full details of this HEC-RAS model can be found in the original Flood Risk Assessment. The present study has made no changes to the modelling apart from the input climate change uplift value used on the 0.5% AP flow. For reference, the cross sections used in the model are shown in Figure 2.

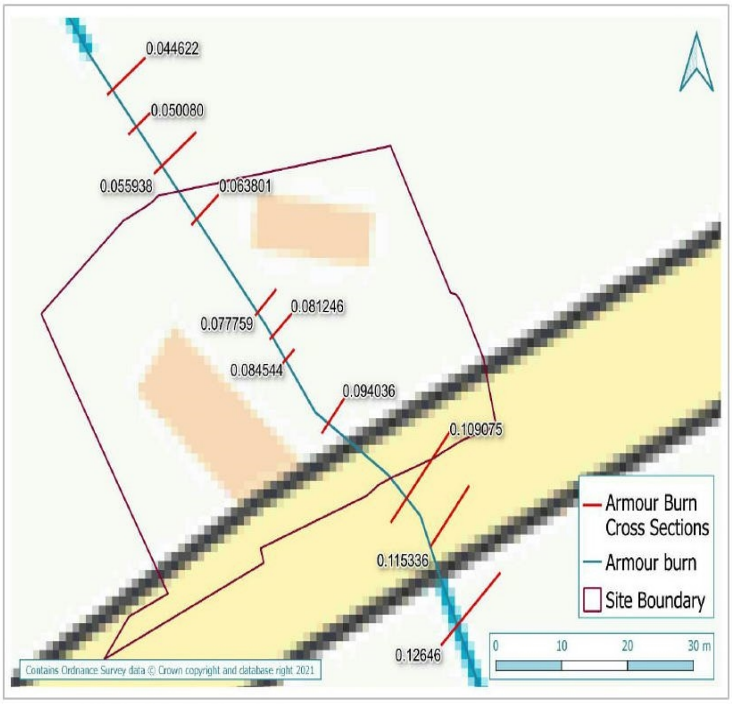

Figure 2 Cross Section Locations

Flood Level Estimation

The estimated flood levels from the HEC-RAS cross sections are provided for a variety of AP events in including the levels associated with an increase in climate change uplift. It should be noted that the flood levels associated with all other return periods have remained the same and have been included for reference only.

Updated HEC-RAS long sections and representative cross sections are shown in Figure 9 and Figure 10. Per the earlier study, the cross sections for the Armour Burn) show a "glass wall" effect for the 0.5% AP (200 year) event (where the estimated flood level is at a higher elevation than the extent of the cross-sectional survey data). The flood levels associated with this magnitude of event might therefore be conservative.

Table 3 Estimated flood levels at various AP events on the Armour Burn (mAOD)

River Station	Left bank elevn	Right bank elevn	QMED	Q25	Q75	Q100	Q200	Q200 + 35% CC	Q1000
0.1153	143.71	143.61	143.35	144.02	144.34	144.40	144.56	144.60	144.80
0.1091	143.05	143.44	142.87	143.01	143.23	143.25	143.34	**143.51**	143.55
0.0940	141.52	141.60	141.36	141.48	141.45	141.46	141.49	**141.56**	141.57
0.0845	140.57	140.70	140.49	140.58	140.61	140.61	140.65	**140.71**	140.74
0.0812	140.35	140.34	140.17	140.24	140.27	140.28	140.30	**140.35**	140.36
0.0778	140.25	140.28	140.08	140.17	140.20	140.21	140.25	**140.32**	140.35
0.0638	139.11	139.25	139.38	139.24	139.33	139.35	139.39	**139.44**	139.45
0.0559	138.93	138.90	138.82	139.11	139.15	139.16	139.19	**139.26**	139.28
0.0501	138.55	138.53	138.48	138.69	138.55	138.55	138.58	**138.63**	138.64
0.0446	138.25	138.13	138.31	138.42	138.46	138.46	138.49	138.56	138.58
0.0030	136.36	136.32	135.74	135.84	135.89	135.90	135.94	136.03	136.05
The farm buildings are located between cross section 0.1091 and cross section 0.0501									

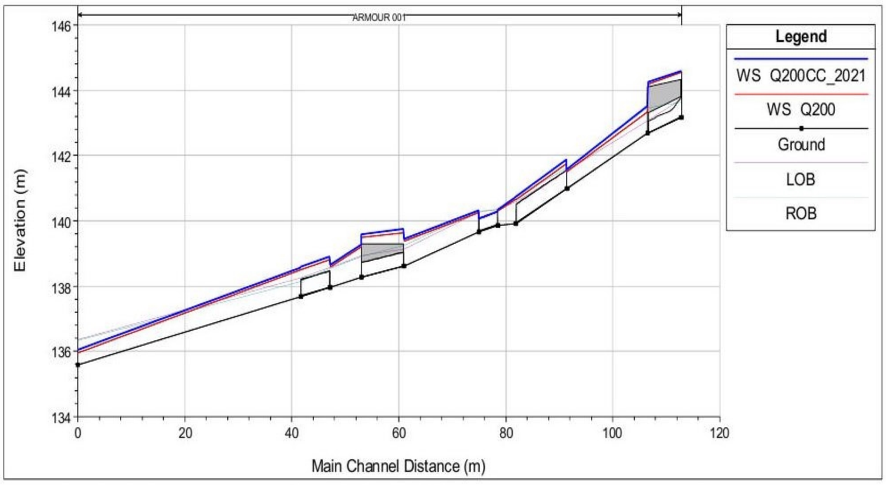

Figure 3 HEC-RAS long sections for the 0.5%AP (200 year) event on the Armour Burn, with and without climate change. Main culverts shown in grey.

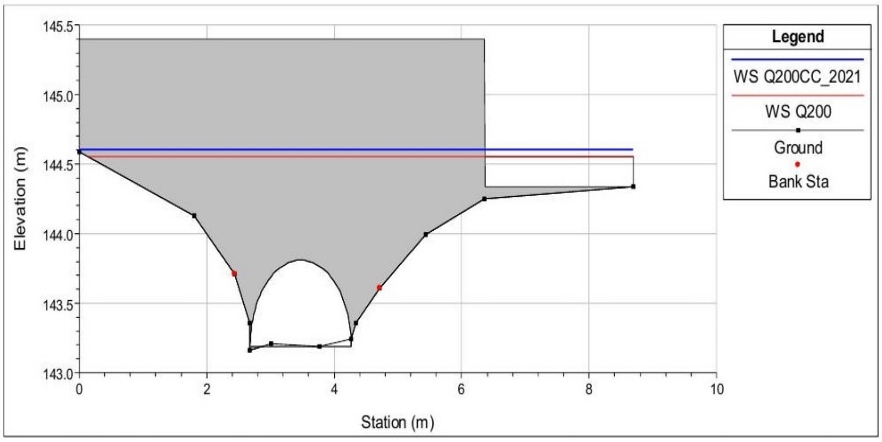

Figure 4 0.5%AP (200 year) with and without climate change events on the Armour Burn at the C-road culvert.

Finished Floor Levels

The HEC-RAS modelling suggests water depths of up to 0.29 m with velocities of greater than 1 m/s, for a 0.5% AP (200 year) event on the Armour Burn in the vicinity of the farm buildings. Following a 35% rainfall uplift to allow for climate change, flood depths in the vicinity of the site are expected to reach 0.36m. This is an increase of 0.03m compared to the depths associated with a 20% climate change uplift (0.33m).

Best practice states that Finished Floor Levels (FFLs) should be set to the 0.5% AP (200 year) plus climate change flood level plus an allowance for freeboard (usually 0.6m). Based on the newly modelled depths this would indicate an appropriate FFL of circa 0.96m (i.e. close to the 1 m requested by SBC) above surrounding ground level. From the supplied site plan, it is understood that the proposed finished floor level (FFL) of the steading is 140.90 mAOD and the existing ground level is circa 140.5 mAOD. The proposed steading FFL is therefore 0.4 m higher than the ground level. The FFLs of the northern and southern buildings making up the farmhouse are 139.90 mAOD and 141.23 mAOD respectively and the existing ground levels are 139.50 mAOD and 141 mAOD. The proposed FFLs of the steading and the northern portion of the farmhouse are therefore 0.4 m and 0.2 m higher than the neighbouring ground level, respectively. Additional raising of the FFLs would therefore be needed in order to meet SBC's requirements. Alternatively, 1D/2D modelling could be used to refine the flood estimates at the development locations and this could perhaps reduce the flood level estimated by more accurately simulating floodplain flow on the slope through the site.

2 FLOW PATHWAYS

The modelling for the Armour Burn indicates that there are two main pathways of fluvial flooding to the farm building area:

- Insufficient capacity of the road bridge culvert under high magnitude flood events. For example. the capacity of the road bridge culvert is estimated to be about 1.5 m^3/s. At the 0.5% AP (200 year) event, which has a flow of 3.7 m^3/s, the modelling suggests that the C-road could be overtopped on the right bank with an estimated depth of 0.22 m (Figure 10). The pathway for the water would then be over the road and through the farm building site and associated buildings before heading towards the Tweed (Figure 5).

- Insufficient capacity of the culverts through the farm building site. For example, the first box culvert on the site (0.4 m wide, 0.56 m high) is estimated to have insufficient capacity to carry a 50% AP (2 year) flow of 0.6 m^3/s.

Flow pathways were derived using a combination of the 1D model outputs and detailed GIS analysis of the available topographic data (LiDAR and associated contour data). This allowed for determination of expected flow direction following out of bank flow on the Armour Burn. As can be seen in Figure 12, pre-development flow pathways are expected to cover a large majority of the site, and impact both of the existing buildings. Though it should be noted depths are expected to be small.

Pre-development

In the pre-development situation, the primary flood risk to the eastern building is expected to arise from flood waters flowing out of bank following overtopping of the C-road bridge. From here water is expected to follow the slope of the site, flow over the road and towards the eastern building. From here some water is expected to re-enter the armour burn whilst some is expected to inundate the building. Following flooding of the eastern building, flood waters are then expected to continue off the site and towards the River Tweed.

The western building is also at risk of flooding; however it is not expected to be at risk from overtopping of the C-road bridge. Instead flood risk to the western building will likely be due to out of bank flow between cross sections 0.0845 and 0.0778. It should be noted that flood depths on the left bank of the Armour Burn are only expected to be around 0.01m. Following out of bank flow in the middle of the site, water is expected to flow west and then south before ultimately travelling off site.

Post development

The above methods have also been used to assess flow pathways in a post-development scenario. In this case, it has been assumed that water ingress to the buildings is not possible (e.g. by raised FFLs). Instead of water flowing through the eastern building, it is expected that all of the water will instead be redirected to re-join the Armour Burn and flow towards the River Tweed. Flow on the left bank is still expected to travel west before encountering the building and being directed north to join the rest of the water flowing in a western direction.

There are no properties on the Armour Burn downstream of the site and the Burn has almost a negligible contribution to flood flows on the River Tweed, therefore it is not expected that an alteration to flow pathways will result in changes to flood risk outwith the site.

The flow pathways could be refined using 1D/2D modelling but this was outside the scope of the current commission.

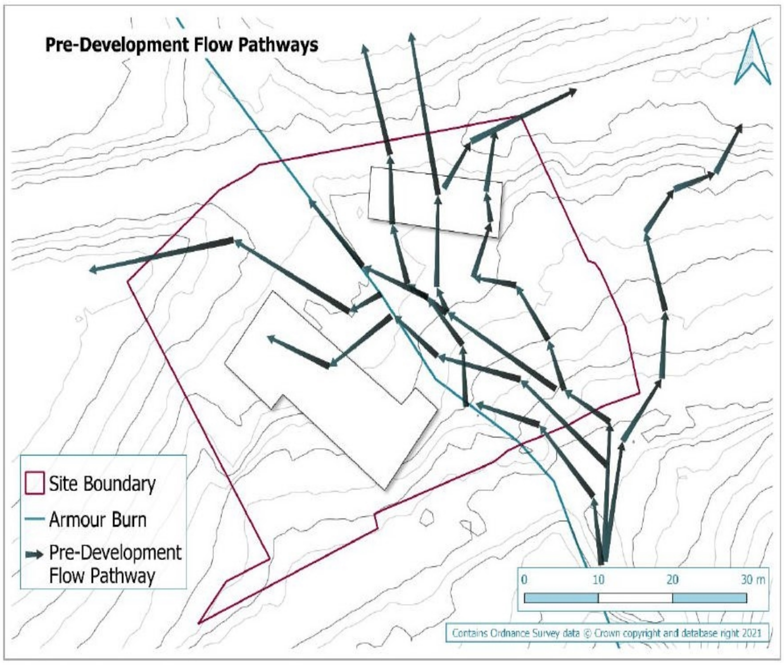

Figure 5 Pre-Development Flow Pathways

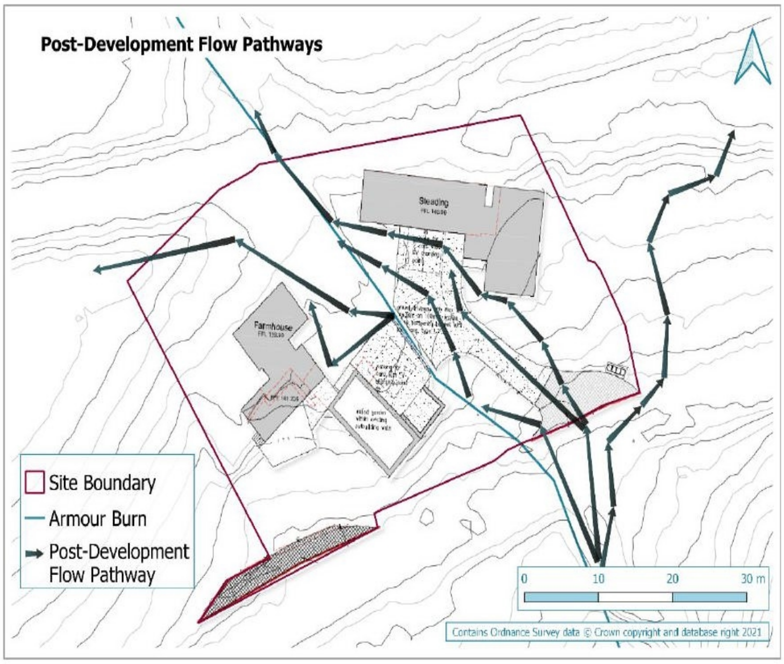

Figure 6 Post-Development Flow Pathways

3 FLOOD RESILIENCE

Flood resilience measures assume that a property will flood. The measures are therefore designed to reduce the impact of that flood. Possible measures include: the use of internal water-resistant material (e.g. for doors, windows and frames), elevating floor levels, electricity points and other equipment. Flood resilience measures are generally useful up to a maximum flood depth of 0.6 m and it is expected that this would be appropriate mitigation based on the modelled flood depths at the site. SBC have recommended flood resilience in the building solum and we would agree with this recommendation.

Other options for flood mitigation which could be considered include use of a flood gate and/or other barriers at the entrance to the site in order to reduce risk from the Armour Burn overtopping and entering the site from the road, and development of the entrance and access track to further encourage a flow pathway away from the buildings and back to the Armour Burn.

The Armour Burn is estimated to present a flood risk to the redevelopment of the farm buildings, normally this would be grounds to suggest they are inappropriate for residential development; however there are multiple flood protection options which can be used to mitigate flood risk to the site:

- *Elevated floor levels.* As far as is practicable, elevate the floor levels of the buildings ideally to at least 1 m above existing ground levels. This should be sufficient to mitigate flood depths of up to 0.4 m while allowing 0.6 m freeboard. Elevating FFLS by

1 m reflects the depths derived in the modelling. Given the model undertaken was 1D in nature, it is possible this will be a conservative estimate of appropriate Finished Floor Levels at this location.

- *Flood resilience measures.* Flood resilience measures assume that a property will flood. The measures are therefore designed to reduce the impact of that flood. Possible measures include: the use of internal water-resistant material (e.g. for doors, windows and frames), elevating floor levels, electricity points and other equipment. Flood resilience measures are generally useful up to a maximum flood depth of 0.6 m and it is expected that this would be appropriate mitigation based on the modelled flood depths at the site. SBC have recommended flood resilience in the building solum and we would agree with this recommendation.
- *Flow pathways*. In addition to raising FFLs, use of a flood gate and/or other barriers at the entrance to the site in order to reduce risk from the Armour Burn overtopping and entering the site from the road. Development of the entrance and access track to further encourage a flow pathway away from the buildings and back to the Armour Burn could also help mitigate flood risk from this source.

4 CONCLUSIONS

From the above it is concluded that flood risk to the proposed site arises from the Armour Burn. It is expected that the primary flood mechanism will be from overtopping of the C-road bridge located to the south of the site. The 0.5% AP (200 year) event was estimated to be 2.2 m^3/s and 3.7 m^3/s following a 35% allowance for climate change onrainfall. This resulted in an increase to the estimated flood depth of circa 0.03 m from the earlier study.

Based on the outputs of the updated 1D modelling, the proposed FFLs do not meet the requirement of SBC to be 1 m above ground level. The FFLs would need to be raised further (circa 0.4 m for the steading and circa 0.2 to 0.4 m for the farmhouse) in order to meet the requirements. However, additional study using 1D/2D modelling may reduce the magnitude of the flood levels by better representing floodplain flow than is available from the 1D outputs at this location. Raising of the FFLs (and assuming no other means of water ingress) would allow the flow pathways to be diverted around the proposed buildings and back to the Armour Burn. Given that there are no properties downstream of the farm site, it is not expected that this type of alterations to the flow pathway will increase flood risk elsewhere.

We hope this letter meets your requirements and should you require any further information please do not hesitate to contact us.

Yours faithfully,
For and on behalf of Jeremy Benn Associates Limited

[redacted]

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